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ORIGINAL ARTICLE

How can team synchronisation tendencies be developed combining Constraint-led and Step-game approaches? An action-research study implemented over a competitive volleyball season

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ABSTRACT
Combining Constraint-led (ecological) and Step-Game (constructivist) approaches through an Action-Research (AR) design conducted throughout a competitive volleyball season, this study aimed to: (i) analyse the impact of increased tactical complexity on lateral and longitudinal collective Synchronisation Tendencies (ST) during defensive and offensive counterattack-subphases, and (ii) examine how opposition attacking contexts (i.e. playing in *full*-system or *in*-system) might influence ST throughout each counterattack-subphase. Performance of a youth team, comprised of 15 players, was studied across three AR-cycles. The team's competitive performance was analysed through three competitive matches (one per cycle). Team ST were evaluated using the cluster-phase method and a 3 (matches) × 2 (counterattack-subphases) × 2 (opposition attacking contexts) × 2 (court directions) repeated-measures ANOVA were used to calculate the differences in cluster-amplitude mean values. Results showed that increments in tactical complexity (second AR-cycle) were followed by decreases in collective ST, which were (re)achieved during the third AR-cycle, possibly due to the ecological-constructivist coaching intervention. Our findings imply that coaches could design representative and specific-didactical learning environments, predicated on a team's tactical needs and strategical ideas from a game-plan, framing player intentionality. Results also support the use of questioning strategies to narrow players' attentional focus, stimulating perceptual attunement to relevant constraints emerging in performance. Finally, the insider AR-design provided valuable contextualised insights on coaching interventions for developing collective coordinative structures.

Keywords: *ecological-constructivist intervention, action-research, synchronisation tendencies, practice design, sport pedagogy, volleyball*

Highlights

- Integrating ecological and constructivist approaches revealed gains to develop collective synchronization tendencies at defensive and offensive counterattacking-subphases of volleyball game.
- The increase of tactical complexity acted as noise to the system (i.e., team), but played a functional role once allowed the re-attainment of high synchrony levels in each counterattacking subphase at the end of the season.
- The insider action-research design enabled a close and contextualized interpretation of the coaching pedagogical process inherent to the improvement of collective synchronization tendencies throughout the competitive season.
- The opposition attacking contexts depicts as an environmental constraint that impacts greatly on team synchronisation tendencies.

Introduction

Throughout the past decade, several researchers have sought to comprehend how players synchronise actions during successful, competitive sport performance (e.g. Chow, Davids, Shuttleworth, & Araújo, 2020). Considering team sports as complex dynamical systems, supported by ecological dynamics fundamentals, the term 'team synergy'

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has emerged in sports science to explain how players interact to satisfy the competitive demands without compromising collective functionality (Araújo & Davids, 2016).

Considered an emergent phenomenon, team synergies are groups of relatively independent degrees of freedom (e.g. players) that functionally re-organise to achieve planned goals (Riley, Richardson, Shockley, & Ramenzoni, 2011). Player coupling in synergy formation is underpinned by perceptual attunement to shared affordances (i.e. awareness of action opportunities) (Gibson, 1979; Silva, Garganta, Araújo, Davids, & Aguiar, 2013). To date, studies have mainly focused on analysis of the synergetic property of *dimensional compression*, with *reciprocal compensation* being less scrutinised (Ramos, Coutinho, Leitão, et al., 2020). The few studies investigating reciprocal compensation have evaluated Synchronisation Tendencies (ST) emerging between players using the cluster-phase methodology (Ribeiro et al., 2020).

Investigations about how team synergies emerge and evolve have been conducted using the Constraint-led Approach (CLA) (Silva et al., 2016). This player-environment-centred pedagogical approach advocates manipulation of informational constraints to build representative learning scenarios, supporting a tight action-perception coupling to utilise affordances available in training and competition (Woods, McKeown, Shuttleworth, Davids, & Robertson, 2019). Continuous representative practice allows players to become perceptually attuned to affordances *of* and *for* others, stimulating their ability to efficiently (re)organise collective behaviours in competition (Araújo, Davids, & McGivern, 2018). In volleyball, based on opposition tactics (e.g. high frequency of line attacks), a practice task can be constrained by rules (e.g. hitters only attacking the line) to induce the block-defence ST needed to overcome opponents in competition. The CLA research has mainly evaluated ST in invasive team-sports. Possible effects of other training processes on development of ST need more research attention (Ramos, Coutinho, Ribeiro, et al., 2020). The impact of training protocols, which are commonly assessed over brief timescales, on synergy formation between players has overfocussed on an 'end-product' (i.e. comparing initial and final practice stages), ignoring the underlying *processes*.

