Increasing tactical complexity to enhance the synchronisation of collective behaviours: An action-research study throughout a competitive volleyball season

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Increasing tactical complexity to enhance the synchronisation of collective behaviours: An action-research study throughout a competitive volleyball season

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Abstract

Implementing an action-research design throughout a competitive season in which Constraint-led and Step-Game approaches were combined, this study investigated the impact of increased complexity on synchronisation tendencies in team players, at different set moments. Youth volleyball team players (n=15) were studied across three action-research cycles, with performance in one competitive match analysed per cycle. Team synchronisation tendencies were assessed through the cluster phase method and a 3 (matches) x 2 (set moments) x 2 (field direction) repeated-measures ANOVA was used to calculate differences in cluster amplitude mean values. Results revealed a reduction in team synchrony when tactical complexity of counterattacking play increased (second AR-cycle). Nevertheless, similar levels of team's synchrony emerged between the first and third AR-cycles. Results also revealed the final moments of a set as a significant environmental constraint that shaped synchronisation processes. Evidence suggested that the (re)achievement of functional synchrony was realised through integration of Constraint-led and Step-Game approaches during practices designed to enhance tactical awareness in players. Finally, the insider action-research design provided relevant contextualised insights on the planned development of a team's synchronisation tendencies.

Keywords: synchrony processes, tactical complexity, action-research, player development, sport pedagogy, volleyball

Introduction

Over the last decade, researchers have argued that performance analytics in team sports should focus on the patterned behavioural interactions emerging between teammates, so that competitive performance can be better explained and understood, rather than being merely described (e.g., Passos, Araújo, & Davids, 2016). Accordingly, the theoretical rationale of ecological dynamics has been used to explain how players self-organize their actions to systematically form new functional and coordinative structures, in a process achievable through exploiting inherent tendencies for synergy formation in sports teams (Araújo & Davids, 2016).

A synergy consists of a group of relatively independent degrees of freedom (dofs; i.e., the players) that self-assemble to function as a (sub)unit (i.e., a team or part of it) to achieve specific task goals (Turvey, 2007). Globally, team synergies exhibit four key properties: dimensional compression, reciprocal compensation, interpersonal linkages and degeneracy (Araújo & Davids, 2016), with coupling of players into synergies being supported by the surrounding information and the collective perceived attunement to shared affordances (Gibson, 1979) (i.e., here, considered as opportunities to coordinate actions as a sub-group in a team (Silva, Garganta, Araújo, Davids, & Aguiar, 2013)). Specifically, the idea of shared affordances explains the reduction of a team's dimensionality (re-organisation of coordinating teammates known as *dimensional compression*) as well as the ability of one player's actions to exert an influence over the competitive behaviours of opponents and/or teammates, so that task goals can still be accomplished (*reciprocal compensation*). Hence, players' actions in forming a synergy should be viewed as being dependent on each other's decisions and movements (Silva et al., 2016).

Understanding how the formation of team's synergies can be functionally developed through learning designs has been investigated in research on the Constraints-led Approach (CLA) (e.g., Olthof, Frencken, & Lemmink, 2017). This player-environment centred approach highlights the need to build representative learning tasks through manipulation of several constraints, so that players can learn to use specified fields of information (a landscape of affordances) to functionally adapt their performance (Passos & Davids, 2005). Through practice, players become perceptually attuned to affordances *of* and *for* others, modifying quickly their behaviour to functionally adjust to teammates and opponents' actions (Araújo, Davids, & McGivern, 2018; Silva et al., 2013).

Despite the extensive body of work undertaken so far, there is a need for focused research to determine coherent links between the manipulation of practice task constraints with the tactical performance problems that need to be resolved. In addition, the impact of ecological learning tasks has been evaluated mostly with cross-sectional designs, usually conducted in a brief part of training sessions, which limits understandings about the performance benefits of such practical intervention. Indeed, more longitudinal investigations are required to extend our knowledge about the processes underlying the development of team synergies over extended periods of time. Due to their collaborative and interventionist nature, Action-Research (AR) designs could play an important role in enhancing understanding in this respect (Carr & Kemmis, 1986). In fact, AR offers the opportunity to systematically reflect, monitor, evaluate and, if needed, change intentionally the practice intervention, providing deep and contextualised understandings about how team synergies evolve and adapt during the timeline. Although there have been recent implementations of AR-designs in physical education contexts (e.g., Farias, Hastie, & Mesquita, 2018), there is a need for more AR applications in sports training contexts.

The didactical content for the recognition and interpretation of the most relevant constraints on emergent behaviours of functional collective synergies are specific in each sport (Hastie & Mesquita, 2016). Therefore, for the design of representative learning tasks in non-invasive sports like volleyball, the specificity of information for players need to be considered. The Step-Game Approach (SGA) is a player-centred approach, specifically conceived for non-invasive sports, in which players are presented with step-by-step meaningful tactical game-problems that emphasize the development of functional technical and tactical game-related behaviours (Mesquita, Graça, Gomes, & Cruz, 2005). Previous studies on SGA have mainly analysed those behaviours with other pedagogical models (e.g., sport-education) in order to investigate the impact of hybrid combinations on learners' performance within physical education contexts (e.g., Araújo, Hastie, Pereira, & Mesquita, 2017). There is a clear lack of studies that have applied SGA in training contexts interventions across longitudinal investigations in which the potential of CLA and SGA is combined. Indeed, these types of investigations may enhance understanding on how representative practice designs and sport-specific augmented informational constraints could influence the emergence of synergetic behaviours in teams.

