Field dimension and skill level constrain team tactical behaviours in small-sided and conditioned games in football.

Journal:	*Journal of Sports Sciences*
Manuscript ID:	Draft
Manuscript Type:	Original Manuscript
Keywords:	Collective behaviours, task constraints, small-sided games

Title: Field dimension and skill level constrain team tactical behaviours in small-sided and conditioned games in football.

Running title: Tactical behaviours in small-sided games

Type of article: original research

Keywords: Collective behaviours, task constraints, small-sided games.

Abstract

This study analysed the influence of field dimension and players' skill level on collective tactical behaviours during small-sided and conditioned games (SSCGs). Positioning and displacement data were collected using global positioning systems (15 Hz) during SSCGs (Gk+4 v. 4+Gk) played by two groups of participants (NLP-national-level and RLP regional-level players) in different field dimensions (small: 36.8 x 23.8 m; intermediate: 47.3 x 30.6 and large: 57.8 x 37.4 m). Team tactical performance was assessed through established dynamic team variables (effective playing space, playing length per width ratio and team separateness) and non-linear signal processing techniques (sample entropy of distances to nearest opponents and the team centroid mutual information). Results showed that the effective playing space and team separateness increased significantly with pitch size regardless of participant skill level (p<0.001, η^2=0.78 and p<0.001, η^2=0.65, respectively). Playing length per width ratio increased with pitch size for the NLP but was maintained at a relatively constant level by RLP across treatments indicating different playing shapes. There was significantly more unpredictability in distances to nearest opponents for the NLP in small (p=0.003) and intermediate fields (p=0.01). Findings suggest that tactical behaviours in SSCGs are constrained by field size and skill level, which need to be considered by coaches when designing training practices.

Introduction

Sports teams have been modelled as interacting social units which benefit from natural processes of self-organization among players who cooperate with each other to achieve common intended goals (Duarte, Araújo, Correia, & Davids, 2012; Silva, Garganta, Araújo, Davids, & Aguiar, 2013). This conceptualisation has several implications for training design in team sports, since manipulation of specific key task constraints may channel individual and team tactical behaviours into stable and functional coordination patterns (or attractors) during goal-directed team activities (Araújo, Davids, Bennett, Button, & Chapman, 2004; Handford, Davids, Bennett, & Button, 1997).

In association football, the use of small-sided and conditioned games (SSCGs) constitutes an example of goal-directed team training activities widely used by coaches to shape technical, physical and tactical skills, concurrently (Davids, Araújo, Correia, & Vilar, 2013; Hill-Haas, Dawson, Impellizzeri, & Coutts, 2011). At present, the acute physiological and technical responses under different SSCGs constraints have been extensively addressed in the literature (see Hill-Haas et al., 2011, for a review). For example, previous studies showed that enlarging field dimensions increased the physical and physiological workload and the rating of perceived exertion of male youth soccer players (Casamichana & Castellano, 2010), while smaller pitches promoted a higher number of shots, tackles, challenges, loss of ball possessions and physical contact incidents (Dellal et al., 2012; Kelly & Drust, 2009). However, interpersonal coordination patterns that may emerge from the individual and team tactical behaviours performed during such tasks have scarcely been studied. In fact, field dimension is one of the most frequently manipulated constraints in SSCGs during team games practice and yet little is known about the outcomes of these changes. By altering the available space to play, the areas covered by players of both teams, and their relationships, trajectories and distances on field, may change due to changing informational constraints like ball trajectory, location of the goal and nearest defenders. Previous research has shown how such informational constraints can afford specific technical actions like shooting (Vilar, Araújo, Davids, Correia, & Esteves, 2012), dribbling (Duarte, Araújo, Davids, et al., 2012; Duarte et al., 2010) and passing (Travassos et al., 2012).

On what concerns tactical performance, experiential knowledge of high level coaches supports the assumption that games played in smaller playing areas reduce the distances between opponent players, whereas creation of space may be more easily achieved using larger playing areas. Clear evidence about the actual tactical behaviours emerging during SSCGs played in different field dimensions is needed, since it can lead to the design of specific affordances (invitations for selected actions; see Withagen, Poel, Araújo & Pepping, 2012) during practice and to the emergence of distinct learning opportunities, skills and decision-making.

A constraints-led approach advocates the need to understand the spatial-temporal relations emerging from the exploratory behaviours of players seeking to adapt to changing task demands (Passos et al., 2008). Some work by Frencken, van der Plaats, Visscher, and Lemmink (2013) has shown that reduced field length and width in SSCGs caused the players to close down space relative to each other, longitudinally and laterally, respectively. This was demonstrated through measurements of lateral and longitudinal distances between the teams' centres in pitches of varying sizes. Teams playing in fields with different sizes but same length to width ratios also revealed performance differences due to different surface area values. The authors also argued that skilled players would be likely to establish stronger relations (depicted by stronger couplings between team centres) between each other due to their ability to anticipate movements of teammates and opponents. From an ecological dynamics perspective, expert behaviour in sport is conceptualised as the ability to functionally adapt to the dynamically changing interacting performance constraints perceived (Seifert, Button, & Davids, 2013). This means that manipulation of the same football training task constraints, with players of different skill levels, might also lead to the emergence of different tactical behaviours. As yet, there is limited understanding of how different field dimensions interact with player skill levels. This information can be useful for adapting task constraints to players of specific skill levels in order to optimize skill acquisition and provide insights on the tactical features that characterize distinct expertise levels.