Development of functional interpersonal synergies needs to be aligned with the specificities, nature, and didactical content of each team sport (Hastie & Mesquita, 2016). Despite their relevance, these issues have been neglected in the literature. Conceptually grounded on constructivist assumptions, the Step-Game Approach (SGA) considers the nature of non-invasive games, like volleyball (Mesquita, Graça, Gomes, & Cruz, 2005). This player-centred approach offers didactic perspectives by structuring the teaching–learning process and defining practice tasks and strategies at different learning stages. Therefore, the development of ST can be didactically supported. The SGA advocates the development of players' abilities through step-by-step challenges, establishing meaningful couplings between tactical demands and technical skills (Mesquita et al., 2005). To exemplify, in volleyball, the blocking technique, using the 'steps-approach-arms' position, can be practised within a tactical activity that develops reading and anticipation of the opposition setter's decisions.

Integrating ecological (CLA) and constructivist (SGA) methodologies could extend our knowledge about how representative learning environments, manipulating specific-didactical constraints, might influence the development of functional coordinative structures (Ramos, Coutinho, Ribeiro, et al., 2020). Given its cyclic and interventive nature, AR designs could be helpful for monitoring the integration of ecological-constructivist approaches over extended time-periods (Carr & Kemmis, 1986). The systematic monitoring of practice programmes can provide contextualised insights about how ST emerge, persist and evolve during pedagogical interventions.

In volleyball, during the counterattack game-phase, lateral and longitudinal ST are preponderant once the oppositions have possession of the ball. To deal with unpredictability of opposition actions and gain a tactical advantage during counterattacking-subphases, players must become perceptual attuned to the most relevant affordances. Specifically, the opposition attacking context, described in volleyball literature as 'setting options/conditions' or 'number of hitters available', is a key constraint influencing a team's performance during competition (Laporta, Afonso, Mesquita, & Deng, 2018). Yet, there is a gap in understanding how opposition tactics/strategy might shape the (re)emergence of functional team synergies in play. It is pertinent to explore how attunement to opposition attacking options could be developed in practice by integrating ecological with constructivist and didactical-specific approaches. Furthermore, it remains unclear how increasing tactical complexity during practice may impact on quality of team transitions between functional synergetic states (system *metastability*) (Hristovski, Davids, & Araújo, 2009).

Adopting an AR-design over a competitive volleyball season, this study sought to integrate CLA-SGA principles to: (i) analyse the impact of increasing tactical complexity on lateral and longitudinal team ST during defensive and offensive counterattack-subphases; (ii) to examine how opposition attacking contexts might influence team ST during each counterattack-subphase. We hypothesised that throughout the season, the team would: (i) change ST as function of increases in tactical complexity; (ii) increase its synchrony in both counterattack-subphases as a result of representative practice designs; (iii), reduce the influence of opposition attacking context on their ST.

Methods

Participants

Fifteen female players (14 and 15 years-old), with at least one year of formal competitive experience, were selected through purposive and convenience sampling criteria (Patton, 2015). These participants were viewed as "information-rich" because they were at the beginning of their sporting experience and due to their ability and willingness to participate. This study was conducted from September 2017 to June 2018, encompassing Regional (September–January) and National championships (February–May). Overall, 143 training-sessions and 32 official matches were undertaken. On average, four training-sessions (2-hour long each) and one match were experienced per week.

Guidelines from the Helsinki Declaration were followed, and ethical approval was granted by the first author's institution Research Ethics Committee. Participants and their parents were informed about the scope of intervention, and the right to withdraw from the study at any time, without penalty. Confidentiality was ensured and informed consent forms were signed.

Study design

An AR-design was adopted in which the coach ongoingly and critically reflected about her practice, adapting it according to self-reflections (Carr & Kemmis, 1986). Specifically, an insider-AR approach was implemented, with the first author assuming the dual role of coach-researcher. This paradigm provided a privileged viewpoint about the teaching–learning processes underlying ST development (Coghlan, 2007). Specifically, the insider-AR was used to extend relevant understanding about team collective dynamics by qualitatively examining – framed upon an interpretative paradigm – processes inherent to the emergent ST in each counterattacking-subphase. The ST observed in each counterattacking-subphase was recorded during three competitive matches (one per-cycle), considering the opposition attacking contexts encountered. The first and second AR-cycles lasted four months each (September–December 2017, and December 2017–March 2018, respectively). The third AR-cycle lasted three months (April–June 2018).

