Informational constraints on interceptive actions of elite football goalkeepers in 1 v1 dyads during competitive performance

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Published version

SHAFIZADEHKENARI, Mohsen, DAVIDS, Keith, CORREIA, Vanda, WHEAT, Jonathan and HIZAN, Haz (2015). Informational constraints on interceptive actions of elite football goalkeepers in 1 v1 dyads during competitive performance. Journal of Sports Sciences. (In Press)

Informational constraints on interceptive actions of elite football goalkeepers in 1 v1 dyads during competitive performance

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{Heading: information constraints in dyad system]

Word count: 4814

Keywords: ecological dynamics, informational constraints, time to contact, dyadic systems, association football, elite goalkeepers

Abstract

The aim of this study was to examine whether perceptual variables can provide informational constraints for the goalkeepers to intercept the ball successfully in 1v1 dyads. Video images of 42 actions (1v1 in direct shots) were selected randomly from different matches and divided into conceded goals (n=20) and saved actions (n=22) to investigate interceptive actions of 20 goalkeepers in the English Premier League in season 2013-2014. Time to Contact (TTC) of the closing distance gap between shooter and goalkeeper was obtained by digitising actions in the 18-yard penalty box. Statistical analyses revealed that, in sequences of play resulting in an intercepted shot at goal, goalkeepers closed down outfield players in the X axis, whereas when a goal was conceded, there was a significantly delayed movement by goalkeepers toward the shooters in this plane. The results of canonical correlations showed that a decreasing distance between a shooter and goalkeeper, and accompanied reduction in relative interpersonal velocity followed a temporal pattern. Findings of this study showed how perception of key informational constraints on dyadic system relations, such as TTC, interpersonal distance and relative velocity, constrain elite goalkeepers' interceptive actions, playing an important role in successful performance.

Introduction

The role of goalkeepers in association football has expanded significantly in recent years, with many coaches expecting them to act like a sweeper and a last line of defence. This new role requires a complete awareness of available space and time. Due to spatial constraints and the need for a good interpersonal coordination between players a goalkeeper's awareness of the positions of other outfield players is essential for successful performance. In fact, the modern goalkeeping in football requires perception of information prospectively for successful interception of the ball in the penalty box. The need for utilising information that is acquired from the dynamic performance environment helps a goalkeeper to plan action accordingly. The theoretical rationale for performance, emphasising the importance of identifying the key perceptual variables that regulate behaviours in different performance environments, has been suggested in previous studies (e.g., Craig et al 2009, Savelsbergh & van der Kamp, 2000, Savelsbergh et al., 2010).

The coupling between perception and action has been widely emphasised in ecological dynamics, a current theory of performance in sport and physical activity which emphasises the person-environment scale of analysis in understanding human behaviours (e.g., Gibson, 1979; Araújo et al, 2006; Passos et al., 2008). According to Gibson's (1979) theory of direct perception there is a direct and cyclical link between human perceptual systems and environmental events (Gibson, 1979). From this perspective, there is sufficient information for the control of actions in the invariant and variant features of an environment. On the other hand, the environment is information rich and the role of the organism is to use seek and use it to support different actions (Gibson, 1979). Some potential perceptual variables in such performance situations are time to contact (TTC), interpersonal distance and relative velocity.

TTC information has been previously proposed as an important informational constraint on the organisation of interceptive actions (e.g., Correia, et al., 2011; Davids et al., 2002;

Travassos et al., 2012; Bootsma et al., 1997; Lee, 1998) and especially in the coupling between perception-action (Lee, 1976). Savelsbergh and Bootsma (1994) have proposed three task constraints for the successful coupling of actions with environmental objects and actions: contact with an object at an appropriate moment in time, at an appropriate velocity and with the intended spatial orientation. All of these elements are important components of perception-action coupling during dynamic interceptive actions. Originally TTC was proposed to be obtained through a solid visual angle that is formed between performer's visual system and an object approaching at a constant velocity, known as the optic variable tau (Lee, 1976), but its conceptualisation has changed over time (e.g., Correia et al., 2011; Watson et al., 2011).