To date, the majority of the studies investigating the synergetic property of reciprocal compensation (measured, for instance, through synchrony between team members) have been conducted within training environments (e.g., Goncalves, Marcelino, Torres-Ronda, Torrents, & Sampaio, 2016). Thus, there is a need to understand how opponents' actions and/or constraints manipulation might influence co-adaptation in collective synergies during competitive environments. Another gap in the literature concerns how opponents' actions constrain the emergence of team synergies in *non-invasive* team sports, as well as how the complexity of different tactical game models could affect the (re)emergence of functional tactical patterns. Specifically, the information extracted from competitive performance is needed to complement current understanding which has emerged from studying team performance in practice designs. It is crucial because it can provide information about team performance behaviours under ecological constraints. This type of research also can support understanding of exactly how to design representative learning environments during training contexts, which simulate competitive performance constraints. In volleyball, one of the most relevant performance constraints is the set, previously identified by Marcelino, Sampaio, and Mesquita (2012) as a 'micro-game' (i.e., an important mini game within the game). The effects of different set moments (e.g., initial and final) on subsequent performance have been studied within a competitive game, however, there remains a dearth of research investigating how team synergetic properties evolve in a nonlinear way, as function of perturbations and effects of different set moments.

Therefore, combining key concepts from the CLA and SGA approaches, and using an AR-design throughout a competitive season, the purposes of this study were twofold. First, we sought to analyse the impact of increased tactical complexity on team synchronization processes in a youth volleyball team within competitive performance. Second, we investigated how different set moments (i.e., initial and final) might influence the team's synchrony throughout the whole season.

We hypothesised that, across the season, the team would increase their synchronisation values as a function of practice experiences; however, we expected different synchrony levels as tactical complexity increases. Additionally, we hypothesised that, as a result of the learning designs applied, the influence of final set moments on team's synchrony would decrease throughout the season.

Methods

Participants

Purposive and convenience sampling criteria were used to select the fifteen female volleyball players who participated in this study (Sarstedt, Bengart, Shaltoni, & Lehmann, 2018). Participants' ages ranged between 14 and 15 years and had at least one year of specialized volleyball training and competitive experience. The participants were considered an "information rich" case since they were at the beginning of their sport developmental pathway (Patton, 2015). This study was conducted over a competitive season, which lasted from September 2017 to June 2018, and comprised two distinct competitions: The Regional (September-January) and National championships (February-May). Globally, 143 training sessions and 32 official, competitive matches were performed. On average, participants performed four training sessions (each lasting 2 hours) and one competitive match per week.

The study followed the guidelines stated in the Declaration of Helsinki and the ethical approval was granted by the Institutional Research Ethics Committee of the first author's institution. Participants and parents were informed in advance about the purpose of the study and the scope of their involvement. Guarantees of confidentiality were ensured and informed consent forms were signed by both. Furthermore, participants were informed that they had the right to withdraw at any moment during the study.

Study Design

This study followed an AR-design where the coach systematically and critically reflected about her practice, changing it as a result of her own reflections (Gubacs-Collins, 2007). Particularly, an insider action-research intervention was applied (i.e., the first author assumed the dual role of coach-researcher). Such a paradigm provided an advantage standpoint concerning the coaching-learning process designed to develop team synchrony processes (Coghlan, 2007). In total, three AR-cycles were performed. Following the recommendations of Gilbourne (1999), the first AR-cycle focused on the exploration context by players. Also, during this cycle, the coach diagnosed the baseline of team synchrony behaviours and identified of the main tactical problems on counterattack that had to be resolved. According to the team tactical needs, during the second to the third AR-cycle the level of tactical complexity rose, through the combination of the key CLA and SGA principles. For each AR-cycle, the team's synchrony was assessed during full official matches as well as considering different set moments. At the end of each AR-cycle, the reflections and identification of unresolved issues, in both training sessions and competitive performance, guided the ensuing coaching intervention. Therefore, it was possible to monitor, evaluate and adjust the coaching pedagogical intervention, whilst supporting its reconstruction and transformation throughout the competitive season.

Based on SGA pedagogical principles, each training session followed the tactical, instructional and didactical specificities required by volleyball performance. Specifically, in terms of content didactical development three types of instructional tasks were implemented: acquisition, structuring and adaptation tasks (Mesquita et al., 2005). Concomitantly, the learning activities encompassed CLA principles, in which representative task constraints were manipulated to support the development of team's synchrony under diverse competitive performance scenarios (Davids, 2009). Table 1 shows a long-term overview of the coaching intervention combining CLA and SGA in the counter-attack learning tasks designed. Additionally, a detailed description of the main CLA and SGA instructional principles applied is presented in Supplement 1. Due to the complexity inherent to the coaching-learning process, as well as to the intrinsic unpredictability of a competitive season, learning task designs and coaching interventions were daily adjusted to team needs.