The first AR-cycle focused on context exploration by players (Gilbourne, 1999), with the coach diagnosing the baseline of collective ST, and identifying the main tactical problems at each counterattack-subphase. The remaining two AR-cycles focused on increasing tactical complexity in practice designs by integrating key CLA-SGA principles. Recorded reflections, aligned with the unresolved problems identified in training and competition, guided the subsequent interventions. This design enabled monitoring and adjustments of the coaching pedagogical intervention, supporting a reframing and transformative process. Based on SGA principles, each training-session sought to enhance technical and tactical performance. The didactical content development comprised acquisition, structuring, and adaptation instructional tasks (Mesquita et al., 2005). These learning tasks were integrated CLA principles, in which manipulation of representative task constraints was designed to promote development of ST (Woods et al., 2019). It is important to emphasise that, in this study, we did not seek to increase the team's levels of ST by applying a "pre-stablished interventional protocol". Rather, by acknowledging the intrinsic complexity and unpredictability of a competitive season, both learning tasks and coaching pedagogical interventions were adapted daily (exemplified in Table I).

To ensure the study's interpretative validity, and to reduce the chance of individual research bias, regular debriefings occurred between the first author and two "friendly researchers" (co-authors of this study) (Patton, 2015). These meetings provided opportunities for reviewing, in a collaborative and constructive fashion, the influence of the CLA-SGA coaching intervention on the team ST development.

Instructional validity

To ensure the CLA-SGA combination, the coaching intervention was confirmed by one co-author, and one knowledgeable, independent observer not associated with the study. The independent observer analysed the documented training-plans, and the training video records. The few disagreements were resolved consensually. A 10-item checklist was adapted according to evidence from studies by Pereira et al. (2011), and Práxedes et al. (2019) to assess behavioural fidelity of the coaching intervention. Eighteen training sessions (10% sample) were

Table I. Overview about the coaching pedagogical intervention implemented over the competitive season, which combined CLA and SGA principles to develop collective ST in each counterattack-subphase

1st AR-cycle		2nd AR-cycle		3rd AR-cycle	
No-ball (defensive)	-Lateral synchrony on 1×1 (block-defense) situations, against opponents playing *in*-system	**No-ball (defensive)**	-Block-defense synchronisation in 1×2 organisation on zone 4 and 2, against opponents playing *in*-system -Block-defense synchronisation in 1×3 organisation on zone 6, against opponents playing *in*-system	**No-ball (defensive)**	-Block-defense synchronisation in 1×2 organisation on zone 3, against opponents playing in-system -Collective block-defense priorities according to the opposition attacking contexts
Ball (offensive)	-Lateral and longitudinal synchronisation tendencies with *in*-system simple attack combinations	**Ball (offensive)**	-Lateral and longitudinal synchrony of simple attack combination during *out*-system situations -Collective synchronisation tendencies of complex attack organisation	**Ball (offensive)**	-Variability on set action as function of opponents' blockers -Variability on offensive organisation according to the setting conditions
SGA **Task type** Acquisition: -Individual dig actions - Individual block actions -Collective dig and set actions on 1×1 situations	CLA **Task constraints** -Starting position for dig with eyes closed - Good transition measured considering the quality of dig and set transition (e.g. scored with 1 point)	SGA **Task type** Structuring: -Collective block and defense against attack on zone 4 and 2 -Triple block against attack on zone 6	CLA **Task constraints** -Blocking with decision-making (i.e. the opponent setter determined who will block) at different attack tempos - setting options fully constrained to narrow the work on block-defense	SGA **Task type** -Collective block-defense against attack on zone 6	CLA **Task constraints** 6x6 rules/score: - setting options briefly constrained to narrow the work of block-defense - positive block contact or defense are rewarded with one extra point. -Complex offensive combination playing *in*-system rewarded with two extra points
Pedagogical strategies -Cue perception (anticipate attackers' intentions)		**Pedagogical Strategies** -Tactical Understanding -Strategic game-plan (exploring opponents' weaknesses)	**Complexity** - 6×6 with two setting options during *in*-system situations	**Pedagogical Strategies** Tactical Understanding Strategic game-plan (block-defense priorities according to opponents' attacker in each rotation) Cue Perception (anticipate opponent's setter intention)	