An important feature of TTC is its dynamic nature. In fact, there is always a conditionally-coupled (van Geert, 1994) system in games due to continuous changes in the relationship between competing and cooperating players over time. A performer's perception of an opponent's movements could be considered as a series of interconnected and highly integrated actions whose sub-components cannot be studied separately during performance (van Geert, 1994). For example, in an attacker-defender dyadic (1v1) system competing in football, continuous changes in TTC provide information (affordances or opportunities) for a player to continuously regulate goal-directed actions with respect to an opponent's actions (Vilar et al., 2014). Previous work has shown how these perceptual variables interact to influence the criticality of a dyad system. That is, when these variables reach specific values, they can enhance the probability of a sudden transition in the organisational state of the dyadic system, leading to successful performance outcomes for one of the system members (Araújo, Davids, & Hristovski, 2006).

Previous studies have examined the role of TTC, interpersonal distance and relative velocity on successful interceptive actions in team sports (Correia, et al., 2011; Passos et al., 2008; Vilar et al., 2014). For example, Correia et al. (2011) studied the spatio-temporal variable tau for passing in rugby union. They calculated tau of the distance motion gap between a

ball-carrying attacker and a defender. Positional data were analysed based on the first attacking player who received the ball (first receiver), the defending player (defender) marking the first receiver and the attacking player (second receiver) who received the ball from the first receiver (i.e. received the pass under analysis). The time period was considered as the key period of approach where the gap was closing between the first receiver and the defender. It began when the first receiver obtained the ball (initial tau value) and lasted until he passed it to the second receiver (final tau value). The results revealed that the initial tau value predicted 64% of the variance found in pass duration (regarded as indicative of the type of pass). Their data showed that the TTC between the attacker that performed the pass and his marking defender may yield information about future pass possibilities and constrain the type of pass that emerges during performance. Passos et al. (2008) identified interpersonal distance and relative velocity as relevant variables leading to qualitative changes in an attacker-defender system in rugby union. They reported that a value of 4m of interpersonal distance was likely to lead to a successful outcome for a defender, whereas when this variable increased in value to between 6-8m, the outcome was finely balanced between attacker and defender.

The dyadic system formed between a goalkeeper and an approaching attacker has not been studied so far in in open plays during competition, rather than in controlled experimental conditions, when a goalkeeper has to face a direct attacker in a 1v1 situation. In fact, previous studies in football have focused mostly on the penalty shootout and the role of visual perception using the occlusion paradigms, eye tracking technologies and virtual reality settings (Savelsbergh et al., 2010; Bakker et al., 2006; van der Kamp, 2006). In that work, decision-making and anticipation times have been examined according to a performer's ability to pick up and use information to plan for an action based upon information-processing stages. These situations have some drawbacks. First, their designs have tended to decouple perceptual processes from actions on relevant external objects (Fajen, et al., 2008), and second, their performance outcomes were often discrete and could

not show how a performer used environmental information continuously to regulate specific actions (Correia et al., 2013). Recently, Lopes et al. (2014) used motion analysis to examine the role of kinematic information on the direction of the ball in performance during the penalty shoot-out. They reported that some variables, especially in lower parts of the body (e.g. foot angle, kicking speed), had a significant correlation with the direction of the ball before the interception of the ball. Their findings, to some extent, represent the dynamic nature of coupling between perception and actions during goalkeeping. Here we sought to investigate the exploratory movement strategies of goalkeepers while continuously using information to regulate performance behaviours to provide insights regarding the emergence of successful and unsuccessful attempts during competitive performance in more open and dynamic situations. The specific aim of this study was to examine whether informational variables, identified in previous work on dyadic systems in team sports, could predict the emergent performance behaviours between a shooter and goalkeeper in football in situations with different performance outcomes. We hypothesised that motion gaps between a goalkeeper and shooter in the X and Y axes would differ when performance outcomes resulted in saved shots and conceded goals. In addition, we expected to observe a significant relationship between values of interpersonal distance, relative velocity and TTC when these different outcomes emerged.

Methods

Design

The design of this study was cross-sectional in which TTC between a goalkeeper and shooter performing in a dyadic system was recorded and compared between conditions with an outcome of saved and conceded goals.