Analyses of complex team behaviours displayed during SSCGs played in fields of varying dimensions are required to uncover the dynamic spatial-temporal relations between players (Vilar, Araújo, Davids, & Button, 2012) and describe specific tactical adaptations of players to field size constraints. From the perspective of the coverage of space, manipulations in field size may impact on the area covered by both teams, with larger dimensions possibly resulting in greater width coverage. The shape of the covered area may vary from elongated playing shapes to more flattened shapes according to field length and width dimensions. Recently, Folgado, Lemmink, Frencken, and Sampaio (2012) found different length per width ratios in teams of youth football players of different ages, with teams of younger players displaying higher length and lower width coverage. This shape indicated the preferred axis of expansion of the teams during match play, an important characteristic of space occupation that can be particularly useful for coaches seeking to enhance specific team tactical behaviours, like the goal-to-goal outstretched distribution, or the distribution of players to lateral zones of the field.

By covering different field areas, the interpersonal distances between teammates and their opponents may also vary, impacting on the collective decision-making behaviour of the players. Previous studies have highlighted the importance of interpersonal distances as a constraint on attacking play in football dyads (Duarte et al., 2010) and functional team coordination in rugby union (Passos et al., 2011).

For understanding the collective movements of teams during play, analysis of the team centres (or centroids) trajectories might provide information about the synchronization of the two teams during both attacking and defensive sub-phases. The centroid represents the relative position of the team on field and its coupling has been revealed to be stronger in the longitudinal direction, both in SSCGs (Duarte, Araújo, Freire, et al., 2012; Frencken, Lemmink, Delleman, & Visscher, 2011) and full-sized matches (Bartlett, Button, Robbins, Dutt-Mazumder, & Kennedy, 2012). Furthermore, as discussed earlier, analyses of centroid coupling strength can provide insights on player expertise level.

Given this theoretical rationale, the aim of this study was twofold. First, we aimed to examine differences in team tactical behaviours when pitch dimensions are manipulated during SSCGs practice. Second, we sought to investigate how skill level impacts on the collective behaviours expressed. We expected that both field size and skill level would constrain different interpersonal interactive behaviours, and thus, lead to the emergence of different action possibilities and tactical adaptations.

Methods

Participants

Twenty male youth football players from two different clubs participated in this research study. Their skill level was determined according to their competitive performance level. Players from Club A (age: 16.20±0.63 yrs; playing experience: 6.6±1.65 yrs) competed at a national-level, whereas players from Club B (age: 15.60±0.52 yrs; playing experience: 6.2±2.35 yrs) competed in the 2nd division of their regional Association Football competition. Based on this criterion, participants were classified at either national-level (NLP) or regional-level (RLP) of performance. The study protocol was approved by the Ethics Committee of the Faculty of Sports of Porto University, Portugal.

Small-sided games

Each group of players was assigned by their coaches to two teams of four players plus one goalkeeper that performed in three Gk+4 v 4+Gk SSCGs using 7-a-side football goals. The goalkeepers played inside an area marked five-meters from the goal line and extending across the field width. Passing the ball to the goalkeeper was not allowed in order to optimize offensive play by the outfield players. All SSCGs were played according to the other official rules of Association Football with the exception of the offside rule that was not applied.

Each SSCG was 7-min duration interspersed with 7-min resting periods. During recovery periods, participants were allowed to recover actively at will and rehydrate. Coaches were instructed to not provide any sort of encouragement or feedback to the players as it could impact on the intensity of participant performance in SSCGs (Rampinini et al., 2007).

Each SSCG field dimension was calculated using official football field dimensions – 105 x 68 m as a reference. Length and width were reduced in proportion to the number of players involved in the SSCGs (Hughes, 1994), providing size estimates of the intermediate field - 47.3 x 30.6 (length x width). The small and large field measures were set by subtracting and adding 10% to the intermediate field measures, respectively. Thus, the small field was 36.8 x 23.8 m (length x width) and the large field was 57.8 x 37.4 m. A ratio of 1.5:1, as reported in official field measures, was maintained between length and width in all SSCGs.

The SSCGs were played in the small field first, followed by the intermediate and large fields (order set arbitrarily).

Data collection

Each outfield player carried an unobtrusive global positioning tracking device (SPI Pro, GPSports, Canberra, Australia) that captured the longitudinal and latitudinal movement coordinate time-series with a sampling frequency of 15 Hz.

