HIGHER VARIABILITY IN DYADIC INTERACTION PLAYS A POSITIVE ROLE IN THE DECISION MAKING OF FUTSAL PASSING

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Abstract:

This study investigated the role the dyadic interaction variability plays in influencing decision making on passing in the sport of futsal. Participants were 40 male students (M_{age} = 13.6 years, SD = 0.7) from physical education classes of a Brazilian school. They were randomly divided into eight teams, which played four games of 24 minutes according to the rules of the under-14 category of the local Futsal Federation. From the games, a sample of 80 sequences of play involving passes were randomly selected, from the moment the ball carrier got possession of the ball until the moment he passed it. From the *x* and *y* coordinates of all outfield players' displacement, variability of running correlation, cross-correlation, centroid, and interpersonal distance were calculated as measures of dyadic interaction. Results showed that the interaction of passer and receiver dyads were more variable than the remaining dyads. Moreover, it was verified that the passer dyad had the highest variability. The findings enabled us to conclude that, from the attackers' point of view, variability played a positive role. In addition, it appeared that the passer sought to disrupt the interaction with his defender to perform a pass more than his teammates did to receive it. It appears that the skills of passing and receiving in the sport of futsal imply the ability to vary.

Key words: *hierarchy, adaptation, motor skill, system, macro-disorder, holon*

Introduction

In the past few decades, team sports have increasingly been investigated based on a systemic view of science, including the sport of futsal (e.g. Corrêa, Alegre, Freudenheim, Santos, & Tani, 2012; Travassos, 2014; Vilar, et al., 2014). This is because such a view allows considering *interaction* (mutual influence, relationship, communication, joint action, coupling or linking between parts or components) as key performance variable of futsal as a team sport (e.g. Davids, et al., 2014; McGarry, Anderson, Wallace, Hughes, & Franks, 2002).

From a systemic point of view, interaction implies emergence (Bertalanffy, 1952). For instance, team sport of futsal is not characterized by the players' individual actions but rather by the game emerging from players' interaction. Specifically, players interact in a cooperative manner to as a team interact in opposition with the other team in the same time and space of game (Corrêa, Bastos, Basso, & Tani, 2019).

Under this conception, a number of studies have sought to understand players' interactions in specific situations characterized by different levels of analysis. For example, studies have focused on the players' interactions among five attackers and five defenders (e.g. Villar, et al. 2014; Travassos, Araújo, Davids, et al., 2012), five attackers and four defenders (e.g. Corrêa, Davids, Silva, Denardi, & Tani, 2014; Fonseca, Milho, Travassos, & Araújo, 2012; Travassos, Araújo, Vilar, & McGarry, 2011), four attackers and four defenders (e.g. Corrêa, et al., 2016; Travassos, Araújo, Duarte, & McGarry, 2012), two attackers and two defenders (e.g. Silva, et al., 2017), two attackers and one defender (e.g. Vilar, Araújo, Davids, Correia, & Esteves, 2013), and between one attacker and one defender (dyad) (e.g. Amaral & Garganta, 2005; Corrêa, et al., 2016). These levels of analysis have also been named as subsystems (McGarry, et al., 2002), sub-phases (Passos, Araújo, Travassos, Vilar, & Duarte, 2014), functional structure (Greco, 1998), small-sided games and conditioned games (Davids, Araújo, Correia, & Vilar, 2013).

In fact, these recent scientific efforts to comprehend the players' interactions at specific levels of analysis have a logical underpinning on a not-so-considered (or still neglected) systemic concept, hierarchy (Bertalanffy, 1952; Koestler, 1967; Weiss, 1971), which only recently has received attention in team sports research (Corrêa, Alegre, et al., 2012). Based on this, we propose that small-sided games are *holons* of a hierarchically organized system.

A hierarchical system has been conceived as a multilevel hierarchy of semi-autonomous sub-wholes, also named holons, which branch into sub-wholes of a lower order, and so on (Koestler, 1969). Holons are self-regulating, open systems that present both autonomous properties of the whole and the dependent properties of the parts, that is, there is an equilibrium between autonomy and constraint at all levels of the hierarchy (Koestler, 1967; Salthe, 1992). Therefore, the small-sided games allow comprehend the players' interactions because, as a holon, they present the same interactional nature of the game of futsal. For instance, even the lowest level of the hierarchy – a dyad – can be seen as a system that emerges from the interaction between two parts (an attacking player and a defending player) (McGarry, et al., 2002).

Holons are composed by fixed sets of rules and flexible strategies. The rules determine the invariant properties of the system, its structural configuration and/or functional pattern, while the strategic selection of the actual step between the permissible options is guided by environmental contingencies (Koestler, 1969). For instance, a dyad is characterized by the attacker-defender interaction (invariant property), but it is not always made up of fixed members because it may comprise different players according to a game situation (variable/flexible property); still, invariably, the defender functions as a discrepancy and deviation reduction mechanism (negative feedback) between him/her and the attacker in order to reduce or eliminate this latter's actions opportunities; at the same time, the attacker works to amplify or create scoring or passing opportunities (positive feedback). However, what and how each one does it to perform their function vary according to game context (Corrêa, Alegre, et al., 2012). Based on these statements, it appears reasonable to think that variability is a *sine qua non* characteristic of a hierarchical system at whatever level of analysis. As Weiss (1971) stated, the regularity that a system manifests macroscopically (e.g. dyad) dissolves progressively to a microscopic level (an attacker and a defender individually). Weiss adds that the variance of the whole is significantly smaller than the variance of its parts.

