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Perceiving affordances in rugby union

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Abstract
To succeed in competitive environments, players need to continuously adjust their decisions and actions to the behaviour of relevant others. Players' interactions demand ongoing decisions that are constrained by what is previously defined (e.g., coaches' prescriptions that establish 'what' to do) and by information that is available in the context and specifies not only 'what' the player should do, but also 'how', 'when' and 'where' . We describe what affordances emerge to the ball carrier as a consequence of changes in kinematic variables, such as interpersonal distances or distances to the nearest sideline. Changes in these variables determine whether and when different actions are possible. The ball carrier tended to perform a pass when the tackler was farthest from the sideline and the velocity of approach to the tackler did not seem to effect the ball carrier's decision. In the few episodes where the ball carrier moved forward instead of passing the ball, he was mainly influenced by contextual information, such as the variability of the players' distance to the nearest sideline. In sum, actors must be aware of the affordances of others that are specified by particular variables that become available just before decision-making.

Keywords: *intersubject distances, intersubject velocity, decision-making*

Introduction

Affordances are determined by the adjustment between a person's action capabilities and a particular set of properties of the environment (Fajen, Riley, & Turvey, 2009; Turvey, 1992). The information that specifies affordances is available to be perceived not only by the actor but also by other people (Gibson, 1979; Stoffregen, Gorday, Sheng, & Flynn, 1999).

The ability to perceive other actors' affordances is highly important for social interaction and decision-making in sports. Two categories of social affordances have been previously identified: i) affordances *for* the others (i.e., what actions another actor can perform under a given set of environmental conditions); and ii) affordances *of* the others (i.e., what actions of another actor afford the perceiver). We focus on the perception of affordances of others, a matter that has received limited attention to date (Fajen et al., 2009). Accordingly, we hypothesise that the behaviour of an actor is guided by information originated by the actions of other actors.

In team sports, the displacement of other players provides crucial information to guide the actor's behaviour, as an ongoing process of gauging the relationship between a person's ability and the significant environmental properties (Ishak, Adolph, & Lin, 2008; Schmidt, O'Brien, & Sysko, 1999). In a competitive environment, adaptive behaviours are grounded on a complex combination of anticipated and emergent features that are constrained by the characteristics and the goal of the task (Marsh, Richardson, Baron, & Schmidt, 2006). Anticipated features are 'what' is previously known (e.g., players' movements that were previously rehearsed) and the task constraints that bound players' actions (e.g., playing field dimensions). The emergent features are sustained by local information and address the question of 'how' a player should perform an action (e.g., the solution adopted by a ball carrier to solve the problems raised by the proximity to a tackler), which cannot be uncoupled from 'when' (i.e., related to the moment/time in which an action was performed) or 'where' (i.e., related to the space/area in which an action was performed) a player should perform an action. These features emerge in space and continuously change over time under the influence of task constraints, such as players'

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positions, interpersonal distances and distance to the sidelines (Headrick et al., 2012; Passos et al., 2008, 2011).

Previously, researchers reported that much of the work on social affordances and coordination has focused on affiliative tasks (e.g., Cordovil & Barreiros, 2010; Cordovil, Santos, & Barreiros, 2012). In contrast, we aim to go beyond affiliative tasks, focusing on competitive environments where adaptive behaviours (i.e., functionally based) are constrained by rules, something very different from simply building friendship or rapport through perceptuomotor coupling (e.g., Hove & Risen, 2009; Marsh, Richardson, & Schmidt, 2009; Richardson, Marsh, Isenhower, Goodman, & Schmidt, 2007; Schmidt, Fitzpatrick, Caron, & Mergeche, 2011).

Affordances of and for others in a competitive environment

Perceiving what others will do (i.e., affordances *for* others) is a paramount issue in team sports. Gibson (1979) distinguished positive and negative affordances as the features in the environment that enable or obstruct certain actions. For example, a ball carrier who perceives a closing gap between the tacklers, or between a tackler and the sideline, is actually detecting a negative affordance for going forward. In fact, a positive affordance for going forward because a gap is open in one moment might be a negative affordance shortly after. The ability to deceive the opponent conveying information that leads him to perceive negative affordances as positive is a key feature of strategic behaviour.