Participants

Video images of 42 actions (sample rate 25Hz), involving 20 elite goalkeepers from the English Premier League, were selected randomly from all matches (season 2013-14) on the

basis of conceded goals (n=20) and saved shots (n=22). The images were recorded from match broadcasting on the SKY Sport TV channel. Inclusion criteria were: i) being the first choice goalkeeper of a team, ii) being part of a 1v1 dyad system between a goalkeeper and a player shooting the ball at the goal, iii) involving direct shots toward a goalkeeper, without deflection by other players, and iv), outcomes leading to either conceded goals or saved shots. Ethics committee of university approved all stages of this study.

Procedure

Calibration of a pitch was carried out with Kinovea software (v.8.2, USA). For each calibration scene there were four known points that were obtained according to the real dimensions of 18-yard and 6-yard boxes, determined by Fédération Internationale de Football Association (FIFA). A perspective grade was used to calibrate the box based on 4 defined points that were on the parallel lines relative to the bye-line and touch line. For example, for the 18-yard box, the defined points for calibration to meter were P_1 (X_0, Y_0), P_2 (X_0, $Y_{40.3}$), P3 ($X_{16.5}$, Y_0) and P4 ($X_{16.5}$, $Y_{40.3}$). In each action sequence, the movement trajectories of a shooter and the goalkeeper were digitized by the analysing the centre of mass of each player that was projected on the ground in each frame. Image coordinates obtained from digitisation were transformed to pitch coordinates for data analysis using a two-dimensional direct linear transformation method (Abdel-Aziz & Karara, 1971; Travassos et al., 2012). The time window for tracking movements was determined from the positioning of a shooter before the moment of foot-ball contact. TTC of the closing distance gap between shooter and goalkeeper was obtained by applying formulae of tau ($x/\dot{x}$), which involved the ratio of the distance between the shooter and goalkeeper (x) and the latter's current velocity ($\dot{x}$) in both longitudinal (X; parallel to the touch lines) and transverse (Y; parallel to the by-line) planes (Lee, 1980). Negative TTC values signify that the distance motion gap was closing between the players in the dyad. Because the initial time was different between actions, thus mean tau and final tau were considered for further analysis.

Relative velocity was calculated for both X and Y axes according to the distance changes between attacker and goalkeeper over time as: $V = x(t) - x(t-1) / \Delta t$.

Eight action sequences with the same participants in both conceded and saved conditions were selected for assessing the reliability of the system. Two experienced observers collected data on two occasions with a one-week time interval. We used measurement error as a method for calculation of reliability because it considers the difference between two raters on the same scale rather than the association between two data sets (Goto & Mascie-Taylor, 2009). The results showed good intra-rater reliabilities for recording mean TTC values in both X (r=0.98, SEE=2.12) and Y (r=0.95, SEE=1.98) directions. In addition, good inter-rater reliabilities for recording mean TTC values in both X (r=0.93, SEE=3.54) and Y (r=0.97, SEE=4.27) directions were reported.

Data analysis

Considering the space and time relations between the goalkeeper and the shooter, not only TTC, but also relative velocity and interpersonal distance, were regarded as candidate action-relevant variables informing goalkeepers about co-adapted positioning needed for goal saving. The variability of TTC values over time was calculated by means of continuous point-by-point variability band (James, 2004). For the purpose of this analysis, the last 20 video frames before the kicking of the ball by an outfield player were considered. This time window was selected according to average duration of an outfield player from positioning in the 18 and 6 yards boxes until striking the ball. The criteria used to set these points' boundary for each period was to comply with the mean percentage of points corresponding to each period for all the trials ($M_{data\ points} = 20.5$, $SD = \pm 9.29$). Independent t tests were used to compare the TTC values between saved and conceded goals conditions. Canonical correlation was used to associate relations between the perceptual variables. Alpha values for all tests were determined at 0.05.

Results

Figures 1 and 2 show the point-by-point variability of TTC in X and Y axes for both conceded and saved conditions. The result of an independent t test showed that there was a significant difference ($t=2.33$, $p<0.05$, $\omega= 0.20$) in mean TTC_X between conceded and saved performance outcomes. In sequences of play resulting in an intercepted shot at goal, the goalkeepers closed down the outfield player ($Mean_{Tau\ x}= -2.92$, $SD= 10.42$), whereas when a goal was conceded, goalkeepers did not ($Mean_{Tau\ x}=0.64$, $SD= 12.42$). The result of an independent t test failed to show any significant difference between conceded ($Mean_{Tau\ Y}= -0.50$, $SD= 1.23$) and saved ($Mean_{Tau\ Y}= -0.25$, $SD= 5.12$) conditions in mean TTC_Y ($p>0.05$). TTC_X values for both conditions differed from 80-160ms before the final strike.