In fact, a number of studies developed under a systemic view have pointed out that variability plays an important role in the decision-making and performance of motor skills, including passing in the team sport of futsal (e.g. Silva, et al., 2017). For instance, Corrêa, Vilar, Davids, and Renshaw (2012) showed that the winning team of a futsal game presented different types of variability (intra- and inter-attack patterns). In this case, variability was associated with adaptation ability because the team was effective. On the other hand, the other team exhibited the greatest variability of defense patterns; however, this reflected adaptation inability because the team lost the game. Therefore, we are assuming that variability may mean ability or inability of a system to adapt and evolve.

Based on the foregoing statements that in hierarchical systems the variability of the whole is less than the variability of the parts (Weiss, 1969), it was supposed that, as a holon, a dyad would be characterized by the consistency in the interaction between an attacker and a defender. This study sought to understand how variability of dyadic interaction would influence the decision-making on passing in futsal. We hypothesized that passing would involve a disruption in the dyadic interaction characterized by an increase in the variabilities of the passer and receiver dyads. By considering the defender works continuously to decrease or avoid the attacker's passing opportunities, the attacker, in order to be successful, needs to overcome the defender or increase the gaps between them (Silva, et al., 2017). To put it in another way, the ball carrier would seek to break the interaction with his/her marker to be able to perform pass, whereas his/her teammate would do the same to possibly receive the pass.

Method

Participants

Forty male students from physical education classes of a Brazilian school voluntarily participated in this experiment. They were of an average age of 13.6 years (SD=0.7). Participation required written consent from the parent or legal guardian and verbal assent from the child. The research protocol was approved by an institutional review board for the protection of human subjects at the local university.

Procedures

Students were randomly divided into eight teams, which played four 24-minute games according to the rules of the under-14 category of the local Futsal Federation. The games were recorded using a digital camera (CASIO HS EX-FH100; frequency of 25 Hz) located behind the short axis of a futsal court, which allowed us to capture the displacement of the players and the ball. From these recordings, a sample of 80 sequences of play involving passes were randomly selected, from the moment the ball carrier got possession of the ball (initial moment) until the moment he performed the pass (final moment).

The *x* and *y* coordinates of each outfield player's displacement trajectories in all sequences of play were obtained using Tacto software (Fernandes, Folgado, Duarte, & Malta 2010). This procedure consisted of using a computer mouse on a slow-motion video image (frequency=2 Hz) to follow the players' working point on the futsal court (projection of the center of gravity of each individual player on the floor). This procedure enabled us to get the virtual *x* and *y* coordinates of each player, which were transformed into real coordinates using the direct linear transformation (DLT2D) software, filtered with a low-pass filter (6Hz) (Winter, 2005). It is important to note that this method considers the *z* coordinate equal to zero.

All displacement coordinates were obtained by considering players as a dyadic sub-system consisting of one attacker and one defender. For this purpose, we considered the proximity between attacking and defending outfield players (Figure 1) as follows: the ball passer and his nearest marker (passer dyad), the ball receiver and his nearest marker (receiver dyad), the ball passer's nearest teammate who did not receive the pass and his nearest marker (dyad 3), and the ball passer's farthest teammate who did not receive the pass and his nearest marker (dyad 4). A positive correlation was verified for the intra-analyzer reliability (r=0.86).

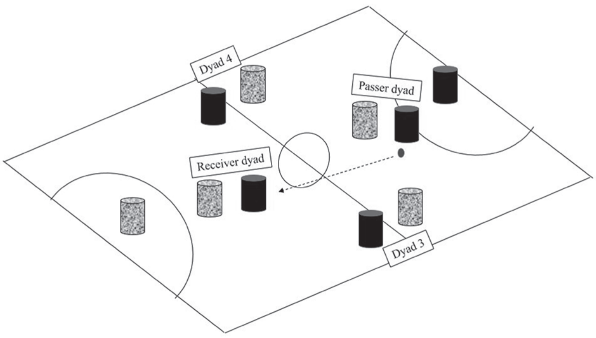

Figure 1. Illustration of dyads passer, receiver, D-3, and D-4.

Dada analyses

From the *x* and *y* coordinates of each outfield player's displacement trajectories from the initial to the final moment (defined by ball possession), we calculated the following measures of dyadic interaction: running correlation, cross-correlation, centroid, and interpersonal distance.

The running correlation and cross-correlation measures show the tendencies of dyad players' synchronization in terms of direction and time of displacement, respectively. To obtain these measures, firstly we calculated the displacements in terms of approaching or distancing of each player in relation to the position of the opposing player in a dyad in the previous frame. Specifically, we considered the imaginary line connecting the two players in the dyad in the previous frame and the projection of their movement between the previous and current frames in this line characterized the measure of approximation and distancing of a player to the other. For this calculation, we used the traditional scalar product formulas: $a \cdot b = a_x b_x + a_y b_y$ for two-dimensional vectors *a* and *b*, and to scale projection: $proj_{a_b} = \frac{a \cdot b}{\|b\|}$. After that, to verify the relation between the measures of approaching and distancing of both players in the dyad, two techniques of time-series were used: running correlation and cross-correlation (Corbetta & Thelen, 1996).

The running correlation calculates a correlation for a given point window between two larger data sets, with the 'displacement' of that window along the data sets. As a result, we obtain a continuous function based on the individual calculations, which allows verifying positive, negative, or neutral associations between these datasets, with values between -1 and 1 as the usual coefficients in the Pearson's correlation. Positive values represent movement in the same direction, while negative values represent movement in the opposite directions (simultaneously approaching or distancing from each other). The running correlation values were analyzed in terms of variability, that is, consistency of synchronization over a sequence of play. The variability of synchronization was calculated through the coefficient of variation (CV =σ/μ), where CV was the ratio of variability, σ was the standard deviation, and σ was the arithmetic mean.