All pitches used in the treatments were calibrated with the coordinates of four GPS devices stationed in each corner of the pitch for about 2 minutes. The absolute coordinates of each corner were calculated as the median of the recorded time series, providing measurements that were robust to the typical fluctuations of the GPS signals. These absolute positions were used to set the Cartesian coordinate systems for each pitch, with the origin placed at the pitch centre. Longitudinal and latitudinal (spherical) coordinates were converted to Euclidean (planar) coordinates using the Haversine formula (Sinnott, 1984). Fluctuations in the players' positioning were reduced using a moving average filter with a time scale of 0.2 seconds and data resampling was employed to synchronize the time series of all players within each game.

Tactical variables

Team tactical behaviours were assessed by measuring: (i) the area of the effective playing space (EPS); (ii) the playing length per width ratio (PLpW); (iii) the teams' separateness (TS); (iv) the uncertainty of the distances separating each player from his nearest opponent; and (v), the teams' mutual dependency during collective lateral and longitudinal movements (see Figure 1A for an illustration).

The effective playing space (EPS) represents the polygonal area defined by the players located at the periphery of play (Gréhaigne & Godbout, 2013) and was calculated (in m^2) by computing the area of the smallest convex hull containing all outfield players in the SSCG (goalkeepers excluded).

The PLpW represents the relationship between the playing length and width and describes the preferable axis direction towards which the players from both teams are distributed, that is, the preferable shape of the match. In this study, an elongated playing shape was considered for values of PLpW above 1.3 (width representing ≈75% of length), whereas values below 0.7 indicated a flattened playing shape (length representing ≈75% of width). Values of PLpW ranging between 0.7 and 1.3 were considered to represent an identical distribution of players in both axes.

The TS was defined as a measure of the degree of free movement each team has available. It was computed by organizing the distances between opponent players in a pair-wise distance matrix *M(t)* of order 16 (4 x 4 players, excluding goalkeepers). The TS for a team was defined as the sum of distances between each team player and the closest opponent. This measure has units of meters and can be interpreted as the radius of action free of opponents. A measure of TS was preferred to other metrics such as the centroids distance to measure the closeness of the teams' players since the latter does not account for the teams' dispersion differences and thus, can not inform about the players' radius of free movement. A value of TS close to 0 indicates that all players are closely marked, while a high value indicates more freedom of movement. The uncertainty of interpersonal distances values throughout the duration of SSCGs was also analysed by means of sample entropy measures (SampEn). SampEn(*m, r, N*) is defined as the negative natural logarithm of the conditional probability that two sequences, similar for *m* points (length of the vector to be compared), remain similar at the next point $m + 1$.(Richman & Moorman, 2000) The similarity criterion is set by r×SD of the time-series. Given the analysed time series length (840 data points), the parameter combination used in this study was $m = 2$ and $r = 0.1$. The structure of variability was reflected by values of SampEn ranging between 0 towards infinity where 0 represents a perfectly repeatable time series and infinity is a totally unpredictable time series. From this quantity we could infer the unpredictability present in each competing dyad.

The mutual dependency between the collective movements of the two teams (for longitudinal and lateral movements) was calculated by measuring the nonlinear correlation of the two centroids' movements as the average mutual information (AMI). The calculation of the AMI is grounded in the measure of mutual information:

$$I(X;Y) = \sum_{X,Y \in \mathcal{A}} P(X,Y) \log\left(\frac{P(X,Y)}{P(X)P(Y)}\right) \quad (2)$$

where X and Y represent each team's centroid movement coordinates and $\mathcal{A}$ is the space discretization, defined by the space binning, from which X and Y take their values (Cover & Thomas, 1991). The AMI was used to identify and characterize relationships between data sets that are not detected by linear measures of correlation. It was provided with normalized values ranging between 0 and 1, where 0 occurs if, and only if, the time series of the two centroid coordinates, X and Y, are independent. Non-zero values account for the reduction in uncertainty about one team's centroid location, given knowledge of the other team's centroid value. A value of 1 represents total predictability of one centroid's movements, from the knowledge of the other centroid's movements.

(Figures 1A and 1B around here)

Statistical analysis

The rate of change of all variables was below 2 m/s and 2 m/s^2 (velocity and acceleration, respectively). Thus, a sampling rate of 2 Hz was considered appropriate to capture the variables' time-variations under the differing pitch and skill conditions. For statistical analysis purposes, the mean values of the variables EPS, PLpW and TS and the AMI values of the teams' centroids were recorded during several playing sequences in each SSCG. Each sequence captured the ebb-and-flow rhythm of the games in which the total match centroid (depicted as the mean x- and y- coordinates of all players in the field) transited the pitch in both directions (goal-to-goal) during coordinated longitudinal movements of both teams on field (Figure 1B). During such playing sequences, both teams maintained possession of the ball and attacked the opposing team's goal alternately. In each trial, the eight longest cycles were identified and recorded for analysis. The overall average period duration was 40.5±14.3 seconds ($M \pm SD$) with no duration differences found between groups (p=0.88) neither treatments (p=0.91). The coefficients of variation of the analysed variables for all periods were below 30% and also revealed no differences in data dispersion between SSCGs and groups (p>0.05 for all variables). Thus, it was assumed that data were identically distributed in all periods and treatments.