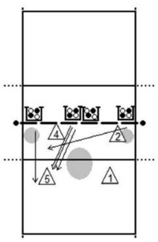
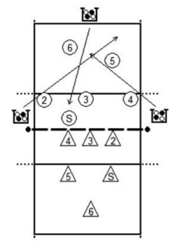
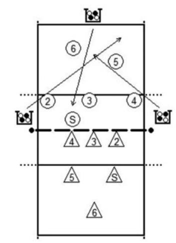
(*Continued*)

arbitrarily analysed for the presence of the items included in Table II (Tabachnick & Fidell, 2007). A 100% agreement level between observers ensured the suitable CLA-SGA combination.

Variables

The counterattack-phase comprises the block, dig, set and attacking actions (Eom & Schutz, 1992). Aligned with the study's purpose, the counterattack-phase was

Table I. Continued.

1st AR-cycle		2nd AR-cycle		3rd AR-cycle	
Description	*Graph*	*Description*	*Graph*	*Description*	*Graph*
Defenders must start with eyes closed. One sequence of three attacks: (1) middle-attack to zone 5 with set transition by z1; (2) line-attack for block and defense; (3) middle-attack to zone 5 and cross attack to zone 4 **Questioning Examples:** -Where are you looking when you open your eyes? Ball? Hand? -How did you end the set? How were your shoulders?		Sequences of two balls: (1) *In*-system ball tossed to the setter (S), who can set free to zone 4 or 2 (side A). Attack from the box and floor at the same time, against block and defense respectively; (2) freeball tossed to the side B, so that can perform a complex offensive combination to one of the spots highlighted. **Questioning Examples:** Did you have a good angle to attack on that trajectory? Did you jump on the right tempo? Why? Why not?		Conditional 6×6 format – sequences of 5 balls: (1) *in*-system ball tossed to the setter who can choose to set on zone 3, 6 or 4; (2) an attack from zone 2; (3) *in*-system ball tossed to the setter who can choose to set on zone 3, 6 or 2; (4) an attack from zone 4; (5) in-system ball tossed to the setter who set free. The set starts at 10/10 – positive block and dig contacts rewarded with one extra point **Questioning Examples:** -Why did you set to that zone? Which were her opponents? Did you see the block open? So why did you dig there?	

divided into two subphases considering the natural and sequential game structure: (i) no-ball possession (defensive-organisation), leading to block and dig actions, and (ii), ball-possession (offensive-organisation), comprising the set and attack actions. The opposition attacking context was reviewed for attacking options available to the setter. Thus, the opponents could be playing *in*-system (all hitters available) or *out*-system (only the outside-hitters and/or the opposite available) (adapted from Laporta et al., 2018). The *full*-system combines both attacking contexts (i.e. playing *in*- and *out*-system).

Recording procedures

Three matches were selected based on the following criteria: competitive moment (i.e. matches from regional and national competitions were included), opposition level (i.e. only matches against the top four ranked teams in the previous competitive season were selected), and number of counterattacking practice tasks undertaken in training (i.e. only included matches from which at least six counterattack practice tasks were performed during training in the previous week). The defensive-subphase was defined from the instant when opponents performed the first ball-contact to the third ball-contact. The offensive-subphase was defined from the instant that the evaluated team performed the first ball-contact to the third ball-contact. Overall, 48 (16 per-match) and 24 (8 per-match) sequences were analysed with opponents playing in *full*- and *in*-system, respectively. Occasionally, the number of counterattacking sequences of the match was greater than the number of sequences selected. Here, the sequences scored using attacking actions were privileged, as they required an intense and challenging cooperative dynamic between teammates.