The dynamic characteristic of affordances results from the ongoing actions of both players (i.e., ball carrier and tacklers). From the ball carrier's perspective, the perception of the right moment to perform a pass or go forward depends on the perception of what the opponents are capable of doing. Frequently, the ball carrier aims to drive the tackler to a certain part of the field and to place him away from the support player. A smart tackler should find a delicate position that allows him to: i) cover the ball carrier corridor towards the goal line (this corridor is bounded by the tackler's distance to the sideline); ii) intercept the ball if it is passed to the support player; or iii) tackle the support player as soon as he receives the ball.

The main issue in this study was to describe how performers perceive which actions are possible in a rugby competitive environment. It is our assumption that ball carriers can perceive action-scaled affordances that are provided by the tackler actions, and act accordingly. We also assume that variables such as interpersonal distances and players' distances to the sidelines are perceived by the players and provide enough information to support decision. It is expected that alternative behaviours, such as performing a pass or running forward, depend on certain space-time configurations of players that afford specific action modes.

The 2v1 situation in rugby (i.e., two attackers – the ball carrier and the support player – versus one tackler) is a stereotyped scenario (Biscombe & Drewett, 1998). It is established that in a 2v1 circumstance the ball carrier's role is to commit the tackler with his/her actions (e.g., running towards the defender) and, as a consequence, to release the support player to receive the ball without opposition, offering a free run towards the score line. Notwithstanding, what happens in match situations is that sometimes the support player is tackled after receiving the ball and sometimes the ball carrier does not follow what was previously settled (or generally expected), deciding not to pass the ball, but going forward to the goal line.

In summary, we present a particular approach to co-adaptive behaviours, based on the perception of affordances of others in a 2v1 situation in rugby union, aiming to describe what is affordable to the ball carrier, as a consequence of changes in interpersonal distances and relative distances to the nearest sideline. We hypothesised that the ball carrier's affordances (i.e., the moment of the pass or the decision to go forward) are influenced by the speed of approach between the ball carrier and the tackler and by both players' relative position to the sideline.

Methods

Twenty-four under-16 rugby union players (14–15 years old), with national level experience, participated in this study, performing a total of 65 trials ($N = 65$) for analysis. The players were randomly assigned to groups of two attackers and one defender. The instructions to the attacker were "Your goal is to stop the defender and score a try" and the instructions to the defender were "Your goal is to prevent a try from being scored". To avoid fatigue, each set of three players performed only nine trials, changing roles on every set of three trials. The ball carrier could choose his position in the beginning of the trial (right hand side or left hand side) and the number of passes was not restricted.

The task was performed on a field with 5 m width and 22 m depth. All the trials were videotaped using a single video camera at 25 Hz. TACTO 8.0 software was used to manually digitise the displacements of the players at 25 frames per second (Cordovil et al., 2009; Fernandes & Malta, 2007; Nema, Schweizer, von Hoff, & Guerreiro, 2009). Players were tracked using a working point between the feet on the ground. Six known reference points were digitised and saved as 'virtual coordinates' in pixels and as 'real world coordinates' representing known distances of a 22 m by 5 m box. The Direct Linear Transformation (DLT) was used to transform the virtual coordinates into real coordinates using the six calibration points (Abdel-Aziz & Karara, 1971). The MATLAB routine was used to transform the digitised players' coordinates into real world displacement trajectories relative to the known reference points.