The cross-correlation was calculated as a usual Pearson's correlation after the 'displacement' of all values of one of the data series with respect to the other, with an advance or delay previously defined. For example, for a delay of a frame of the second series relative to the first, all data of the second series are 'delayed' in relation to the corresponding frame of the first series, with the later calculation of the correlation between the two series thus organized. This procedure is repeated for the advanced or delayed values (lags) of interest. In the case of this study, the passes for which the observed duration was greater than 10 frames were selected, and after that, cut windows were established of 2 frames for running correlation and -2 to +2 frames for cross correlation. Thus, lags (from -2 frames to +2 frames) show the time delay introduced from one player's to the other's whole time-series movement data in each pass.

From the *x* and *y* coordinates we calculated the average position of the players of each dyad in terms of centroid, that is, the dyad's geometric center: centroid $(x, y) = (x, y) = \sum_{i=1}^{n} x_i / n, \sum_{i=1}^{n} y_i / n$, where each the player's coordinate pair and the total number of players whose centroid was calculated. Then, the centroid values were analyzed in terms of variability, that is, the consistency of average position of the players over a sequence of play. The variability of average position was calculated through the coefficient of variation (CV=σ /μ), where CV was the ratio of variability, σ was the standard deviation, and σ was the arithmetic mean.

Finally, the interpersonal distance was obtained to access how close or distant the players were. We calculated this by considering the imaginary line (vector) linking an attacker and his marker through the following equation:

$$a \sqrt[2]{(P2x - P1x)^2 + (P2y - P1y)^2},$$

where a is the distance between player 1 (P1) and player 2 (P2). As with the previous measures, the consistency of interpersonal distance of each dyad over a sequence of play was calculated through the coefficient of variation (CV=σ /μ), where CV was the ratio of variability, σ was the standard deviation, and σ was the arithmetic mean.

Therefore, whereas running correlation and cross-correlation allowed accessing the dyadic interaction related to the tendencies of players' synchronization, interpersonal distance and centroid made it possible to capture the relative positioning from one player to the other.

Statistical analyses

To consider the influence of the dyadic interactions' tendencies on decision making of passing, the variabilities of running correlation, centroid, and interpersonal distance were compared using analyses of variance (ANOVAs) in relation to the four dyads (Passer, Receiver, D3, and D4). For this purpose, we considered the initial (first half of the frames), final (second half of the frames), and total variabilities in the sequence of play. In addition, the running and cross-correlation measures were analyzed in descriptive terms. Lastly, passing dyads' results were analyzed in conjunction with the relation to passing outcomes (successful and unsuccessful passes) by one-way ANOVAs for each interaction variable. Observed significant effects were followed up using LSD test *post-hoc* tests. All data analyses were undertaken with STATISTICA® 12.0 software (Stat Soft Inc., Tulsa, USA).

Results

Concerning the running correlation, it is possible to observe in the histograms (Figure 2) that for all dyads there is a non-random distribution