Matches were performed on volleyball courts measuring 18 m × 9 m (width × length). Video recordings were captured using a camera positioned above (2 m) and behind (5 m) the court. The camera zooming rate was fixed to simplify image treatment. Images were recorded at a 25 Hz frequency and a resolution of 1920 × 1080 pixels. Calibration points were located on the ends of the court (two points) on the lateral 3 m line (two points), and over each antenna (two points) (Duarte et al., 2010). Players' positional coordinates were recorded using TACTO software (version 8.0) with an accuracy level higher than 95% at 25 Hz (Fernandes,

Table II. Instructional checklist

Elements of the training session	Present	Absent
1. Create tactical problem as the centre of learning tasks organisation.		
2. The coach explained the task, observed individual and collective behaviours, and used questioning to guide players' tactical understanding.		
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, as well as promoting the emergence of the synchronisation tendencies at each counterattacking-subphase previously emphasised.		
7. Manipulation of constraints of the full game were performed, so that players can guide their attentional focus for specific tactical coordinative structures.		
8. All tasks were constrained in terms of rules, space, time and/or opposition attacking contexts.		
9. All tasks required the exploration of different performance solutions by the player.		
10. All tasks were built to ensure that learning designs represent the demands of competitive performance environments.		

Folgado, Duarte, & Malta, 2010). In this procedure, the players' working point was tracked (projection of gravity centre locating the mean distance between players' feet) using a computer mouse in slow-motion video. This software afforded players' 2D virtual coordinates (expressed in pixels). The Direct Linear Transformation method ensured conversion from virtual to real coordinates (expressed in metres) (Duarte et al., 2010).

Reliability

Five sequences were randomly selected, with players' data trajectories being re-digitised by the same author. Data reliability and accuracy were checked through the percentage of technical error of measurement (%TEM) and coefficient of reliability (R) (Goto & Mascie-Taylor, 2007). Intra-observer results demonstrated good accuracy and reliability levels (%TEM = 2.7, $R > 0.9$, respectively).

Cluster-phase method (CPM)

The CPM was used to compute means and continuous group synchrony levels, ρ_{group} and $\rho_{\text{group}}(t_i)$, and player's relative phase, θ_k (Richardson, Garcia, Frank, Gergor, & Marsh, 2012). This method was recently used by Ribeiro et al. (2020) to assess emergent ST at a meso-scale level through multilevel-hypernetworks in teams. Here, we adapted the expressions used by Ribeiro and colleagues to calculate the cluster-phase, that is, cluster-amplitude values, and to capture the team ST in each time-series. The ST refers to the coordination patterns developed by players through their interactions over time that allow them to temporarily form functional synergies in each counterattack-subphase. Specifically, we replaced the simplice sets Γ_j, 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 kth player movements measured in radians $[-\pi\ \pi]$, where $k = 1, \ldots, N$ and $i = 1, \ldots, T$ time steps, the Team A or *cluster* phase time-series, $\bar{\emptyset}_A(t_i)$, can be calculated as:

$$r'_A(t_i)\frac{1}{n_A}\sum_{k\in\Gamma_A}\exp\left(i\theta_k(t_i)\right) \tag{1}$$

and:

$$\bar{\emptyset}_A(t_i)a\tan 2(r'_A(t_i)) \tag{2}$$

where $1 = \sqrt{-1}$ (when not used as a time step index), $r'_j(t_i)$ and $\bar{\emptyset}_j(t_i)$ comprise the resulting cluster phase in complex and radian form, respectively. Ultimately, the continuous degree of synchronisation of Team A $\boldsymbol{\rho}_{\Gamma_A}(\boldsymbol{t_i}) \in [0, 1]$, , that is, the cluster amplitude $\boldsymbol{\rho}_{\Gamma_A}(\boldsymbol{t_i})$ at each time step t_i can be computed as:

$$\rho_{\Gamma_A}(t_i) = \left|\frac{1}{n_A}\sum_{k\in\Gamma_A}\exp\left(i(\theta_k(t_i)\ \bar{\emptyset}_A(t_i))\right)\right| \tag{3}$$

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

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

Summarising, the Hilbert transform of each sequence of values for the longitudinal and lateral players' coordinates was calculated for each time frame of the match, obtaining each player's phase value. Next, we measured the cluster-phase (i.e. team's phase value) by summing all of each player's phase values. Afterwards, we computed the differences of each player's phase values with respect to the cluster-phase, and calculated the mean of those differences, finding the cluster-amplitude mean value. The cluster-amplitude value corresponds to the inverse of the circular variance of $\Phi k(t_i)$. Therefore, if $\rho\Gamma_A = 1$, the team is totally synchronised, and if $\rho\Gamma_A = 0$, the team is completely unsynchronised. The cluster-amplitude values were computed through specific routines implemented in GNU OCTAVE (version 5.1.0).