The moment of the pass was defined as the first frame in which the ball is not in the hands of the ball carrier. The ball carrier-tackler interpersonal distances at the moment of the pass displayed a normal distribution, occurring mostly between 1 m and 2 m distance. Thus, we split the passes from below 1 m with increases of 0.5 m until 2 m and above. The tackler in a 2v1 scenario is in a delicate condition because his position will determine the odds to succeed. The position of the tackler should allow him to manage the balance between preventing the ball carrier from going forward and having a suitable chance to intercept the ball or the support player. In this situation, the nearest sideline becomes a physical task constraint for the attacker, which bounds the width of the corridor momentarily available to go towards the goal line.

The ball carrier then has two alternatives: i) to pass the ball; or, ii) to go forward. The moment of 'go forward' was defined as the last behavioural change in the ball carrier's action (e.g., deceptive pass and run; an abrupt change in running line trajectory) just before running past the tackler. We hypothesised that the velocity of approach between the ball carrier and the tackler influences the ball carrier's decisions. Accordingly, the first variable under analysis was the velocity of approach, which is the first derivative of interpersonal distance between ball carrier and tackler. The second variable under analysis was the intersubject distance to the sideline (the difference of the distance to the nearest sideline between tackler and ball carrier). A positive intersubject distance to the sideline means that the ball carrier is closer to the sideline than the tackler (opening a 'door' to go forward) and a negative value indicates that the tackler is closer to the sideline than the ball carrier (the 'door' is closed).

We hypothesised that the position of the tackler influences the ball carrier's affordances as follows: i) for intersubject distance to the sideline negative values, the ball carrier passes the ball to the support player; ii) for intersubject distance to the sideline positive values or close to 0 (zero), both affordances (i.e., pass/go forward) are available, meaning that the ball carrier keeps both alternatives open for future exploration. A time series data analysis was performed to avoid the reduction of an interactive behaviour to a single moment analysis.

The third variable under analysis was the intersubject velocity to the sideline between the tackler and the ball carrier, calculated from the beginning of the trial until the moment of the pass or the moment to go forward. Velocity was calculated using the first derivative of intersubject distance to the sideline.

In a first step, we calculated the first derivative of intersubject distance to the sideline until the moment of the pass or the moment when the ball carrier decided to go forward towards the goal line. Next, we plotted the intersubject velocity to the sideline over time for each trial. Visual inspection of the graphs revealed evidence of the nonlinearity of this variable, as depicted in Figure 1 (from 1a to 1e). The variation of intersubject velocity to the sideline over time might reveal space-time windows that are momentarily available, which might influence the ball carrier's options to pass or to go forward. The Approximate Entropy (ApEn) was computed as an indicator of the variability of the intersubject velocity to the sideline. ApEn is a nonlinear measure of the regularity of complex systems. The regularity of a signal relates to the complexity of the system generating it, thus, the greater the value of ApEn, the lower the regularity of the signal, and the greater the complexity of the system (Pincus, 1991).

The regularity/variability of the players' velocity to the sideline along the trial can produce information concerning the space that is left available for the ball carrier to go forward or pass the ball. Therefore, we explored how the variability of the players' velocity to the sideline (using ApEn) relates to the interpersonal distances between the ball carrier and the tackler at the moment of the pass or at the moment to go forward.

Results

The influence of ball carrier-tackler velocity of approach on the ball carrier's affordances

Figures 2a and 2b present examples of the velocity of approach between ball carrier and tackler. The data revealed that when the pass was performed to the support player, the ball carrier-tackler velocity of approach could increase or decrease right before the moment of the pass. In Figure 2a, the black line displays a sudden increase in the interpersonal distance velocity (between 3.2 and 3.4 s), which is consistent with an increase in the velocity of approach between the ball carrier and the tackler; whereas the grey line displays a sudden decrease in the interpersonal distance velocity (between 3.4 and 3.8 s), which illustrates a slowing down of both players' velocity of approach.