All values of EPS, PLpW, TS, AMI and SampEn were then subjected to two-way ANOVAs to identify possible differences between skill-level groups and SSCGs formats. Effect sizes were reported as partial eta squared (η^2) and, whenever justified, pairwise differences were followed-up using Bonferroni post hoc tests.

Results

Figure 2 shows values of EPS, PLpW, TS, and SampEn across SSCGs and expertise groups. EPS increased with field dimension for both groups, as expected. Results revealed a main effect of SSCG, F=70.96, p<0.001, η^2=0.78, with mean values differing significantly between all treatments (p<0.001 for all pairwise comparisons, SE=0.88).

The PLpW revealed an interaction effect, F=4.14, p=0.02, η^2=0.17, with the NLP displaying significantly higher values than the RLP on the large field condition (p=0.007) and was close to conventional levels of statistical significance (p=0.06) in the intermediate field condition. Results indicated an elongated playing shape for the NLP in the intermediate and large fields (values of PLpW above 1.3). Additionally, the NLP revealed marked differences between performance on the small and the intermediate field (p<0.001) and between the small and the large field (p<0.001), while the RLP did not present statistically significant differences between any of the field conditions.

The TS exhibited the same trend as EPS, observable in Figure 2C. The ANOVA results revealed a main effect for SSCG, F=36.84, p<0.001, η^2=0.65, with TS values increasing with field dimension as well. Statistically significant differences were found between all treatments (p<0.001 for all pairwise comparisons, SE=0.82).

Analysis of the SampEn values of the distances to nearest opponents revealed an interaction effect for skill level and SSCG, F=3.76, p=0.03, η^2=0.15. NLP displayed significantly larger values in the small (p=0.003, SE=0.06) and intermediate fields (p=0.01, SE=0.06) than RLP, whereas in the large field, values of both groups were approximate (Figure 2). The NLP presented statistically significant entropy differences between all treatments (p<0.05 for all pairwise comparisons), whereas RLP only decreased their SampEn values significantly when comparing the small with the large field treatments (p=0.001, SE=0.05). A main effect for SSCG, F=30.13, p<0.001, η^2=0.59, was also found, with entropy values decreasing as field size increased.

(Figures 2A, 2B, 2C and 2D around here)

Regarding the AMI values of both teams' centroids movements, Figure 3 verifies that the centroids' mutual dependence is slightly higher on longitudinal movements than in lateral movements with both values having remained relatively stable across conditions for both groups. No statistically significant differences were observed between SSCGs, (goal-to-goal: F=1.03, p=0.36, η^2=0.04; side-to-side: F=0.08, p=0.91, η^2=0.004), nor between groups (goal-to-goal: F=1, p=0.32, η^2=0.02; F=0.2, p=0.65, η^2=0.05) for any of the centroids' movement directions.

(Figure 3 around here)

Discussion

Different types of SSCGs are frequently used in football training sessions and have been widely studied from a physiological performance viewpoint. This study aimed to extend knowledge on the influence of SSCGs in tactical performance by providing information about adaptations of teams' collective behaviours displayed by players of different skill levels during SSCGs played in fields of varying size.

In general, results confirmed our initial expectations that different field sizes and skill levels constrain different team tactical adaptations in SSCGs. As expected, the EPS increased with field dimension, with teams covering a significantly wider area of play on larger fields. This area almost tripled from the smaller to the largest field dimension but without any differences for skill level. The main difference between the two groups was found in the playing shape assumed in the different fields. While the RLP maintained similar PLpW values across conditions, the NLP evidenced a more elongated playing shape in the intermediate and large fields, which might be seen as a strategy to approach the goals more quickly in larger areas by playing preferably outstretched in the goal-to-goal direction. Increased EPS areas and elongated playing shapes might also have constrained different playing styles, for instance, with teams performing a higher number of long passes. Grant, Williams, Dodd, and Johnson (1999) previously reported significantly more long passes performed in youth football games played in larger field areas, which corroborates this assumption. This hypothesis should be further examined in future studies, however.

PLpW values observed in the small field were similar to those reported by Folgado et al. (2012) for intra-team length per width ratios in U-13 players. They used 30 x 20 m field measures that closely matched field dimensions in this study. However, they found larger intra-team length per width ratios (elongated playing shapes) in younger age groups (under-9s). A possible reason might be a different relation of pitch size and the sphere of action capacity of each age group. Younger participants are not able to cover the same amount of space per time unit as older participants, due to obvious body size and physical and maturational differences (Buchheit, Mendez-Villanueva, Simpson, & Bourdon, 2010; Harley et al., 2010; Mendez-Villanueva, Buchheit, Simpson, & Bourdon, 2013). This might have constrained a preference for a larger dispersion in the longitudinal direction to facilitate an approach towards goal. In this study, given the age of our participants, the elongated shape displayed by the NLP in larger fields does not seem to be related to physical constraints. More knowledge is needed to understand the advantages of playing in this type of team shape.