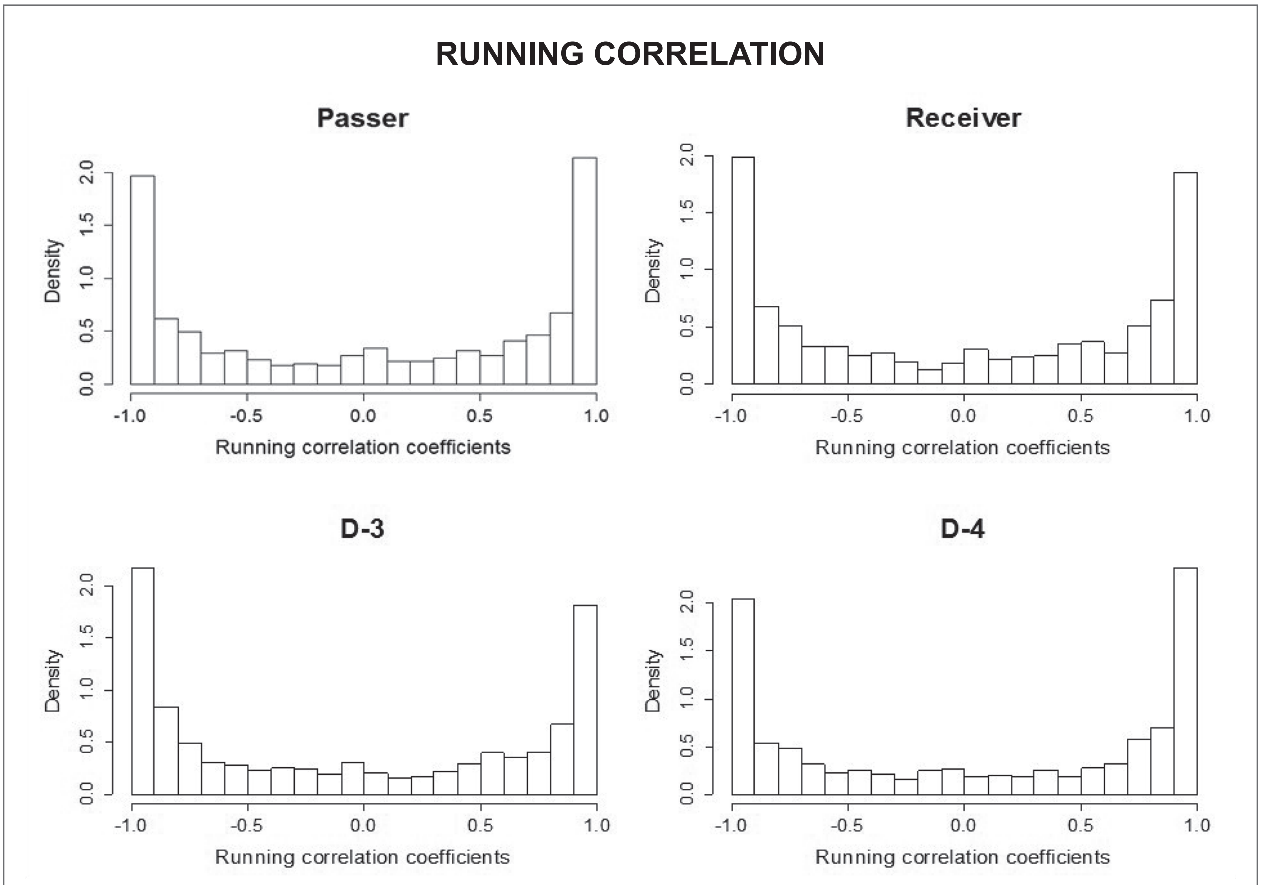

Figure 2. Distribution of density (frames' relative frequency) by running correlation coefficients concerning players' movement towards or away from each other in all dyads (passer, receiver, D-3, and D-4). Positive values represent movement in the same direction while negative values represent movement in opposite directions (simultaneously approaching or distancing away from each other).

of correlation values. Values close to -1 and 1 were those more frequent, which suggests two patterns of displacement of the players in the dyad: opposite directions (-1) or same direction (1).

Regarding the consistency of synchronization, the one-way ANOVA did not reveal differences for either the initial [$F(3, 316)=2.06$, $p>.05$, $\eta^2=.02$], final [$F(3, 316)=0.64$, $p>.05$, $\eta^2=.01$], or total synchronizations [$F(3, 316)=1.14$, $p>.05$, $\eta^2=.01$].

In relation to the cross-correlation, results did not show any remarkable tendency of dyads in the various delays of the cross-correlation (Figure 3), which suggests that the players' displacements did not follow an observable pattern of either anticipation or delay.Regarding the consistency of advancing or delaying behaviors (Figure 4), the one-way ANOVA revealed differences for the initial [$F(3, 316)=3.03$, $p<.05$, $\eta^2=.02$] and the total

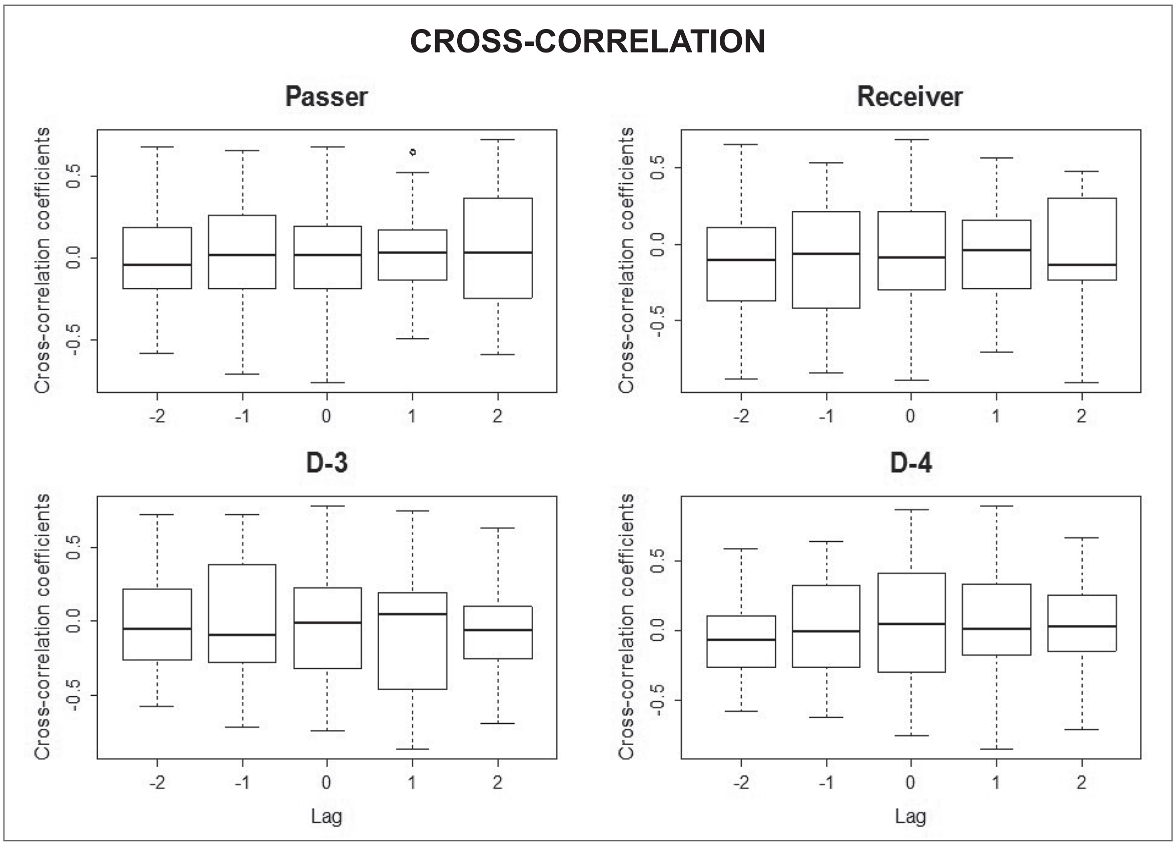

Figure 3. Boxplots for cross-correlation coefficients concerning players' movement towards or away from each other in all dyads (passer, receiver, D-3, D-4). Positive values represent movement in the same direction while negative values represent movement in opposite directions (simultaneously approaching or pulling away from each other). Lags (from -2 frames to +2 frames) show the time delay introduced from one player to the other's whole time-series movement data in each pass.