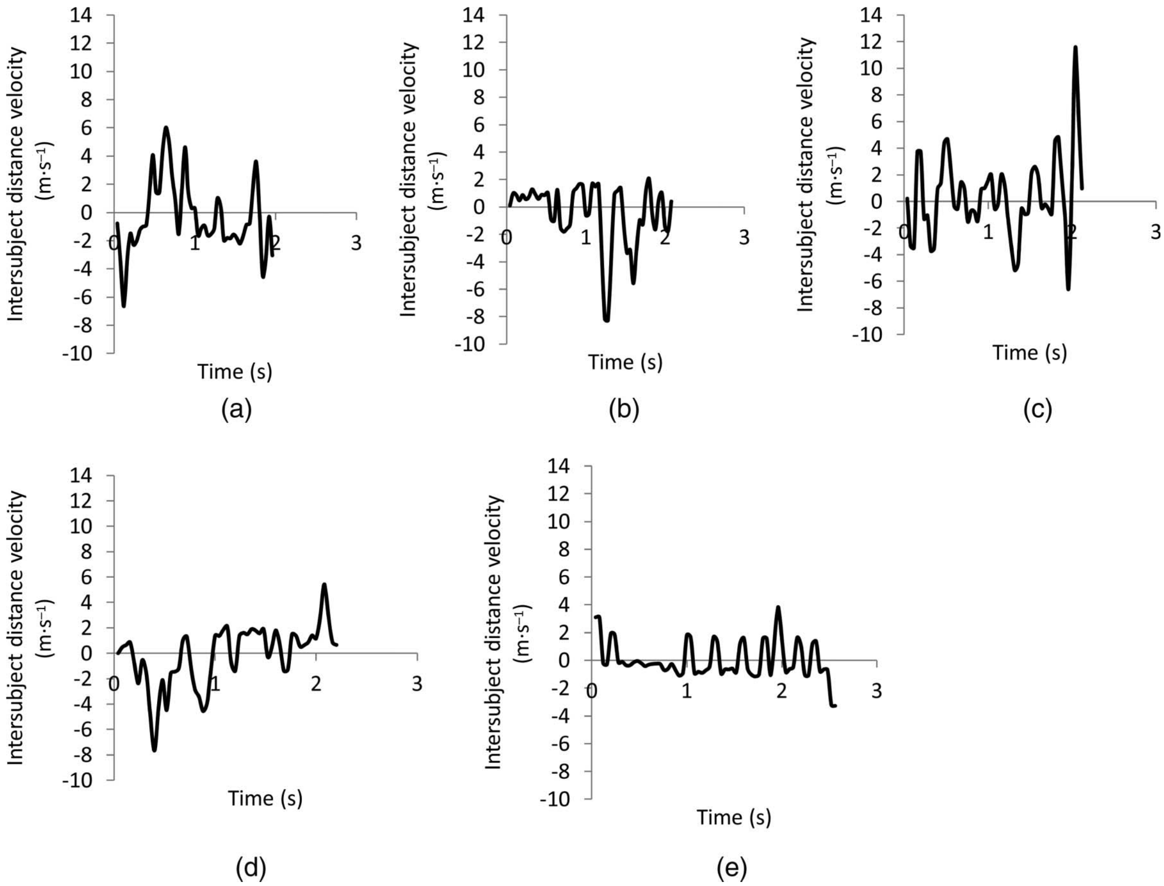

Figure 1. Intersubject velocity to the sideline.1a represents the intersubject velocity to the sideline for a pass performed below 1 m of tackler-ball carrier interpersonal distance. 1b represents the intersubject velocity to the sideline for a pass performed between 1 m and 1.5 m of tackler-ball carrier interpersonal distance. 1c represents the intersubject velocity to the sideline for a pass performed between 1.5 m and 2 m of tackler-ball carrier interpersonal distance. 1d represents the intersubject velocity to the sideline for a pass performed above 2 m of tackler-ball carrier interpersonal distance. 1e represents the intersubject velocity to the sideline when the ball carrier decides to go forward.