The TS also increased with field dimension, meaning that players were further away from their nearest opponents as the area of play increased. This result is in agreement with the findings of Frencken et al. (2013) that showed the centroids' distance to be higher in larger fields, both longitudinally and laterally. By enlarging distances to nearest opponents, manipulations of field dimension may also shape the emergence of affordances (opportunities) to shoot, pass and dribble. It is expected that larger spaces facilitates, at least, the emergence of affordances for assembling successful passes by augmenting the distances of opponents to ball trajectories (Travassos et al., 2012; Vilar, Araújo, Davids, Correia, et al., 2012). Larger playing areas may also not provide affordances for players to dribble as they are offered less risky behavioural options (e.g., passing the ball to a free teammate in space). Shooting opportunities may be additionally constrained by the distance to goal, which is clearly affected by field dimension. Previous research has reported shots to occur more frequently on smaller pitches (Dellal et al., 2012; Kelly & Drust, 2009), probably because of reduced distances of players to goals. Further studies are needed to clarify what specific game actions are afforded with increased TS.

Although there were no observed differences between groups in TS, when the unpredictability of each player's distance to his nearest opponent was considered, the NLP presented significantly more unpredictable distance values than RLP in the small and intermediate fields. The same aforementioned studies have shown that, on smaller pitches, more tackles, challenges, loss of ball possessions and physical contact occurs (Dellal et al., 2012; Kelly & Drust, 2009). Therefore, a possible reason for the higher unpredictability displayed by NLP for distances to nearest opponents in smaller areas may be related to their superior ability to perform "off-the ball" movements more often in an attempt to get unmarked and create free space in order to maintain ball possession (Lervolino, 2011) while at the same time, the defenders try to restrict space available to their direct opponents.

With regards to the teams' coupling tendencies, the nonlinear dependency found between the teams' centroids was slight superior for movements in the longitudinal direction in both groups confirming results from previous studies in regular matches (Bartlett et al., 2012; Yue, Broich, Seifriz, & Mester, 2008) and SSCGs (Frencken et al., 2011; Frencken et al., 2013). Both groups maintained similar levels of mutual dependency on movement trajectories across SSCGs. Thus, our data did not confirm the assumption advanced by Frencken et al. (2013) that expertise level could impact on the coupling relations between players or, perhaps, the teams' centroids do not capture the essentials of synchronization tendencies between players.

Conclusions

SSCGs played on fields of different dimensions clearly constrained different interpersonal interactive behaviours in players of distinct skill levels. Increases in field dimensions promoted similar larger playing areas and similar larger distances between direct opponents in both groups. However, the more skilled players tended to adapt differently to the SSCGs since, without specific instructions, they assumed an elongated playing shape when the playing area increased. The less skilled players practically kept the same playing length per width ratio across treatments. The advantages of displaying a more elongated playing shape during performance are unknown and should be addressed in further studies. However, this disposition might promote affordances to adopt different playing styles. These invitations for action (Withagen et al., 2012) can be stimulated by simply manipulating field dimensions. Playing outstretched in the longitudinal (goal-to-goal) direction on a larger playing area may afford or invite a higher number of long passes as well as directing passes to the furthest forward players, nearer the goal. Larger pitches also promoted a larger amount of space free of opponents to both NLP and RLP, which can impact on affordances for the emergence of specific actions like shooting, passing and dribbling. These assumptions should be verified in future studies aiming to capture the possibilities for action provided with such tactical adaptations.

Finally, regardless of field dimensions, the more skilled players presented higher, more unpredictable values of distances to an immediate opponents, which was interpreted as a strategy for creating space and avoid close marking.

These findings have implications for training design and for the development of tactical skills in football.

Practical applications

Collective tactical behaviours are flexible and can be shaped intentionally by manipulating simple variables like field dimensions. Through such manipulations coaches can minimally control the size of the effective playing space, its shape and the available space between players (teammates and opponents), and thus, constrain the emergence of affordances as different tactical adaptations while specifying the precise nature of task constraints in SSCGs.

Ultimately, SSCGs may be used as a performance development and evaluation tool for the identification and recruitment of players with emerging talent in football. The more skilled players seem to explore the available space differently and to be more difficult to mark.

References

Araújo, D., Davids, K., Bennett, S., Button, C., & Chapman, G. (2004). Emergence of sport skills under constraints. In M. Williams & N. Hodges (Eds.), *Skill acquisition in sport research, theory and practice*. UK: Routledge.

Bartlett, R., Button, C., Robbins, M., Dutt-Mazumder, A., & Kennedy, G. (2012). Analysing team coordination patterns from player movement trajectories in soccer: Methodological considerations. *International Journal of Performance Analysis in Sport, 12*, 398-424.

Buchheit, M., Mendez-Villanueva, A., Simpson, B.M., & Bourdon, P.C. (2010). Match running performance and fitness in youth soccer. *International Journal of Sports Medicine, 31*, 818-825.