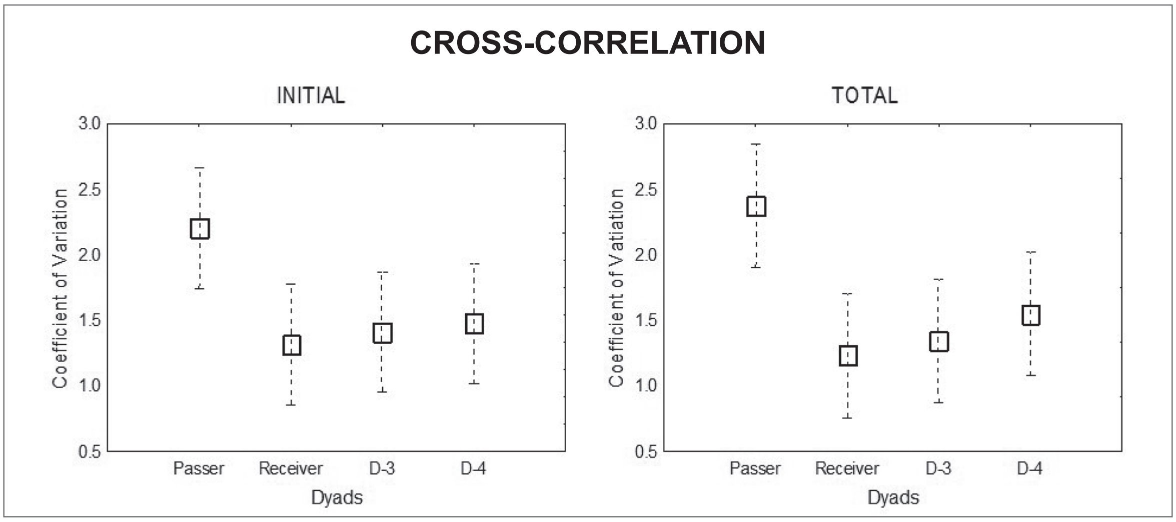

Figure 4. Mean of variability of initial, final, and total cross-correlation of passer, receiver, D-3, and D-4.

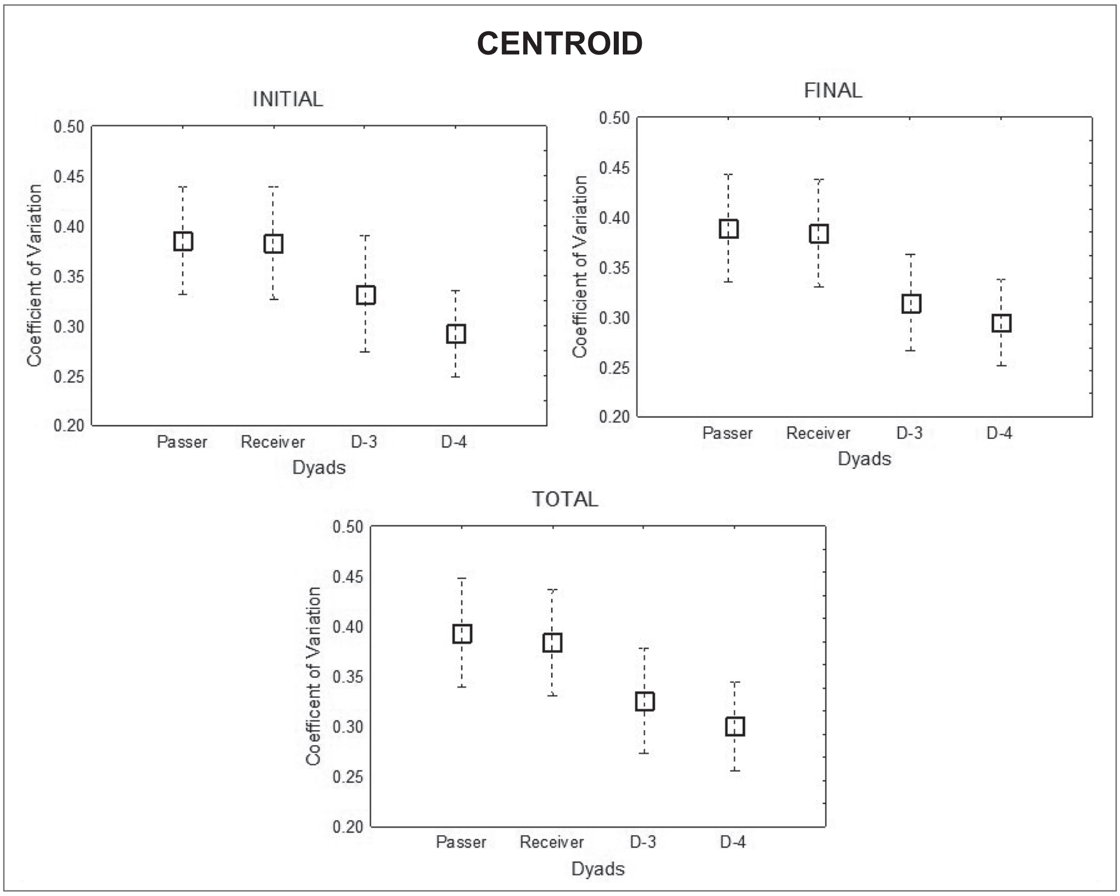

Figure 5. Mean of variability of initial, final, and total centroids of passer, receiver, D-3, and D-4.