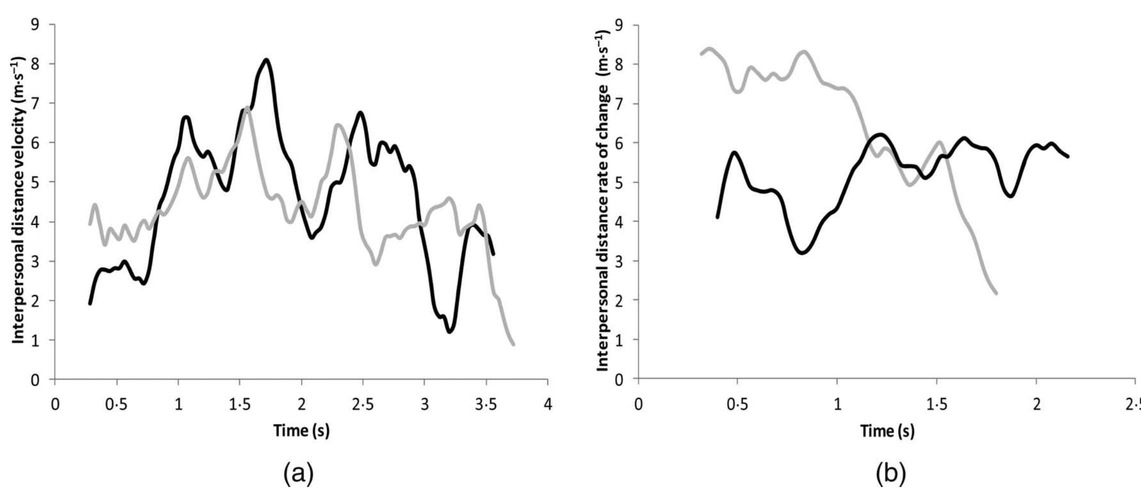

Figure 2. Exemplar data of velocity of approach between the ball carrier and the tackler in pass (Figure 2a) and go forward (Figure 2b) situations.The black line represents the velocity of interpersonal distance between ball carrier and tackler for trials when a sudden increase in the players' velocity of approach occurs just before the moment of the pass (Figure 2a) or of going forward (Figure 2b). The grey line represents the velocity of interpersonal distance between ball carrier and tackler for trials when a sudden decrease in the players' velocity of approach occurs just before the moment of the pass (Figure 2a) or of going forward (Figure 2b).

Similarly, when the ball carrier decides to go forward and not to pass the ball to the support player, the ball carrier-tackler velocity of approach might increase or decrease right before the moment of going forward. In Figure 2b, the black line displays a slight increase in the interpersonal distance velocity (between 1.8 and 2.0 s), which is consistent with an increase in the velocity of approach between the ball carrier and the tackler, and remains stable until the moment of going forward. Conversely, the grey line displays a sudden decrease in the interpersonal distance velocity (between 1.5 and 1.8 s), which is illustrative of a slowing down of the velocity of approach between players.

What action does the players' distance to the sideline afford the ball carrier?

The intersubject distance to the sideline may afford the ball carrier to pass the ball to the support player or to dribble past the tackler and run free to the goal line. We aimed to investigate if the intersubject distance to the sideline influenced the ball carrier's action (i.e., an affordance for other) and how that happens.

Generally, the ball carrier passed the ball to the support player. As expected, in 57 trials (87.6%) the ball carrier passed the ball to the support player, and only in 8 trials (12.3%) the ball carrier decided to go forward towards the goal line. In the 57 trials in which the ball carrier passed the ball, 45 resulted in a try, a dropped pass occurred in 4 trials, and in 8 trials the support player was tackled. The ball carrier succeeded in all the 8 trials in which he decided to go forward. The mean value of intersubject distance to the sideline when the ball carrier decided to go forward was 0.46 m ($s = 0.72$) against 0.33 m ($s = 0.56$) in the pass situation. These values were not significantly different ($t(63) = 2.3$, $P = 0.63$). Large s values indicate that the decision of the ball carrier to go forward or to pass the ball to the support player happened with negative and positive intersubject distances to the sideline. This means that the 'door' (to the sideline) being open or closed at the moment of the decision (i.e., passing or going forward) was not a variable that helped to make a decision to pass the ball or to go forward.