Casamichana, D., & Castellano, J. (2010). Time-motion, heart rate, perceptual and motor behaviour demands in small-sides soccer games: Effects of pitch size. *Journal of Sports Sciences 28*(14), 1615-1623. doi: 10.1080/02640414.2010.521168

Cover, T., & Thomas, J. (1991). *Entropy, relative entropy and mutual information*: John Wiley and Sons, Inc.

Davids, K., Araújo, D., Correia, V., & Vilar, L. (2013). How small-sided and conditioned games enhance acquisition of movement and decision-making skills. *Exercise and Sport Sciences Reviews, 41*(3), 154-161.

Dellal, A., Owen, A., Wong, D.P., Krustrup, P., van Exsel, M., & Mallo, J. (2012). Technical and physical demands of small vs. Large sided games in relation to playing position in elite soccer. *Human Movement Science, 31*(4), 957-969. doi: 10.1016/j.humov.2011.08.013

Duarte, R., Araújo, D., Correia, V., & Davids, K. (2012). Sport teams as superorganisms: Implications of biological models for research and practice in team sports performance analysis. *Sports Medicine, 42*(8), 633-642.

Duarte, R., Araújo, D., Davids, K., Travassos, B., Gazimba, V., & Sampaio, J. (2012). Interpersonal coordination tendencies shape 1-vs-1 sub-phase performance outcomes in youth soccer. *Journal of Sports Sciences, 30*(9), 871-877.

Duarte, R., Araújo, D., Freire, L., Folgado, H., Fernandes, O., & Davids, K. (2012). Intra- and inter-group coordination patterns reveal collective behaviors of football players near the scoring zone. *Human Movement Science, 31*(6), 1639-1651. doi: 10.1016/j.humov.2012.03.001

Duarte, R., Araújo, D., Gazimba, V., Fernandes, O., Folgado, H., Marmeleira, J., & Davids, K. (2010). The ecological dynamics of 1v1 sub-phases in association football. *The Open Sports Sciences Journal, 3*, 16-18.

Folgado, H., Lemmink, K., Frencken, W., & Sampaio, J. (2012). Length, width and centroid distance as measures of teams tactical performance in youth football. *European Journal of Sport Science, iFirst article*, 1-6.

Frencken, W., Lemmink, K., Delleman, N., & Visscher, C. (2011). Oscillations of centroid position and surface area of soccer teams in small-sided games. *European Journal of Sport Science, 11*(4), 215-223.

Frencken, W., van der Plaats, J., Visscher, C., & Lemmink, K. (2013). Size matters: Pitch dimensions constrain interactive team behaviour in soccer. *Journal of Systems Science and Complexity, 26*(1), 85-93. doi: 10.1007/s11424-013-2284-1

Grant, A., Williams, M., Dodd, R., & Johnson, S. (1999). Physiological and technical analysis of 11v11 and 8v8 youth football matches. *Insight, 2*(3), 3-4.

Gréhaigne, J.-F., & Godbout, P. (2013). Colective variables for analysing performance in team sports. In T. McGarry, P. O'Donoghue & J. Sampaio (Eds.), *Routledge handbook of sports perfomance analysis* (pp. 101-114). Oxon: Routledge.

Handford, C., Davids, K., Bennett, S., & Button, C. (1997). Skill acquisition in sport: Some applications of an evolving practice ecology. *Journal of Sports Sciences, 15*, 621-640.

Harley, J., Barnes, C., Portas, M., Lovell, R., Barrett, S., Paul, D., & Weston, M. (2010). Motion analysis of match-play in elite to u12 to u16 age-group soccer. *Journal of Sports Sciences, 28*(13), 1391-1397.

Hill-Haas, S., Dawson, B., Impellizzeri, F.M., & Coutts, A.J. (2011). Physiology of small-sided games training in football. A systematic review. *Sports Medicine, 41*(3), 199-220. doi: 10.2165/11539740-000000000-00000

Hughes, C. (1994). *The football association coaching book of soccer tactics and skills*. Harpenden: Queen Anne Press.

Kelly, D., & Drust, B. (2009). The effect of pitch dimensions on heart rate responses and technical demands of small-sided soccer games in elite players. *Journal of Science and Medicine in Sport, 12*(4), 475-479. doi: 10.1016/j.jsams.2008.01.010

Lervolino, A. (2011). The creation of space. Principles and practice. *Soccer Journal, May-June*, 31-32.

Mendez-Villanueva, A., Buchheit, M., Simpson, B., & Bourdon, P.C. (2013). Match play intensity distribution in youth soccer. *International Journal of Sports Medicine, 34*, 101-110.

Passos, P., Araújo, D., Davids, K., Gouveia, L., Milho, J., & Serpa, S. (2008). Information-governing dynamics of attacker-defender interactions in youth rugby union. *Journal of Sports Sciences, 26*(13), 1421-1429. doi: 10.1080/02640410802208986

Passos, P., Milho, J., Fonseca, S., Borges, J., Araujo, D., & Davids, K. (2011). Interpersonal distance regulates functional grouping tendencies of agents in team sports. *Journal of Motor Behavior, 43*(2), 155-163. doi: 10.1080/00222895.2011.552078

Rampinini, E., Impellizzeri, F.M., Castagna, C., Abt, G., Chamari, K., Sassi, A., & Marcora, S.M. (2007). Factors influencing physiological responses to small-sided soccer games. *Journal of Sports Sciences, 25*(6), 659-666. doi: 10.1080/02640410600811858

Richman, J., & Moorman, R. (2000). Physiological time-series analysis using approximate entropy and sample entropy. *Am J Physiol Heart Circ Physiol, 278*, H2039-H2049.