**** Please insert Table 1 around here****

Instructional validity

In order to guarantee that the integration of CLA and SGA was accomplished, the coaching protocol was confirmed by one researcher of the present study and an external observer not associated with the study. The external observer, who is an expert on sports pedagogy research field, analysed the documented training plans and the video records of training sessions. The rare disagreements were debated and resolved among the first author and the co-authors. A ten-item checklist was adapted from the studies of Práxedes and colleagues (2019) and Pereira, Graça, Blomqvist and Mesquita (2011) to test the behavioral fidelity of the coaching intervention. Accordingly, 18 training session - more than 10% of the total sample - were randomly examined for the presence of items included in Table 2 (Tabachnick & Fidell, 2007). Items 1, 2, 4, 5 and 6 encompass characteristics of SGA, while items 3, 7, 8, 9, and 10 are related to CLA. One of the co-authors and the external observer, both pedagogical experts, confirmed the appropriate integration of CLA with SGA. A 100% agreement between observers confirmed the appropriate integration of both pedagogical approaches.

**** Please insert Table 2 around here****

Recording Procedures

The matches analysed were played on a volleyball court with dimensions of 18 x 9 m (width x length). The game sequences were filmed by a digital video camera positioned above (2 meters) and behind (5 meters) the volleyball court. The camera zooming rate was fixed in order to simplify the motion image processing. The images were captured at a frequency of 25 Hz and a resolution of 1920 x 1080 pixels. Positional coordinates were recorded through TACTO software (version 8.0) (see Duarte et al. (2010) for software details) at an accuracy level higher than 95% at 25Hz (Fernandes, Folgado, Duarte, & Malta, 2010). The procedures involved tracking the players' working point (projection of the gravity centre on the floor locating the mean distance between participant's feet) using a computer mouse in a slow-motion video. This software package provided players' 2D virtual coordinates (expressed in pixels). The conversion from virtual to real spatial coordinates (expressed in meters) was performed using the Direct Linear Transformation (2D-DLT) (Duarte et al., 2010). Table 3 provides a detailed description of matches and sequences' selection criteria as well as the number of sequences analysed per match.

****Please insert Table 3 around here****

Reliability

A total of six playing sequences (two per match) were randomly selected from the recorded video footage for analysis of the players' movement trajectories in the lateral and longitudinal directions for digitisation by the same researcher. The data were evaluated for reliability and accuracy using the coefficient of reliability (R) and technical error of measurement (TEM), respectively (Goto & Mascie-Taylor, 2007). The intra-observer results depicted good accuracy and reliability levels (%TEM =0.5, R =0.99).

Cluster-Phase Method (CPM)

Kuramoto and Nishikawa (1987) developed the Kuramoto order parameter, a model built to analyse systems whose oscilatory units tend to the infinity (Strogatz, 2000). Using a multiple-rocking chair experiment, Frank and Richardson (2010) adapted this model to test its aplicability on systems with only six oscilatory components. Overall, the CPM enables to compute the means and continous group synchrony, ρ_{group} and $\rho_{group}(t_i)$, as well as the individual's relative phase, θ_k, concerning the group measure (Richardson, Garcia, Frank, Gergor, & Marsh, 2012). This method was recently applied by Ribeiro and colleagues (2019) who proposed a multilevel hypernetworks approach to capture synchronisation tendencies (i.e., how players synchronised their behaviours with the simplices (sub-groups of players, e.g., 3vs.2) with which they interacted during competitive performance) emerging at a meso-level scale of performance analysis. Considering our study's purposes, we adapted the expressions used by Ribeiro et al. (2019) to compute the cluster phase, providing us with a global measure, the cluster-amplitude, that represents the team synchronisation in each time-series. Specifically, we replaced the simplices sets Γ_j, previously employed in the model of Ribeiro et al. (2019), by the set of players composing team Γ_A. Therefore, Γ_A and its size n_A, is defined by the number of players that compose Team A. The expressions used are described below, from (1) to (4).

Given the phase time-series obtained through Hilbert transformation, $\theta_k(t_i)$, for the k^{th} player movements measured in radians [-π π], where $k = 1, \cdots, N$ and $i = 1, \cdots, T$ time steps, the Team A or *cluster* phase time-series, $\overline{\emptyset}_A(t_i)$, can be calculated as:

$\acute{r}_A(t_i)\, \frac{1}{n_A} \sum_{k \in \Gamma_A} \exp(i\theta_k(t_i))$……………………………………………………..(1)

and:

$\overline{\emptyset}_A(t_i)\; atan2(\, \acute{r}_A(t_i))$…………………………………………………………..(2)

where $i = \sqrt{-1}$ (when not used as a time step index), $\acute{r}_j(t_i)$ and $\overline{\emptyset}_j(t_i)$ comprise the resulting cluster phase in complex and radian form, respectively.