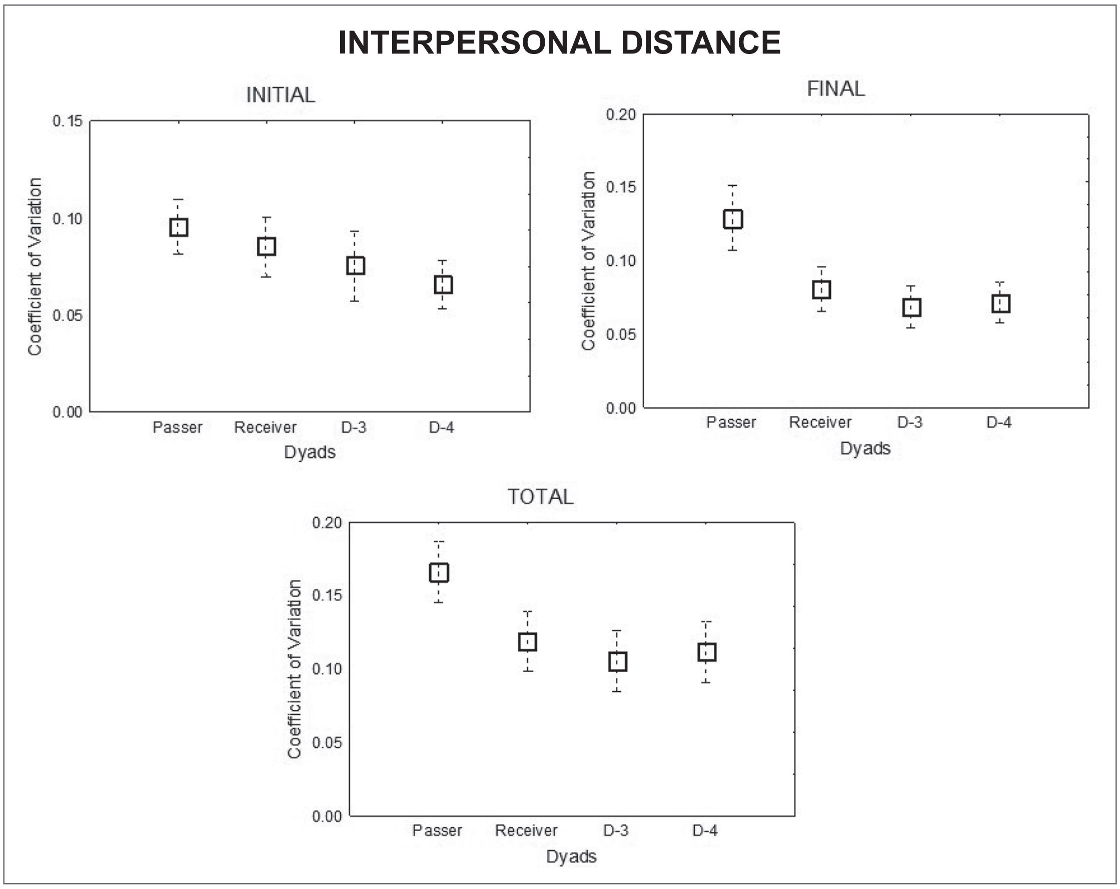

Figure 6. Mean of variability of initial, final, and total interpersonal distance of passer, receiver, D-3, and D-4.

synchronizations [F(3, 316)=4.61, $p<.05$, $\eta^2=.04$]. *Post-hoc* testing showed that the Passer dyad had a more variable temporal synchronization in the initial and total frames than the remaining dyads ($p<.05$).

Considering the centroid (Figure 5), the one-way ANOVA revealed differences for the initial variability [$F(3, 316)=5.44$, $p<.01$, $\eta^2=.05$], the final variability [$F(3, 316)=6.39$, $p<.01$, $\eta^2=.06$], and the total variability [$F(3, 316)=6.22$, $p<.01$, $\eta^2=.06$]. For all of them, the *post-hocs* showed that the passer and receiver dyads were more variable than the D3 ($p<0.01$) and D4 dyads ($p<.05$).

Regarding the interpersonal distance (Figure 6), the one-way ANOVA revealed differences for the initial variability [$F(3, 316)=6.61$, $p<.01$, $\eta^2=.05$]. The *post-hoc* showed that the passer dyad was more variable than D3 and D4 ($p<.01$), and that the receiver dyad had interpersonal distance more variable than D4 ($p<.05$). For the final variability, the one-way ANOVA also revealed differences [$F(3, 316)=21.50$, $p<.01$, $\eta^2=.17$]. The *post-hoc* showed that the passer dyad was more variable than the receiver, D3 and D4 dyads ($p<.05$). Concerning the total variability, the one-way ANOVA revealed that [$F(3, 316)=12.90$, $p<.01$, $\eta^2=.11$]. The *post-hoc* showed that the passer dyad was more variable than the receiver, D3 and D4 dyads ($p<.05$), and that the receiver dyad was more variable than D3 ($p<.05$).

Passing outcomes

The one-way ANOVAs did not reveal effects for any variable.

Discussion and conclusion

This study investigated the influence of variability of dyadic interaction on the decision making of passing in the team sport of futsal. Results showed that the passer dyad had greater variability of temporal synchronization in the initial and total frames than the remaining dyads, and the passer and receiver dyads had more variable initial, final, and total centroids than the D3 and D4 dyads. Additionally, the passer dyad had greater variability of interpersonal distance than the D3 and D4 dyads (initial); the receiver, D3 and D4 dyads (final); D3 and D4 dyads (total). Finally, the receiver dyad had greater variability of interpersonal distance than the D4 (initial), D3 and D4 (final), and D3 (total) dyads.

It is longstanding that scientists have focused on variability to comprehend phenomena in different areas of knowledge (e.g. see Conrad, 1983; Newell & Corcos, 1993). In fact, the significance given to variability has changed over time, mainly because of changes in the systemic paradigm. For example, until about the half of the past century, the systems receiving the most focus were those based on mechanisms of neutralization-deviations (i.e. negative feedback). In such systems, variability was synonymous with error, discrepancy, or noise, which should be eliminated. The arsenal of automatic machines performing military or industrial functions are some examples. There seems to be no doubt that World Wars I and II were great influencers of this view (Wiener, 1948).