However, the intersubject distance to the sideline and the interpersonal distance between the ball carrier and the tackler at the moment of the decision (i.e., passing or going forward) were correlated. As expected, the distance between the dyad and the intersubject distance to the sideline are variables that might influence both the moment for a pass and the decision to go forward towards the goal line.

When to perform the pass? When the pass occurred in a condition of interpersonal distance greater than 2 m the ball carrier was always closer to the sideline. That also happened in 81.3% of all passes which occurred at interpersonal distances between 2 m and 1.5 m. When the interpersonal distance was shorter (1–1.5 m), this value decreased to 78.2% and, finally, to 45.5% for interpersonal distances below 1 m. These differences are significantly different, $\chi^2(3) = 8.01$, $P = 0.046$. Data are consistent with the tackler and ball carrier increasingly approaching vertical alignment as the interpersonal distance is reduced, as expected.

The results indicated that the ball carrier and the tackler positions relative to the sideline play an important role in the decision of *when* to make a pass. Figure 3 depicts a tendency for the ball carrier to perform a pass at higher interpersonal distances (i.e., sooner), when the tackler is further from the sideline.

Approximately 20% ($R^2 = 0.195$) of the variance at the moment of the pass, expressed by the ball carrier-tackler interpersonal distance, was explained by the intersubject distance to the sideline (see Figure 3), indicating that the players' relative position to the sideline contributes to the regulation of the moment of the pass.

When does the ball carrier decide to go forward? All the 'go forward' trials succeeded. Figure 4 indicates that the ball carrier decides to go forward at higher distances of interpersonal distance (i.e., sooner), and at higher values of intersubject distance to the sideline. However, the ball carrier also decided to go forward when the tackler was at lower distances to the sideline, specifically with intersubject distance to the sideline between −0.5 m and 0.5 m.

Approximately 69% ($R^2 = 0.694$) of the variance in the ball carrier-tackler interpersonal distance at the moment when the ball carrier decides to go forward

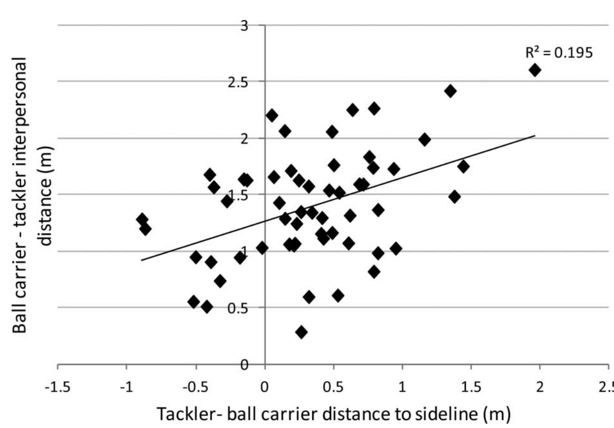

Figure 3. Correlation between the ball carrier-tackler interpersonal distances and intersubject distance to the nearest sideline in the moment of the pass.

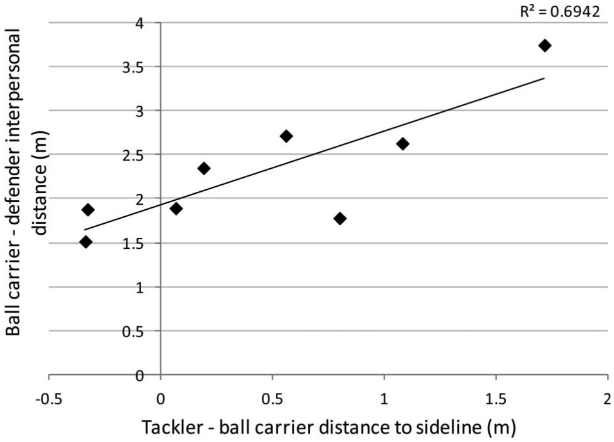

Figure 4. Correlation between the ball carrier-tackler interpersonal distances and intersubject distance to the nearest sideline when the ball carrier *goes forward*.