Ultimately, the continuous degree of synchronisation of Team A $\boldsymbol{\rho}_{\Gamma_A}(\boldsymbol{t_i}) \in [\mathbf{0}, \mathbf{1}]$, i.e., the cluster amplitude $\boldsymbol{\rho}_{\Gamma_A}(\boldsymbol{t_i})$ at each time step t_i can be computed as:

$\rho_{\Gamma_A}(t_i) = \left| \frac{1}{\mathrm{n}_A} \sum_{k \in \Gamma_A} \exp(i(\theta_k(t_i)\; \overline{\emptyset}_A(t_i))) \right|$………………………………………...(3)

and the temporal mean degree of group synchronisation, $\boldsymbol{\rho}_{\Gamma_A} \in [\mathbf{0}, \mathbf{1}]$, is computed as:

$\rho_{\Gamma_A}\, \frac{1}{T} \sum_{i=1}^{T} \rho_{\Gamma_A}(t_i)$…………………………………………………………...(4)

The cluster amplitude value corresponds to the inverse of the circular variance of $\emptyset k(ti)$. Therefore, if $\rho\Gamma_A$ = 1, the group is in complete intrinsic synchronisation (intra-team relationships), and if $\rho\Gamma_A$ = 0, the group is completely unsynchronised. Here, synchronisation refers to the coordination patters developed by players over time that allow them to establish functional synergies to achieve common performance goals. All the computations for calculating the cluster amplitude were performed using specific routines implemented in GNU OCTAVE (version 5.1.0).

Data Analysis

A 3 (matches) x 2 (set moments) x 2 (field direction) repeated-measures ANOVA was used to calculate differences in the cluster amplitude mean values between matches, and as a function of set moments (initial and final) and field directions (lateral and longitudinal). The equality of variances was assumed once groups were composed of equal sample sizes (Field, 2009). Possible violations of sphericity assumption in the RM of the within–participant factors were checked using Mauchly's test and, when necessary, the Greenhouse-Geisser or Huynh-Feldt correction procedure was used to adjust the degrees of freedom. Pairwise differences were assessed with Bonferroni post-hoc. Paired t-tests were used to calculate the cluster amplitude mean differences between set moments (initial-final). The inferential procedures were carried in SPSS 25.0 software (IBM, Inc., Chicago, IL). The level of statistical significance was set at $p<0.05$. Effect sizes were presented as Cohen's *d* values and eta squared. Threshold values for the effect sizes were > 0.0 (trivial), > 0.2 (small), > 0.6 (moderate) and > 1.2 (large) (Cohen, 1988).

Results

Table 4 summarises the mean and standard deviation values of the team's cluster amplitude in each AR-cycle as function of set moment and field direction.

****Please insert Table 4 around here****

Figure 1(a) portrays the team's synchronisation patterns throughout the three AR-cycles. Over the season, the results indicated significant differences for synchronisation tendencies in the lateral ($F_{(1,945)}$=710,909; $p<0.001$, η2 = 0.017) and longitudinal ($F_{(1,970)}$=737,711; $p<0.001$, $\eta^2 = 0.017$) field directions. In the lateral field direction, the lowest level of team synchrony was attained in the second match, while the highest level of synchrony was achieved in the first match. Significant small differences in synchrony levels ($p<0.001$) were observed between matches (M1-M2: *d*=0.27 [0.25; 0.28]; M2-M3: *d*=-0.21 [-0.23; -0.20]; M1-M3: *d*=0.05 [0.03; 0.06]). In the longitudinal field direction, the results showed significant small differences in synchronisation ($p<0.001$) between M1-M2 (*d*=0.23 [0.21; 0.24]) and M2-M3 (*d*=0.26 [-0.27; -0.25]). However, we did not observe statistical differences in the synchronisation levels from the first to the third match ($p=0.214$, *d*=0.05 [-0.06; -0.03]). The lowest level of team synchrony, during the counterattack phase, was observed in the second match, whilst the highest level was verified in the third match.

Analysis of team synchrony according to the set moment is represented in Figure 2(b). Results showed significant differences in team's synchrony between the initial and final set moments in lateral ($t_{(45087)}=11,176$; $p<0.001$, *d*=0.05 [0.04; 0.07]) and longitudinal ($t_{(45076)}=21,417$; $p<0.001$, *d*=0.15 [0.13; 0.16]) field directions, with the team displaying higher levels of asynchrony during the final set moments. Throughout the season, we observed significant differences in team synchrony levels in lateral ($F_{(1,945)}=129,1789$; $p<0.001$, $\eta^2=0.009$) and longitudinal ($F_{(1,980)}=47,037$; $p<0.001$, $\eta^2=0.003$) field directions during the initial moments of the set. The results depicted significant differences ($p<0.001$) in both field directions, with the team progressively increasing the levels of synchronisation (Lateral: M1-M2: *d*=-0.11 [-0.13; -0.08]; M2-M3: *d*=-0.11 [-0.13; -0.08]; M1-M3: *d*=0.24 [-0.26; -0.21]; Longitudinal; M1-M2: *d*=-0.05 [-0.08; -0.03], M2-M3: *d*=-0.10 [-0.13; -0.08], M1-M3: *d*=0.17 [-0.19; -0.14]).