Seifert, L., Button, C., & Davids, K. (2013). Key properties of expert movement systems in sport. *Sports Medicine, 43*, 167-178.

Silva, P., Garganta, J., Araújo, D., Davids, K., & Aguiar, P. (2013). Shared knowledge or shared affordances? Insights from an ecological dynamics approach to team coordination in sports. *Sports Medicine, 43*, 765-772.

Sinnott, R.W. (1984). Virtues of the haversine. *Sky and Telescope, 68*(2), 159.

Travassos, B., Araújo, D., Davids, K., Vilar, L., Esteves, P., & Vanda, C. (2012). Informational constraints shape emergent functional behaviours during performance of interceptive actions in team sports. *Psychology of Sport & Exercise, 13*(2), 216-223.

Vilar, L., Araújo, D., Davids, K., & Button, C. (2012). The role of ecological dynamics in analysing performance in team sports. *Sports Medicine, 42*(1), 1-10.

Vilar, L., Araújo, D., Davids, K., Correia, V., & Esteves, P. (2012). Spatial-temporal constraints on decision-making during shooting performance in the team sport of futsal. *Journal of Sports Sciences, 31*(8), 840-846.

Withagen, R., Poel, H.J.d., Araújo, D., & Pepping, G.-J. (2012). Affordances can invite behaviour: Reconsidering the relationship between affordances and agency. *New Ideas in Psychology, 30*, 250-258.

Yue, Z., Broich, H., Seifriz, F., & Mester, J. (2008). Mathematical analysis of a soccer game. Part ii: Energy, spectral and correlation analyses. *Studies in Applied Mathematics, 121*, 245-261.

Figure captions

Figure 1A) - Graphical illustration of the variables used: *a* illustrates the effective playing space, *b/c* was calculated for playing length per width ratio, *d* depicts an example of a radius of action free of opponents and *e* shows the centroids of each team. 1B) - Exemplar time series of the total match centroid (solid black line) and each team's centroids (dashed and solid grey lines) longitudinal movements in one SSCG condition. The periods encompassing three time points (e.g., dots t_a: t_c and so on) correspond to movements of the teams towards both goals (t_a: t_b towards team B's goal and t_b : t_c towards team A's goal).

Figure 2 – Mean values of the effective playing space (A), playing length per width ratio (B), teams' separateness (C) and sample entropy (D) according to field size (small, intermediate and large fields) and skill level (national- and regional-level players). Error bars represent standard deviation.

Figure 3 – Average mutual information values of the centroids' movements according to SSCG format (small, intermediate and large fields), skill level (national- and regional-level players) and axis (longitudinal and lateral directions). Error bars represent standard deviation.

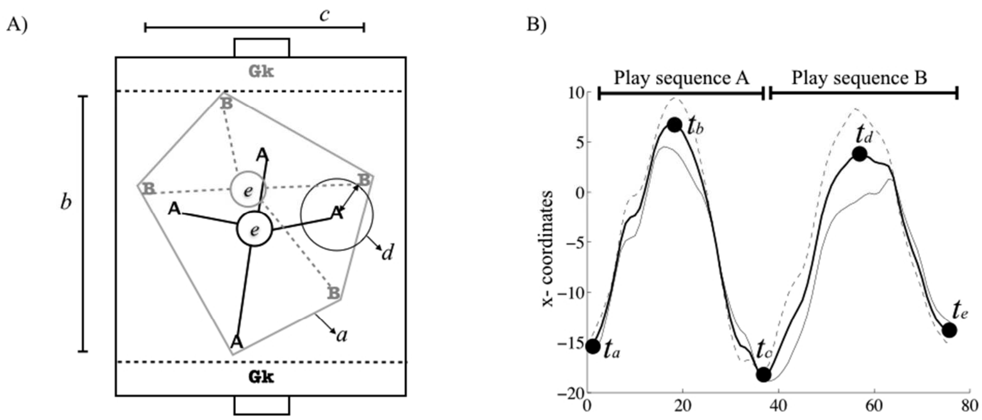

Figure 1A) - Graphical illustration of the variables used: a illustrates the effective playing space, b/c was calculated for playing length per width ratio, d depicts an example of a radius of action free of opponents and e shows the centroids of each team. 1B) - Exemplar time series of the total match centroid (solid black line) and each team's centroids (dashed and solid grey lines) longitudinal movements in one SSCG condition. The periods encompassing three time points (e.g., dots ta: tc and so on) correspond to movements of the teams towards both goals (ta: tb towards team B's goal and tb : tc towards team A's goal).
341x145mm (72 x 72 DPI)