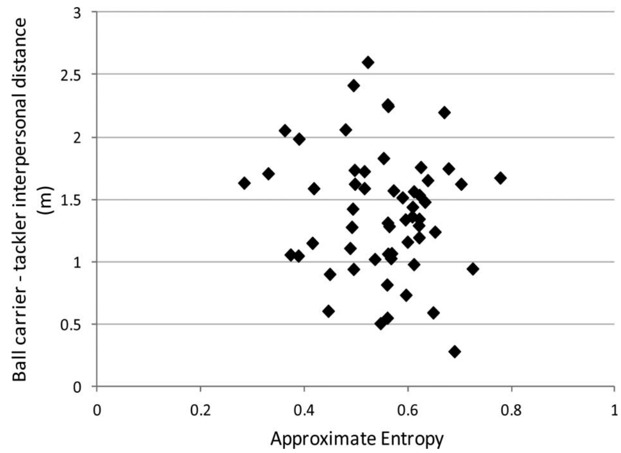

Figure 5. Correlation between ApEn values until the moment of the pass and the ball carrier-tackler interpersonal distances at the moment of the pass.

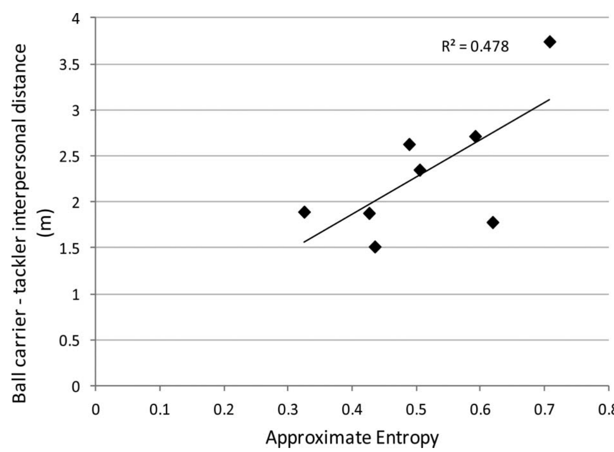

Figure 6. Correlation between ApEn values until the moment of *go forward* and the ball carrier-tackler interpersonal distances at the moment of *go forward*.

towards the goal line was explained by the intersubject distance to the sideline (see Figure 4). This fact highlights the importance of space constraints in decision-making.

The intersubject velocity to the sideline

Approximate Entropy (ApEn) was used to analyse the regularity/variability of intersubject velocity to the sideline from the beginning of the trial until the moment of the decision to pass or to go forward. The ApEn values varied between 0.2 and 0.7 for passes performed at an interpersonal distance between 0 and 2.5 m, and between 0.3 and 0.7 for the situations in which the ball carrier decided to go forward, as displayed in Figures 5 and 6 respectively.

The correlation between the variability of the intersubject velocity to the sideline until the moment of the pass and the ball carrier-tackler interpersonal distance at that moment was close to zero ($R^2 = 0.014$) (see Figure 5), indicating that the moment of the pass was not influenced by the variability of the intersubject velocity to the sideline.

The determination coefficient of 48% ($R^2 = 0.478$) between the variability of the intersubject velocity to the sideline until the moment of 'go forward' and the players interpersonal distance at that moment (see Figure 6) means that the decision to go forward was partially influenced by the changes in the intersubject velocity to the sideline from the beginning of the trial.

Discussion

In competitive settings in sports, many affordances result from the behaviour of other participants (Cordovil et al., 2009; Turvey, 1992). Some variables, like the distances between players or the position of the players relative to the boundaries of the play area, are natural candidates to investigate affordances in team sports (Correia et al., 2011). In this study, we aimed to describe the ball carrier's affordances, considering the distance to the tackler and both players' distances to the nearest sideline.