Regarding the final moments of the set, results revealed significant differences in team's synchrony in lateral ($F_{(1,945)}=178,886$; $p<0.001$, $\eta^2=0.014$) and longitudinal ($F_{(1,960)}=680,630$; $p<0.001$, $\eta^2=0.052$) field directions across the season. Although in the second match the team exhibited unsynchronised behaviours for both field directions, at the end of the season (third match analysed) the team had increased their levels of synchrony in both field directions. Moreover, we observed significant differences ($p<0.001$) between matches in both field directions (Lateral: M1-M2: *d*=0.14 [0.11;

0.16]; M2-M3: *d*=-0.20 [-0.23; -0.18]; M1-M3: *d*=-0.05 [-0.07; -0.02]; Longitudinal; M1-M2: *d*=0.35 [0.32; 0.37], M2-M3: *d*=-0.44 [-0.47; -0.42], M1-M3: *d*= -0.10 [-0.12; -0.07]).

Despite the prevalence of high mean values of cluster amplitude (>0.8), indicating collective synchronisation, Figure 1 also showed the presence of low cluster amplitude values (near 0), indicating the presence of asynchronized behaviours during the counterattack phases of play.

****Please insert Figure 1 around here****

Discussion

Implementing an AR-design throughout a competitive season along with the combination of CLA and SGA approaches, this study aimed to investigate the impact of increased game complexity on the synchronisation processes of a volleyball team. We also investigated whether direction of synchronisation tendencies could be shaped at different set moments. Overall, results revealed a reduction in synchronisation levels between players when tactical complexity of counterattacking play was increased (second AR-cycle). However, similar levels of between-player synchrony emerged between the first and third AR-cycles. Additionally, our findings highlighted that the final set moments acted as an environmental constraint which impacted on the team's synchronisation. The use of an 'insider' AR-design afforded the capacity to closely monitor the coaching-learning processes changes underlying the development of a team's synchronisation tendencies over a competitive season. In fact, the engagement of a coach-researcher in the context of youth volleyball training supported the regular adjustment of the design of ecological and sport-specific didactical practice tasks according to the team's developing tactical needs. These changes were made based on team' technical and tactical development, with the collective learning being monitoring by the coach during the practice across the season.

The first AR-cycle focused on the diagnosis of the team's current synchronisation tendencies, as well as the identification of the main tactical changes that needed to be resolved to enhance performance. The initial tactical modelling for the counterattack-phase corresponded to a simple block-defense organization (i.e., only one blocker with remaining five defenders filling the central part of the court – near zone 6). In order to develop the players' co-adaptive interactions under different match play constraints, during this AR-cycle, the training intervention was conceived to afford opportunities for players develop their capacity to perceive the most relevant tactical information sources within similar, but not identical, representative game situations. Accordingly, the complete analysis of performance in the first match at different set moments, portrayed lateral and longitudinal values of synchronisation tendencies close to 1, indicating high levels of functional synchrony between teammates within this tactical counterattacking model.

To endow participants with adaptable skills and increase the number of collective tactical options on counterattack, during the second AR-cycle, the coach increased the tactical complexity in the defensive (double-block on zone 4 and zone 2) and offensive (complex attack combinations) counterattack sub-phases. For example, learning tasks were designed to emphasise co-adaptative moves between the middle-blocker and the outside-hitter or opposite. Also, synchronisation tendencies between double-block and defenders were highlighted through small-sided games under manipulated set score. Thus, as predicted, during the second match, we observed a significant reduction in the team's synchrony levels in lateral and vertical directions on court, possibly due to this increase in tactical complexity that was slowly being instigated during practice. Indeed, as suggested by Balagué and colleagues (2013) the introduction of complexity in a system (e.g., a sports team) implies a co-adaptation of the informational channels that supports the system self-organization properties. This process in a complex system like a sports team requires significant amounts of practice time spent training under meaningful ecological constraints. The same tendency for a decrease in synchronisation between players' actions was detected in the final moments of the set during the second match. The final set periods have been previously identified by Marcelino et al. (2012) as critical environmental game constraints, which can determine the set's victory or defeat. Our findings in the current study support this assumption because the final moments seemed to influence the ability of players to identify the most relevant tactical performance constraints, influencing their capacity to interact and synchronise their tactical behaviours, particularly when the tactical complexity increased.

Interestingly, from the first to the second AR-cycles the team's synchrony levels were elevated at initial set moments. A possible explanation for this finding may lie in the effect of developing a basic strategic game-plan to use during the initial stages of the match. In order to improve the team's tactical awareness, during the second AR-cycle, the coach started to identify, together with the players, some simple tactical game constraints to focus from early competitive interactions with the opposition (e.g., who was the best opposition spiker or who was the worst receiver). Afterwards, during an interactive and constructive discussion, the coach and players co-defined tactical game principles that may be needed to gain a tactical advantage over their opponents. Gradually, during initial competitive moments, the players became able to recognise these most relevant performance constraints, interacting between each other to anticipate and respond to the opposition's tactical actions.