On the other hand, the second half of the past century was marked by the emphasis on systems which also functioned as amplifying-deviations mechanisms (i.e. positive feedback) (Prigogine & Stengers, 1984). These were the cases of living phenomena in which variability may signify a source of adaptability (Conrad, 1983; Touwen, 1993). The development of this new emphasis was stimulated by the consideration of living systems as systems far from equilibrium and dissipative structures (Murphy & O'Neill, 1997). It was in this context that a view of hierarchically organized systems in which variability plays different roles was proposed.

Our hypothesis was supported because results showed that the dyadic interactions involved in the pass were characterized by the highest variability. On the basis of our hypothesis, variability of dyadic interaction would reflect the continuous trials of the attacker players 'to get rid' of the defender players as they continually try to avoid it. We proposed that the increase of variability would be a result of the attackers' actions trying to destroy the system (dyad), i.e. to break their interaction with their markers (defenders) to be able to successfully pass the ball. Thus, from the attackers' point of view, variability plays a positive role. Interestingly, the results also showed that the passer dyad had a more variable interaction than the receiver dyad. Thus, it appeared that the ball passer sought more to disrupt the interaction with the defender to pass the ball than his teammates did to receive it.

Although greater variability influenced the decision for dribbling in futsal because it implied risk and/or uncertainty of the ball carrier losing the ball (Corrêa, et al., 2016), here it afforded the possibility of a pass to be completed because the attacking player is breaking his interaction with his marker. Importantly, the greater variability in the dyads involved in the pass (passer and receiver) was observed in relation to all interaction measures. Based on this, one could infer the robustness of the results. Different measures were used assuming that a complex system cannot be reduced to a single measurement or interpreted from a single path. In fact, recent scientific advances have made possible not only a new phenomenon view and investigation technology but also the use of a number of measures for accessing players' interactions in team sports (Passos, et al., 2014). For instance, in the futsal context interpersonal distance (Corrêa, et al., 2016), relative phase (Travassos, et al., 2012), and centroid (Bueno, et al., 2018) have been used to access players interactions.

Finally, the results showed that variability did not affect passing outcomes. This means that variability was a key aspect only for decision making on passing. Or the results may reveal that perhaps a greater variability functions similarly to a region of self-organized criticality. What we mean by this is that when variability increases significantly, the system reaches a critical state of organization, which prompts it to evolve. A region of self-organized criticality refers to a state reached by a complex system near the border or edge of chaos and prompt for changing (Bak & Chen, 1991).

In summary, the findings of this study enabled us to conclude that decision making on passing was influenced by the higher variabilities of dyadic interaction measures of running correlation, cross-correlation, centroid, and interpersonal distance. This is because the passer and receiver dyads had greater variabilities in the foregoing measures than the remaining dyads; and the passer dyad had the highest variabilities. Moreover, we conclude that success in passing was not affected by the variabilities of dyadic interactions.

Our findings advance the existing knowledge by showing that a higher variability in dyadic interaction plays a positive role in the decision making of passing in futsal. It appears that the motor skills of passing and receiving in the sport of futsal imply the ability to vary. This add useful insights for applying in practical contexts in the sense that teachers/coaches should teach the attacking players to maximize positioning changes relative to their markers (defenders). On the other hand, defenders should be instructed to be attuned to the attacking players' positioning changes to avoid breaking their couplings. Obviously, considering that such insights are limited to our results, therefore, their utilization as instruction needs further investigation.

References

Amaral, R., & Garganta, J. (2005). A modelação do jogo em Futsal. Análise sequencial do 1x1 no processo ofensivo. [Game modelling in futsal. Sequential analysis of 1x1 in attacking process. In Portuguese.] *Revista Portuguesa de Ciências do Desporto, 3*(V), 298-310.

Bak, P., & Chen, K. (1991). Self-organized criticality. *Scientific American, 264*, 26-33.

Bertalanffy, L. von (1952). Problems of life. London: Watts.

Bueno, M.J.O., Caetano, F.G., Yonezawa, M.K., Grella, A.S., Cunha, S.A., & Moura, F.A. (2018). How do futsal players of different categories play during official matches? A tactical approach to players' organization on the court from positional data. *PLoS ONE 13*(6), e0199619. doi: 10.1371/journal.pone.0199619

Conrad, M. (1983). *Adaptability: The significance of variability from molecule to ecosystem*. New York: Plenum.

Corbetta, D., & Thelen, E. (1996). The developmental origins of bimanual coordination: A dynamic perspective. *Journal of Experimental Psychology: Human Perception and Performance, 22*, 502-522. doi: 10.1037/0096-1523.22.2.502

Corrêa, U.C., Alegre, F., Freudenheim, A.M., Santos, S., & Tani, G. (2012). The game of futsal as an adaptive process. *Nonlinear Dynamics, Psychology and Life Sciences, 16*, 185-204.

Corrêa, U.C., Bastos, F., Basso, L., & Tani, G. (2019). Futsal: concepção, estudo e intervenção. [Futsal: conception, study and intervention. In Portuguese.] In R. Mendes & G. Dias (Eds.), *Controlo motor e aprendizagem: Aplicações no treino desportivo* (pp. 31-41). Coimbra: Universidade de Coimbra.

Corrêa, U.C., Davids, K., Silva, S.L, Denardi, R.A., & Tani, G. (2014). The influence of a goalkeeper as an outfield player on defensive subsystems in futsal. *Advances in Physical Education*, *4*, 84-92.