Our results suggest that some aspects of the interaction between the ball carrier and the tackler play a relevant role in the decision-making process in 2v1 in rugby union. According to our data, neither the velocity of approach between ball carrier and tackler nor the intersubject distance to the sideline helps to discriminate the ball carrier's affordances. Results indicated that the moment of the pass is anticipated when the tackler is further from the sideline than the ball carrier. This conclusion is grounded on higher intersubject distance to the sideline values when the pass is performed at a longer interpersonal distance. This finding is contrary to what was expected, since it was expected that the ball carrier would attempt to 'go forward' whenever the corridor was open. However, that did not happen, and in most of the trials the ball carrier performed a pass to the support player. Additionally, the data revealed that the intersubject distance to the sideline can only explain about 20% of the moments of the pass. The timing of the pass is a matter of great relevance to the game and it is not clear why the pass usually happens at that precise moment. There are three possible explanations for this 'unexpected' situation: i) the ball carrier was strongly conditioned by what was previously defined for a 2v1 situation (i.e., to commit the tackler before performing the pass), which inhibited his perception of other affordances that were available in the context; ii) the ball carrier was aware of the possibility of being 'trapped' between the tackler and the sideline, and performed the pass as a solution to prevent the tackler's interception; iii) at longer distances the ball carrier was not fine-tuned to the relevant information (e.g., tackler positioning/displacement) and was not fully aware of when the 'door' was open or when the tackler was committed with him.

The regularity/variability (ApEn values) of the continuous changes of the intersubject velocity to the sideline did not influence the moment of the pass. Nevertheless, the players' relative position to the sideline at the moment of the pass has a strong influence on the ball carrier's affordances of when to make the pass. This means that there is no leading behaviour information available well in advance. In this specific condition, the players were involved in a continuous co-adaptation, in which the most relevant information is available shortly before the moment of the pass.

We concluded that when the tackler is at a longer distance to the sideline than the ball carrier, there seems to be a tendency to perform the pass earlier. It was expected that the players should be aware of contextual information emerging from different aspects of the game dynamics, but that did not happen. The data revealed that the changing nature of the distance between the ball carrier and the tackler to the sideline did not explain the moment of the pass. This leads to the conclusion that the moment of the pass was mainly constrained by what was previously prescribed (i.e., to commit the tackler before passing the ball to the support player). The ball carrier's behaviour was directed to 'what' to do, but not 'how', 'when' or 'where'.

The moment to decide to go forward to the goal line was mainly influenced by the intersubject distance to the sideline, meaning that, up to a certain point, the ball carrier was aware of this contextual variable. The greater the tackler's distance to the sideline, the sooner the ball carrier decides to go forward. Contrary to what happened when a pass was performed, the changes in the intersubject velocity to the sideline influenced the ball carrier decision about 'when' to go forward. The greater the variability in the intersubject velocity to the sideline, the sooner the ball carrier decided to go forward. Less variability in the intersubject velocity to the sideline meant that the ball carrier needed to decrease the interpersonal distance to the tackler, aiming to explore other available affordances, and consequently the decision to go forward was delayed. Although the position of the tackler offers a constraint that defines a bifurcation for the attacker, all ball carriers used only one of the alternatives – the sideline side. The reason for this systematic behaviour should be addressed in future research. Also, due to the reduced number of trials in which the ball carrier decided to go forward ($N = 8$), this aspect deserves further research.

The first take-home message is that a requisite to succeed in continuously changing environments implies that actors must be aware of the affordances of others, which in turn requires emergent contextual information. The second take-home message is that previously set actions are, in fact, task constraints that bound players' behaviour, but are not a condition to succeed. It was concluded that players perceive affordances of others, that they act accordingly, and that some variables are important to define general affordances that are later specified by events that happen just before decision-making.

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