At the end of the third AR-cycle, the team showed values of synchrony similar to first AR-cycle. This outcome supports the assumption that, at the end of the season the team (re)achieved higher levels of functional synchronisation using a tactical game model, which had become progressively more complex. In addition, this finding highlights the importance of the value of time spent in practice in order to develop tactical awareness, which impacted on collective synchronisation processes in teams. From the second to the third AR-cycles, aligned with the increase in the team's tactical performance complexity, analysis of opposition performance also became more refined (for instance, defining their specific block-defence priorities for each rotation of players according to different moments in the set). This performance enhancement seemed to improve the participants' tactical understanding. Concomitantly, the learning tasks began to be constrained by analyses of the next immediate opponent's performance characteristics at different competitive set moments. The importance of developing representative training designs has previously been emphasised by Travassos, et al. (2012). Following their recommendations, thematic games were developed and implemented in practice designs which were constrained by implementation of specific 'rules' (e.g., setting options), incentives (e.g., extra points to positive double-block actions) and scenarios such as initial set scores (e.g., the set starting on 20-20).

The continuous exposition of this ecological and sport-specific coaching intervention facilitated the participants' perceptual attunement to affordances *of* and *for* others that, in turns, allowed them to adjust their tactical behaviours as performance constraints changed. Possibly for this reason, the highest levels of the team's synchronisation tendencies were observed during the initial and final set moments of the third match, indicating that the players had acquired the ability to functionally re-organise their complex tactical behaviours at significant competitive moments.

Nevertheless, our results also depicted the presence of completely asynchronous movements during the counterattack phase, probably due to the setter's displacements as well as the creation of space by spikers during the preparation for the attack.

Although this study has made an important contribution in understanding how to analyse and implement practice designs to enhance synchronisation tendencies in volleyball players, it only provided a global macroscopic view of the team's tactical patterns. Future research needs to focus on the analysis of team synchronisation tendencies during counterattack subphases (e.g., with and without ball possession). Furthermore, these initial findings suggest how future research on team sports performance enhancement could implement AR-designs within training and competitive contexts.

Based on the findings reported, we recommend that coaches explore the co-adaptation processes in sports teams through the development of players' tactical awareness and the design of representative learning tasks, both congruent with: (i) the specificities of each team's tactical game plan model, (ii) the principles established for each strategic game-plan and (iii), the team's tactical needs. Additionally, the findings also encourage coaches to manipulate the set scores when creating training scenarios in order simulate the players' interactions under specific competitive scenarios. Finally, we recommend the exploration of different, but complementary, pedagogical approaches that may enable coaches to develop a team's tactical needs during training.

Conclusion

This study highlighted the relevance of team synergetic behaviours expressed in the synchronisation tendencies emerging during the counterattack phase in a non-invasive sport. Results suggested that more complex tactical organisations emerged to lead to a reduction in a team's synchronisation levels at an initial phase of competitive performance, with the (re)achievement of functional synchrony being possible through the integration of CLA and SGA approaches during practices designed to enhance tactical awareness of players during performance. Additionally, our findings highlighted the final set moment as an environmental constraint that impacts greatly on a team's levels of synchrony. From a research methodology perspective, the use of an insider AR-design provided relevant contextualised understandings about the planned development of a team's synchronisation tendencies.

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Table 1. Combining CLA and SGA approaches within an AR-longitudinal design

1st AR-cycle - Match 1 ***Functional Synchrony***		**2nd AR-Cycle – Match 2** ***Introducing tactical complexity***		**3rd AR-cycle – Match 3** ***(Re)Achieving functional synchrony***	
Tactical Counterattack Goals					
Offensive	- Promote lateral and longitudinal coordination on in-system organization with simple attack combinations	**Offensive**	- Promote lateral and longitudinal coordination on out-system - Promote lateral and longitudinal in-system organization with complex attack combinations	**Offensive**	- Promote variability on set action according to the opponents' blockers - Explore the attack by middle-blockers
Defensive	- Block-defense relationship on 1x1 situations	**Defensive**	- Block-defense relationship on 1x2 situations against the outside-hitters and the opposite	**Defensive**	- Block-defense relationship on 1x2 situations for all spikers, including middle-blockers
SGA	CLA	SGA	CLA	SGA	CLA
Task type: <u>Acquisition:</u> - Individual block actions - Collective defense action on 1x1 situations - Block-defense relationship on 1x1 situations **Pedagogical strategies:** - Cue perception	**Designing actions' opportunities** - Avoid attack repetition by the previous player **Task constraints** <u>Rules:</u> -Player must perform different attack actions (e.g., roll shot followed by tip) on a sequence of consecutive attacks	**Task type:** <u>Structuring:</u> - Double-block actions (zone 4 and zone 2) - Collective defense actions on 1x2 situations -Block-defense relationship on 1x2 situations **Pedagogical Strategies:** -Tactical Awareness - Strategic game-plan (identification of best and worst spiker, digger and blocker)	**Task Constraints** <u>Score:</u> - Mini set from 0 to 15 points - Set starts at 17/17 until 25 points. Every ball punctuates. - Reward attacks scored during out-system situations or with complex attack combinations - Reward block and dig actions **Complexity** - 6x6 with two setting options during in-system situations	**Task type:** <u>Adaptation:</u> - Double-block actions (zone 3) - Collective defense action according to opponents' tactical game model **Pedagogical Strategies:** - Tactical Awareness - Strategic game-plan (definition of specific block-defense priorities for each rotation according to different set moments)	**Task Constraints:** <u>Score:</u> - Set starts from 20/20 to 25. Sequences of 5 balls to the same team. At maximum team could win 3 points, such as: 5-0, 3 points; 4-1, 2 points; 3-2, 1 point -Reward middle-blockers' attacks and block actions as well. **Representativeness** - Block and defense according to strategic game-plan principles **Complexity** - 6x6 with free setting options during in-system situation