****Figure 1 near here****

****Figure 2 near here****

Figure 3 shows the time evolution of average compound correlations between interpersonal distance and relative velocity in goalkeepers and kickers in both X and Y axes until the point of final ball strike in two conditions (conceded goals and saved shots). The results showed that in both conditions there was a temporal pattern in utilising dyadic system perceptual information to adjust whole body movements. In the saved shot condition, in a critical time period 760-480ms before the final strike, and less than 80ms before the final strike, there were significant correlations (0.59-0.95) between interpersonal distance and relative velocity. In the conceded goals condition (0.61-0.76), the temporal pattern was shorter (760-680ms) in the initial part of dyadic system interactions, and was longer (less than 200ms) just before the final strike. The results of Z Fisher transformation tests also showed that there were significant differences in correlations analyses between the two conditions at 40ms ($Z= -2.07$, $p<0.05$) and before the final strike ($Z= -4.62$, $p<0.05$).

****Figure 3 near here****

Discussion

The aim of this study was to examine the role of TTC and other variables whether informational variables, identified in previous work on dyadic systems in team sports, could predict the emergent performance behaviours between a shooter and goalkeeper in football in situations with different performance outcomes. The results revealed the utilisation of TTC_X as a predictor variable for successful interception of the ball by goalkeepers in 1v1 dyads. On the other hand, when goalkeepers regulated their displacement according to the shooter's motion to close down the gap between them, they successfully intercepted the ball. In contrast, delayed adaptive behaviours to reduce the gap with a shooter increased the chance of a goal being conceded. Figure 1 shows that the goalkeepers in the saved condition started to close down the gap with the shooter earlier and maintained the narrow gap before the final strike (negative TTC_X). However the TTC_X values for both conditions were very similar at the moment of the final strike and at 40 ms before the final. It seems that adaptive movement behaviours of goalkeepers, in response to the continuous movement of an approaching shooter dribbling the ball, depend on how goalkeepers adjust body motion in response to upcoming events, attempting to minimise the distance to an attacker with the ball, displaying a negative Tau_x during the entire action.

These data showed that TTC is a variable that can be picked up and utilised by goalkeepers to adapt their actions according to changes in informational constraints of a performance environment (Correia et al., 2011). From this perspective, our data suggested that TTC might act as an affordance for a goalkeeper to utilise in regulating the gap with an approaching shooter in football, a few moments before the final strike. This idea suggests that a goalkeeper and a shooter in football can be conceptualised as a conditionally-coupled dyadic system. Our results propose that the performer's perception of an immediate opponent's movements should be considered by looking at coupled actions rather than isolated ones (van Geert, 1994). On the other hand, maintaining interpersonal distance values and relative velocity in a goalkeeper-shooter dyadic system allows skilled athletes to engage in exploratory movement behaviours for successful ball interception.

Another explanation of current findings relates to the pattern of adaptive behaviours in a dyadic system. Although the entire sequence of actions was less than a second (0-760 ms), we believe it was enough to demonstrate how affordances might be guiding goalkeepers' actions when facing an approaching attacker with the ball in the penalty box. The adaptive behaviours of goalkeepers were continuous, relatively stable and regular apart at some moments of the time series (see figures 1 and 2). This kind of adaptive behaviour could represent the effect of expertise in coupling perception and action in football. Montagne (2005) suggested that the acquisition of a functional information-action coupling requires a large amount of practice and it is expected that adaptive movement behaviours of this group of goalkeepers, many with experience at an international level of performance would be regular and consistent, regardless of performance outcomes (shots saved or conceded goals). In fact, with high level of spatial and temporal awareness and game-reading, expert performers can adapt very easily to changes in the performance environment as they become attuned to relevant affordances to constrain their actions (Araujo, et al., 2006).

The results showed that, in both conditions, there was a temporal pattern in utilising dyadic system perceptual information to adjust the whole body movement. According to the results of canonical correlations in the saved shot condition, the highest association between interpersonal distance and relative velocity was observed between 760-480ms before the final strike, and less than 80ms up to the final strike. In the conceded goal condition the temporal pattern was shorter (760-680ms) in the initial part, and was longer (less than 200ms up to final strike) just before the final strike. These findings indicate the existence of a critical time scale in utilisation of TTC information to guide the actions of goalkeepers. On the other hand, GKs in saved shot conditions, representing successful actions, tried to use information earlier and for longer than in the conceded goal condition.