Data analysis

A 3 (matches) × 2 (counterattack-subphases) × 2 (opposition attacking contexts) × 2 (court directions) repeated-measures ANOVA was used to calculate differences in cluster-amplitude mean values between matches, as a function of counterattack-subphases (defensive and offensive), opposition attacking contexts (*full*-system and *in*-system) and court directions (lateral and longitudinal). Given the equality in group sample sizes, the homogeneity of variances was assumed (Field, 2009). Violations of sphericity assumption for the within-participant variables were checked using Mauchly's test. The Greenhouse-Geisser correction procedure was used to adjust the dofs. Pairwise differences were evaluated through Bonferroni *post hoc*. Statistical significance level was set at $p = 0.05$. Effect size values were interpreted by partial eta-squared (η_p^2) (Levine & Hullett, 2002), as small ($\eta_p^2 < 0.06$), moderate ($0.06 \leq \eta_p^2 < 0.15$) or large ($\eta_p^2 \geq 0.15$) (Cohen, 1988). Inter-match differences were calculated through standardised mean differences (SMD), via Cohen's *d*, with 95% confidence intervals. Inferential statistical procedures were conducted using SPSS 25.0 software (IBM, Inc., Chicago, IL).

Results

Table III summarises the mean and standard deviation values of the team's cluster-amplitude in each AR-cycle as a function of counterattack-subphases, opposition attacking contexts and court directions. Figure 1 portrays the inter-standardised mean differences among matches.

Defensive subphase (no-ball possession)

The inter-match analysis when opponents were playing in *full*-system, revealed small significant differences for ST in lateral ($F_{(2,000)} = 188,174$; $p < 0.001$, $\eta_p^2 = 0.03$) and longitudinal ($F_{(2,000)} = 135,996$; $p < 0.001$, $\eta_p^2 = 0.02$) court directions. Significant differences in lateral ST were observed between all matches ($p < 0.001$), with the lowest and the highest values being attained at M1 and M3, respectively. Similarly, we observed significant differences in longitudinal ST between all matches ($p < 0.001$), with the lowest and the highest synchronisation values being verified at M2 and M3, respectively.

The inter-match analysis when opponents were playing *in*-system, revealed significant differences for ST in lateral ($F_{(2,000)} = 451,974$; $p < 0.001$, $\eta_p^2 = 0.2$) and longitudinal ($F_{(2,000)} = 455,146$; $p < 0.001$, $\eta_p^2 = 0.2$) directions. Significant differences ($p < 0.001$) for lateral ST were found between M3–M1 and M3–M2, with no statistical differences between M2–M1 ($p = 0.410$). The lowest and the highest values for lateral ST were verified during the first and third match, respectively. Significant differences ($p < 0.001$) for longitudinal ST were found between all matches, with the lowest synchronisation value being observed during M2, and the highest value in M3.

Offensive subphase (ball possession)

The inter-match analysis when opponents were playing in *full*-system, showed significant differences for ST in lateral ($F_{(2,000)} = 539,309$; $p < 0.001$, $\eta_p^2 = 0.05$) and longitudinal ($F_{(2,000)} = 314,071$; $p < 0.001$, $\eta_p^2 = 0.03$) court directions. Significant differences ($p < 0.001$) for lateral ST were observed across all matches, with the lowest and highest synchronisation values being verified during the M2 and M3, respectively. Significant differences in longitudinal ST were found between M2–M1 and M3–M2 ($p < 0.001$), with the lowest synchronisation value being observed during M2. No significant differences in longitudinal ST were observed between M3–M1 ($p = 1.000$).

The inter-match analysis when opponents were playing *in*-system, revealed moderate and small significant differences for team ST in lateral ($F_{(2,000)} = 263,792$; $p < 0.001$, $\eta_p^2 = 0.08$) and longitudinal ($F_{(2,000)} = 171,209$; $p < 0.001$, $\eta_p^2 = 0.06$) court directions. Significant differences ($p < 0.001$) in lateral ST were found between all matches, with the lowest and highest synchronisation values being attained at M1 and M3, respectively. Significant differences ($p < 0.001$) in longitudinal ST were observed between M1–M3 and M2–M3, with the highest value being observed during M3. No significant differences in longitudinal ST were attained between M2–M1 ($p = 1.000$).