Table 2. Instructional checklist

Elements of the training session	Present	Absent
1. Create tactical problem as the center of learning tasks organization.		
2. The coach explained the task, observed individual and collective behaviors, and used questioning to induce players' reflection.		
3. The tasks and game complexity increased throughout the season.		
4. All training sessions included acquisition, structuring and/or adaptation tasks.		
5. The tasks frequently included accountability criteria.		
6. The training sessions were closed with SSCG or thematic game stressing the application of technical and tactical skills initially addressed.		
7. Manipulation of constraints of the full game were performed.		
8. All tasks were constrained in terms of rules, space, and/or time.		
9. All tasks required the exploration of different performance solutions by the player.		
10. All tasks were built in order to ensure that learning designs represent the competitive performance environments.		

Table 3. Detailed description concerning to the matches and sequences' selection criteria and the number of sequences analysed per match

Matches' selection criteria		
Competitive Moment	**Opposition Level**	**Frequency of counterattack (KII) practice**
Matches from the regional and national championship	Matches against the top four ranked teams in the previous season	Number of learning tasks designs, related with counter-attack phase, performed during the week before each match.

Sequences' selection criteria
From the moment when the opposition player performed the first ball contact (pass or dig), to the instant when the attacker touched the ball (during an attack by the player of the team under analysis)

Description of the matches and sequences selected						
	Competitive Moment	Opposition Level	Frequency of (KII)	**Number of sequences**		
				Match	Initial Set Moment	Final Set Moment
Match 1 (M1) *1st AR-cycle*	Regional Championship, 1st round 15th October, 2017	2nd place	7	24	7	7
Match 2 (M2) *2nd AR-cycle*	Regional Championship, 2nd round 2nd December, 2017	4th place	7	24	7	7
Match 3 (M3) *3rd AR-cycle*	National Championship, 1st round 21st April, 2018	2nd place	6	24	7	7

Table 4. Mean and Standard Deviation values of cluster amplitude during each AR-cycle (match 1, match 2, match 3) as function of set moment (initial and final) and field directions (lateral and longitudinal)

General						
	1st AR-cycle (M1)		**2nd AR-cycle (M2)**		**3rd AR-cycle (M3)**	
Field Direction	Lat	Long	Lat	Long	Lat	Long
Mean ± SD	0.87 ± 0.21	0.86 ± 0.21	0.81 ± 0.24	0.81 ± 0.23	0.86 ± 0.23	0.87 ± 0.23

Set Moment				
	Initial		**Final**	
Field Direction	Lat	Long	Lat	Long
Mean ± SD	*0.90* ± 0.18	0.89 ± 0.19	0.89 ± 0.20	0.86 ± 0.22

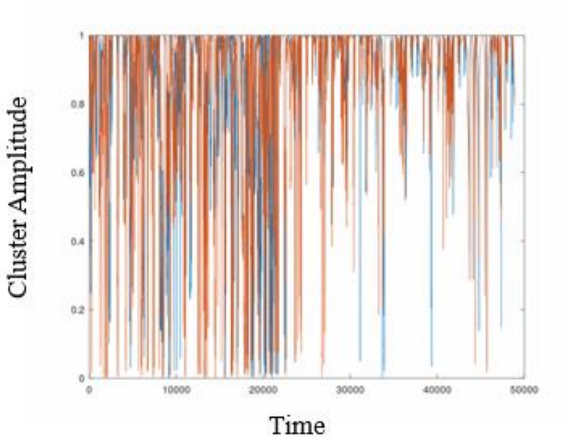
Initial						
	1st AR-cycle (M1)		**2nd AR-cycle (M2)**		**3rd AR-cycle (M3)**	
Field Direction	Lat	Long	Lat	Long	Lat	Long
Mean ± SD	0.88 ± 0.17	0.88 ± 0.17	0.9 ± 0.2	0.89 ± 0.2	0.92 ± 0.17	0.91 ± 0.19

Final						
	1st AR-cycle (M1)		**2nd AR-cycle (M2)**		**3rd AR-cycle (M3)**	
Field Direction	Lat	Long	Lat	Long	Lat	Long
Mean ± SD	0.88 ± 0.22	0.87 ± 0.21	0.85 ± 0.21	0.79 ± 0.25	0.89 ± 0.18	0.89 ± 0.2

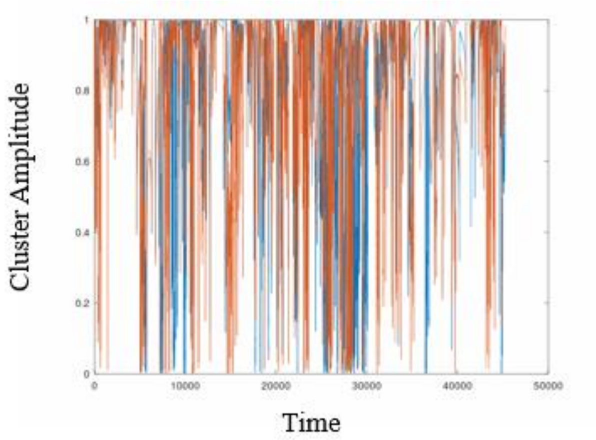
Note: SD = Standard Deviation; Lat = Lateral; Long = Longitudinal