It seems that the continuous coupling between perceptual information and movement is a successful strategy for a GK in a dyadic system in football. Goalkeepers directly perceived the changes in the gap between them and a shooter with the ball to regulate their relative

velocity in order to intercept a shot at goal. This finding may be considered as supporting a key notion of ecological dynamics theory: the direct link between perception and action in a dyadic system (Vilar et al., 2014). Because of time constraints, this direct link between perception and action in goalkeeping helps performers to explore the environment in order to reduce the gap with an approaching shooter for successful interception. This is consistent with data from Passos et al. (2008) that showed a significant relationship between relative velocity and relative distance between participants in an attacker-defender dyad in rugby. They suggested that relative velocity may have been used for exploratory decisions and actions due to the changes in direction and speed of both players to maintain their goal-directed behaviours. Another important finding of this study was a temporal pattern in adaptive behaviours (e.g. relative velocity). This finding may suggest that there is a critical period for goalkeepers to close down the gap with an approaching attacker. Critical periods have been defined as brief windows during which a system's organization is most open to modification from external and internal influences, such as informational constraints of perceptual variables (Davids, Button & Bennett, 2008). When goalkeepers adapt their actions according to informational constraints, their final position, relative to that of an approaching shooter with the ball, reveals emergent adaptive behaviour (see figure 3). Thus, attunement to relevant perceptual variables supports their functional positioning in terms of time and space, being an important factor for goalkeeping because of the dynamic nature of dyadic systems formed with an approaching attacker. Goalkeepers in saved shots conditions demonstrated the strongest correlation between interpersonal distance and accompanied velocity changes near to the final strike. However due to the small sample size in this study, the findings of the canonical correlations should be interpreted with caution until verified by further research.

The findings of this study have some implications in talent development and goalkeepers' training. One relevant implication is to help learners become progressively more attuned to functional perceptual information in 1v1 situations by manipulation of task constraints that

promote opportunities to search for and find functional perception-action couplings in 1v1 situations. Perceiving the critical values of variables like the relative velocity for intercepting the ball should be emphasised in task performance so that players become capable of picking up relevant information for proper positioning. Task constraints in goalkeeping should be manipulated with developing goalkeepers to facilitate their search for and attunement to TTC values to regulate their actions. Variability of practice task constraints for goalkeeping is recommended to acquire the necessary skills to prospectively guide interception of a shot on goal for a successful interception.

Since the actual timing for a goalkeeper to adapt positioning and movement velocity is time constrained, it is suggested that goalkeepers should practice interceptive actions in representative performance situations (Araújo et al., 2007; Pinder, et al., 2011) with similar time constraints to adapt to at critical moments of interceptive behaviours. This is very important for understanding the time needed for closing down an approaching shooter in the penalty box.

In conclusion, the findings of this study showed that perception of information on interpersonal distance and relative velocity provide affordances from movements of outfield players, providing, constrained the elite goalkeepers' actions and played an important role in successful interception of a shot at goal.

Future studies could attend to understanding how less skilled goalkeepers, such as developing athletes, explore perceptual variables, such as TTC_x, TTC_Y and relative velocity in 1v1 dyads. Research should also focus on more complex situations to examine the role of information for successful goalkeeping. For example, this could involve testing a goalkeeper's ability to intercept the ball when there are more outfield players in the scene or in situations when the final strikes are preceded by further phases of action (e.g. pass 1, pass2, etc.). These situations could provide useful insights about the complexity of performance environments in team games and the roles of experience and practice as

important factors in emergent behaviours of goalkeepers. One limitation of this study that could be addressed in future research was about the location of players in global space. Like time, space can provide useful information regarding subsequent actions. For example, entry to the penalty box from the centre can provide very different performance situations relative to entry from the right or left sides of the box. The viewing angle to close down the distance between a goalkeeper and an attacker can provide very different perceptual information sources for the performers. In order to understand the role of space in these dyadic system interactions, future studies could consider the location of outfield players relative to the position of a goalkeeper.

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