Table III. Mean and standard deviation of cluster-amplitude values during each AR-cycle as function of counterattacking-subphases (defensive and offensive), opposition attacking contexts (*full*-system and *in*-system) and court directions (lateral and longitudinal)

	1st AR-cycle Match 1 (M1)		2nd AR-cycle Match 2 (M2)		3rd AR-cycle Match 3 (M3)	
Defensive subphase (no-ball possession)						
Opponents' playing in *full*-system						
Court Direction	Lat	Long	Lat	Long	Lat	Long
Mean ± SD	0.82 ± 0.27	0.85 ± 0.24	0.83 ± 0.22	0.83 ± 0.22	0.87 ± 0.21	0.87 ± 0.20
Opponents' playing *in*-system						
Mean ± SD	0.70 ± 0.30	0.82 ± 0.25	0.71 ± 0.29	0.73 ± 0.3	0.85 ± 0.21	0.90 ± 0.18
Offensive subphase (ball possession)						
Opponents' playing in *full*-system						
Mean ± SD	*0.85* ± 0.25	0.86 ± 0.24	0.80 ± 0.25	0.81 ± 0.23	0.87 ± 0.21	0.86 ± 0.22
Opponents' playing *in*-system						
Mean ± SD	0.75 ± 0.27	0.78 ± 0.26	0.77 ± 0.27	0.78 ± 0.25	0.85 ± 0.24	0.84 ± 0.23

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

Discussion

Integrating ecological (CLA) and constructivist (SGA) approaches through an insider-AR implemented over a season, this study analysed the influence of increasing tactical complexity on collective ST in both counterattack-subphases. Additionally, we investigated how opposition attacking contexts impacted on the team ST at each counterattack-subphase. Overall, combining CLA-SGA principles seems to support the development of tactical coordinative structures. Results depicted that: (i) tactical complexity increments (second AR-cycle) were followed by decreases in ST, (ii) opposition attacking contexts progressively