General

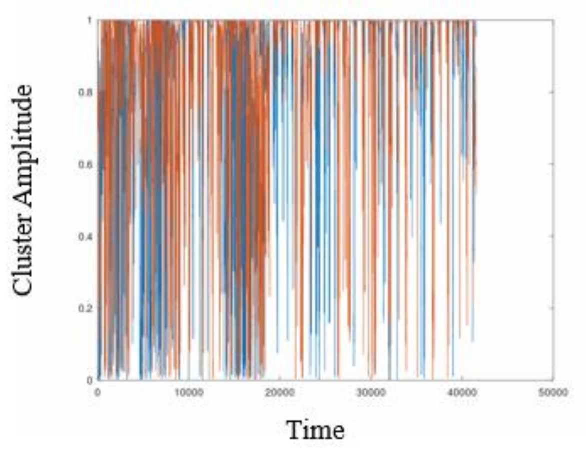
1st AR-cycle (M1)



2nd AR-cycle (M2)



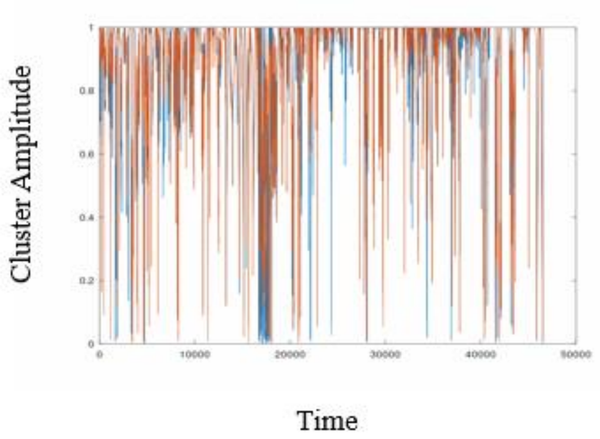
3rd AR-cycle (M3)



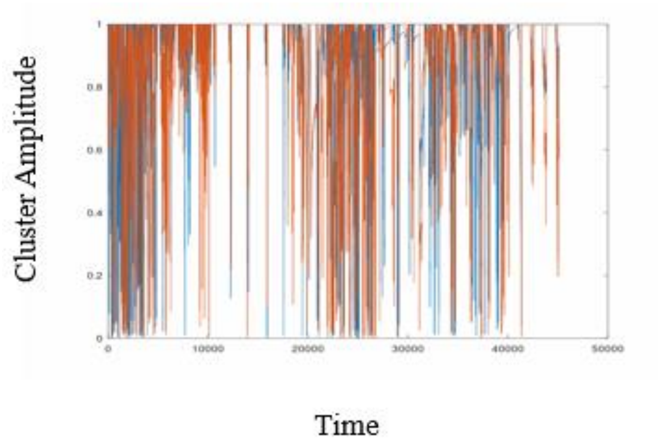
(a)

Set Moment

Initial



Final



(b)

Figure 1. Team synchronization throughout the three matches using cluster amplitude values as a function of field direction (lateral and longitudinal) and set moment (initial and final). The blue lines correspond to the team's cluster amplitude on lateral direction, while the orange lines concern to the longitudinal direction

Supplement 1. Main instructional principles considered in each approach

Constraints-led Approach	Step-Game Approach
Manipulation of constraints - to shift the players intentionality, guide attentional focus, create a desirable instability, and encourage the problem-solving of a specific tactical/technical issue within multiple environments	***Tactical Understanding*** – players' must be invited to see the relationships among pieces of information, which help them to make the connections between the tactical purpose of the game and the official game-form
Affordances driven designer – learning designs must development players' understanding that allow them to construct for themselves the 'how, why, where, when' to perform an action	***Tactical Awareness*** – the ability of players to interpret and adapt tactically to different game contexts
Co-adaptation – to achieve the task goal players must cooperate with their teammates by self-organizing to satisfy the interacting constraints	***Strategic game-plan*** – tactical principles of play, constructively discussed and defined before the game, which guided collective or individual tactical behaviours
Representativeness - practice task constraints represented the competitive performance environment so that players can maintain the same perceptual-motor relations with key events ***Complexity*** – the game forms evolve in terms of tactical complexity according to the currently tactical understandings of players	***Content didactical development*** – Three types of instructional types were implemented: (i) acquisition, focused on the development of a specific skill, (ii) structuring, focused on understanding the tactical and technical skills of the game but without opposition, and (iii) adaptation, in which in which the goal, action structure and basic tactical features were identical to the full volleyball game. The adaptation tasks included thematic games, where was emphasised the specific action structures without overlooking adherence to the main game goal (e.g., giving extra points to attack or blocks actions), and small sided and conditioned games in which were emphasised specific tactical issues.