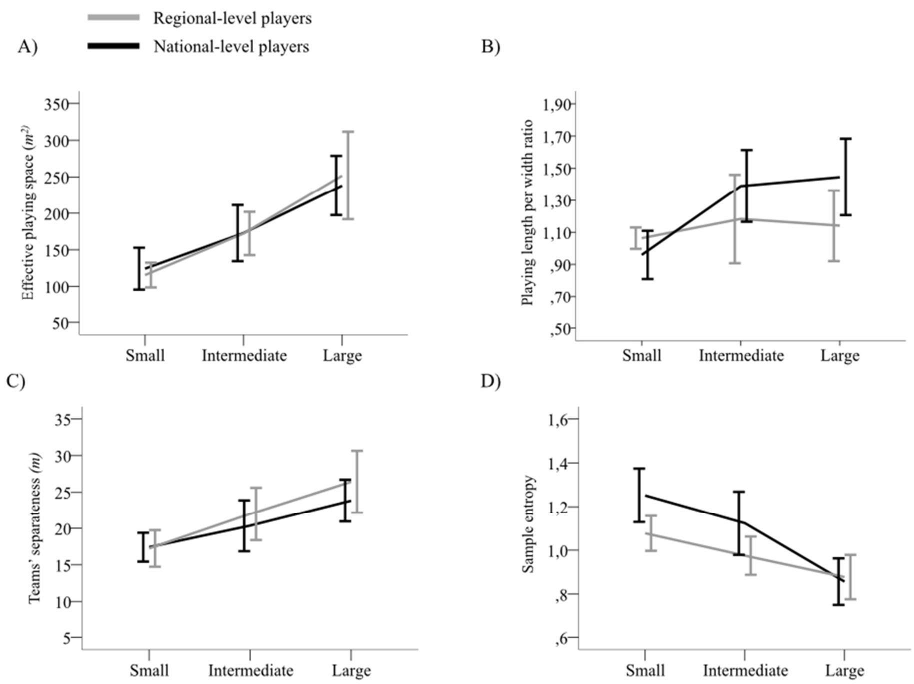

Figure 2 – Mean values of the effective playing space (A), playing length per width ratio (B), teams' separateness (C) and sample entropy (D) according to field size (small, intermediate and large fields) and skill level (national- and regional-level players). Error bars represent standard deviation.
361x270mm (72 x 72 DPI)

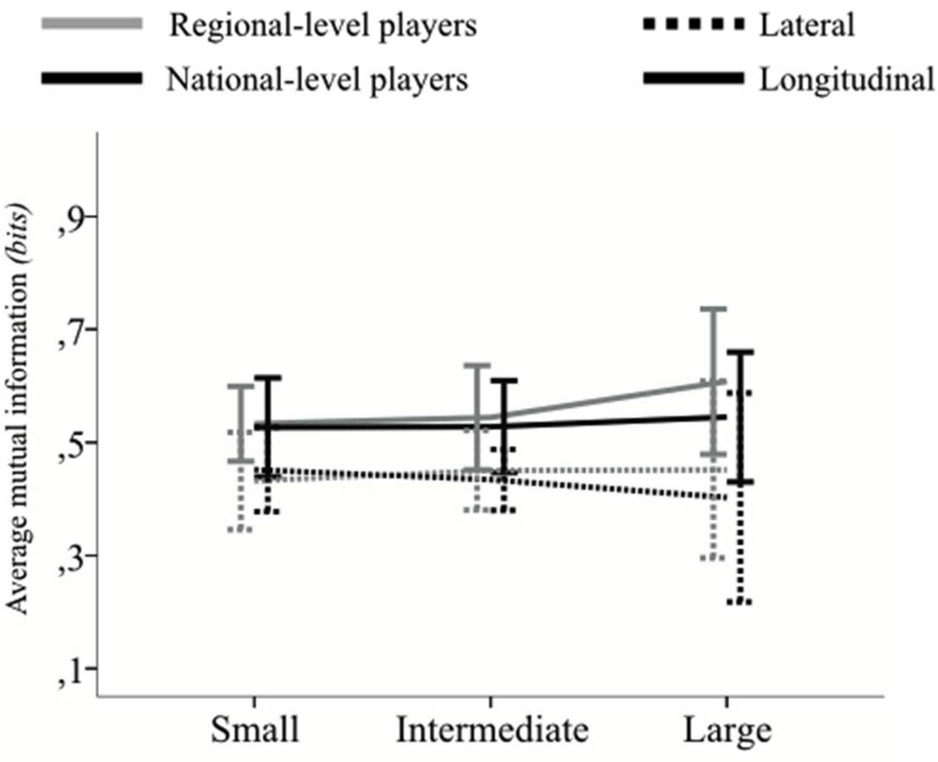

Figure 3 – Average mutual information values of the centroids' movements according to SSCG format (small, intermediate and large fields), skill level (national- and regional-level players) and axis (longitudinal and lateral directions). Error bars represent standard deviation.
185x152mm (72 x 72 DPI)