Corrêa, U.C., Pinho, S.T., Silva, S.L., Clavijo, F.A.R., Souza, T.O. & Tani, G. (2016). Revealing the decision-making of dribbling in the sport of futsal. *Journal of Sports Sciences 34*, 1-8. doi: 10.1080/02640414.2016.1232488

Corrêa, U.C., Vilar, L., Davids, K., & Renshaw, I. (2012). Informational constraints on the emergence of passing direction in the team sport of futsal. *European Journal of Sport Science*, *6*, 1-8. doi: 10.1080/17461391.2012.730063

Davids, K., Araújo, D., Correia, W., & Vilar, L. (2013). How small-sided and conditioned games enhance acquisition of movement and decision-making skills. *Exercise and Sport Sciences Reviews, 41*, 154-161. doi: 10.1097/JES.0b013e318292f3ec

Davids, K., Hristovski, R., Araújo, D. Serre, N.B., Button, C., & Passos, P. (2014). *Complex systems in sports*. New York: Routledge.

Fernandes, O., Folgado, H., Duarte, R., & Malta, P. (2010). Validation of the tool for applied and contextual time-series observation. *International Journal of Sport Psychology, 41*, 63-64.

Fonseca, S., Milho, J., Travassos, B., & Araújo, D. (2012). Spatial dynamics of team sports exposed by Voronoi diagrams. *Human Movement Science, 31*, 1652-1659. doi: 10.1016/j.humov.2012.04.006

Greco, P.J. (1998). *Iniciação esportiva universal: metodologia da iniciação esportiva na escola e no clube*. [Universal sports initiation: methodology of sports initiation in school and club. In Portuguese.] Belo Horizonte: UFMG.

Koestler, A. (1967). *The ghost in the machine*. London: Hutchinson.

McGarry, T., Anderson, D.I., Wallace, S.A., Hughes, M., & Franks, I.M. (2002). Sport competition as a dynamical self-organizing system. *Journal of Sports Sciences, 20*, 771-781. doi: 10.1080/026404102320675620

Murphy, M.P., & O'Neill, L.A.J. (1997). O que é vida? Uma introdução sobre os próximos 50 anos. [What is life? An introduction on the next 50 years. In Portuguese.] In M.P. Murphy & L.A.J. O'Neill (Eds.), *O que é vida? 50 anos depois: especulações sobre o futuro da biologia*. São Paulo: Editora da UNESP.

Newell, K., & Corcos, D. (1993). *Variability and motor control*. Champaign, IL: Human Kinetics.

Passos, P., Araújo, D., Travassos, B., Vilar, L., & Duarte, R. (2014). Interpersonal coordination tendencies induce functional synergies through co-adaptation processes in team sports. In K. Davids, R. Hristovski, D. Araújo, N.B. Serre, C. Button, & P. Passos (Eds.), *Complex systems in sport* (pp. 104-124). New York: Routledge.

Prigogine, I., & Stengers, I. (1984). *A nova aliança: metamorfose da ciência*. [The new alliance: metamorphosis of science. In Portuguese.] Brasília: Editora da UnB.

Salthe, S.N. (1992). Hierarchical non-equilibrium self-organization as the new post-cybernetic perspective. In G.V. Vijver (Ed.), *New perspectives on cybernetics: Self-organization, autonomy and connectionism*. Dordrecht: Kluwer.

Silva, S.L., Travassos, B., Davids, K., Sabino da Silva, A., Moreira, A., & Corrêa, U.C. (2017). Effects of experience, knowledge and skill on regulating the performance of futsal passing actions. *International Journal of Sport Psychology, 48*, 37-49.

Touwen, B.C. (1993). How normal is variable or how variable is normal? *Early Human Development, 34*, 1-12. doi: 10.1016/0378-3782(93)90035-S

Travassos, B. (2014). *A tomada de decisão no futsal*. [Decision making in futsal. In Portuguese.] Estoril, Portugal: Prime Books.

Travassos, B., Araújo, D., Davids, K., Esteves, P.T., & Fernandes. O. (2012). Improving passing actions in team sports by developing interpersonal interactions between players. *International Journal of Sports Science and Coaching, 7,* 677-688. doi: 10.1260/1747-9541.7.4.677

Travassos, B., Araújo, D., Duarte, R., & McGarry, T. (2012). Spatiotemporal coordination behaviors in futsal (Indoor Football) are guided by informational game constraints. *Human Movement Science, 31,* 932-945. doi: 10.1016/j.humov.2011.10.004

Travassos, B., Araújo, D., Vilar, L., & McGarry, T. (2011). Interpersonal coordination and ball dynamics in futsal (Indoor Football). *Human Movement Science, 30,* 1245-1259. doi: 10.1016/j.humov.2011.04.003

Vilar, L., Araújo, D., Davids, K., Correia, V., & Esteves, P.T. (2013). Spatial-temporal constraints on decision-making during shooting performance in the team sport of futsal. *Journal of Sports Sciences. 31*, 840-846. doi: 10.1080/02640414.2012.753155

Vilar, L., Araújo, D., Davids, K., Travassos, B., Duarte, R., & Parreira, J. (2014). Interpersonal coordination tendencies supporting the creation/prevention of goal scoring opportunities in futsal. *European Journal of Sport Science, 14*, 28-35. doi: 10.1080/17461391.2012.725103

Weiss, P. (1969). Living systems: Determinism stratified. In A. Koestler & J.R. Smythies (Eds.), *Beyond reductionism* (pp. 3-42). London: Hutchinson.

Weiss, P.A. (1971). The basic concept of hierarchic systems. In P.A. Weiss (Ed.), *Hierarchically organized systems in theory and practice* (pp.1-44). New York: Hafner.

Wiener, N. (1948). *Cybernetics*. New York, NY: Wiley.

Winter, D.A. (2005). *Biomechanics and motor control of human movement*. (3rd ed.). New York, NY: John Wiley & Sons.

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