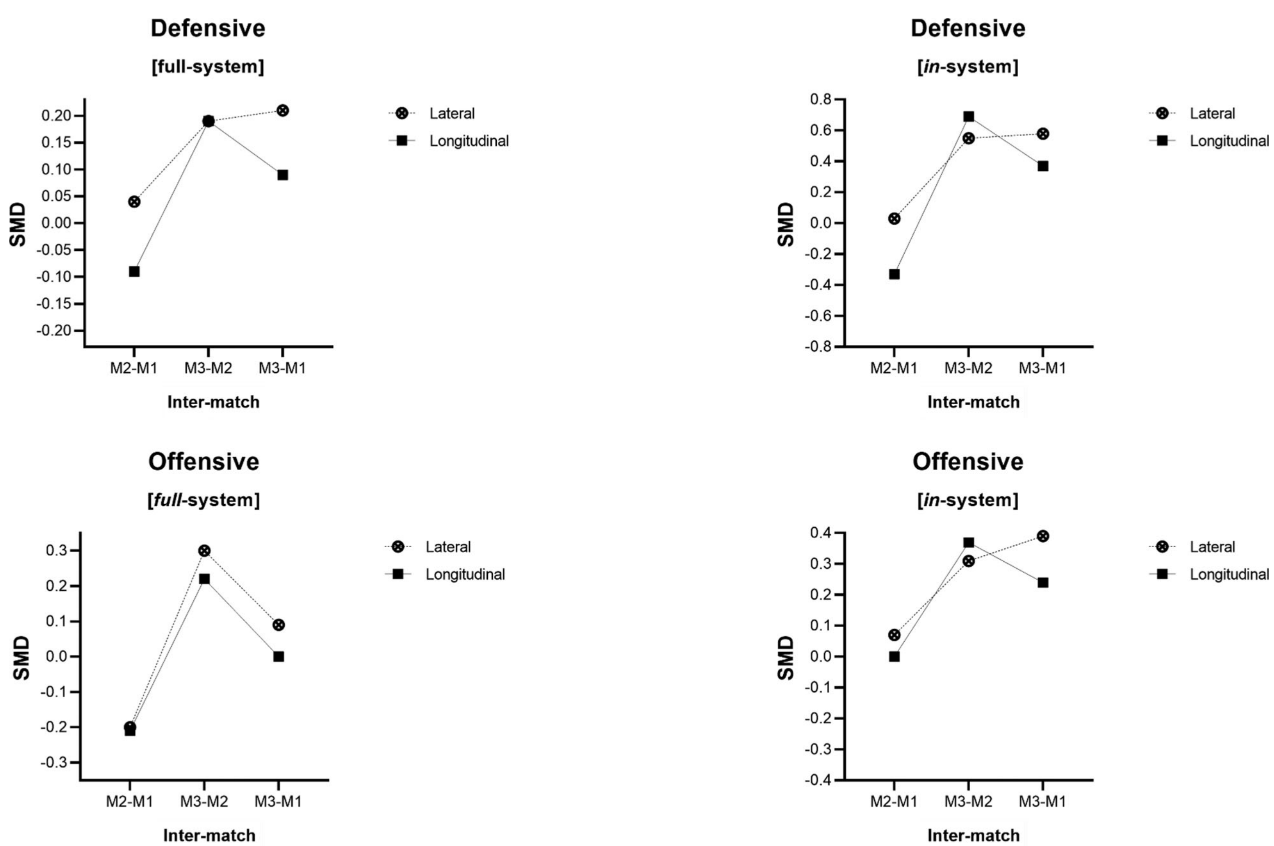


Figure 1. Standardised mean differences for inter-match ST of the team (via cluster-amplitude values) throughout the competitive season as function of counterattack-subphase, opposition attacking contexts and court directions

reduced their influence on team ST, (iii) the insider-AR ensured a close monitoring of training processes, providing contextualised insights about team's tactical needs which supported the coaching pedagogical interventions.

Throughout the first AR-cycle, diagnosis of the main co-adaptative weaknesses identified on team ST during the defensive-subphase (no-ball possession), mirrored by the lowest synchronisation values observed. This outcome suggested difficulties in players' picking up relevant information sources when they were playing without the ball, perhaps expressing attentional focus flaws. This idea corroborates the findings of McGuckian and colleagues (2020), who showed that footballers used fewer visual head movements without ball possession. The ability to identify and interpret key informational constraints in competition is particularly relevant in non-invasion sports, which given their nature, requires quick and continuous tactical adaptations. At this stage, the players' game-related knowledge of the environment and the use of tactics (Woods et al., 2020) was still at the beginning of its development, limiting the exploration of key opposition constraints.

To reverse this trend, from the first AR-cycle, practice tasks (i.e. based on specific skills performance) were 'time-constrained' didactically to narrow players' attentional focus. For instance, players started defending with eyes-closed to scan rapidly for relevant information when opened. During such tasks, the coach used convergent questioning (e.g. are you looking at the ball or attackers' arm? Looking at the direction of the attackers' arm may help to predict the ball trajectory after the strike) (Siedentop & Tannehill, 2000). This coaching intervention sought to simplify nested constraints (i.e. embedded in different timescales) inherent to competition, by isolating the key action opportunities (e.g. anticipate the dig action) (Balagué, Pol, Torrents, Ric, & Hristovski, 2019).

Possibly due to this coaching intervention, across the second AR-cycle, we observed slight improvements in lateral ST at the defensive-subphase. To continue these improvements, didactical structuring tasks (i.e. focused on comprehending the tactical-technical skills within the competitive environment) evolved in terms of content complexity. To exemplify, playing against *in*-system context, the opposition setter was able to freely choose the attack zone. Thus, players were stimulated to intentionally looking for meaningful information from the opposition setter so that they could anticipate the attacking zone. Divergent questioning (e.g. where should you look? Why?) was included to enhance the players' attention (e.g. when the setter contacts the ball close to herself, she only can set to zone 2).

To develop players' co-adaptative skills, during the second AR-cycle, the coach increased tactical complexity in both counterattack-subphases, through tactical step-by-step challenges (SGA) practically implemented using a Constraint-Led perspective. To exemplify, in offensive organisation, fast tempos and attack combinations were introduced. Defensively, the number of defenders was reduced (i.e. a double-block organisation implying fewer defenders covering more space). As hypothesised, increasing tactical complexity prompted a decrease in collective ST during the second match, particularly during the offensive-subphase. This finding supports the assumption of Balágue et al. (2013), namely that the team's co-adaptative process could be affected by introduction of complexity, acting as system "noise".

Interestingly, the highest team synchrony values emerged during the third match, suggesting a re-emergence of functional ST within more complex tactical patterns from relative spatial location of players (Gréhaigne & Godbout, 2014) Therefore, the "noise" introduced seems have played a functional role, allowing the system to reach a "dynamic stability" (Passos, Araújo, & Davids, 2016). This finding supports the assumption of Hristovski et al. (2009), explicitly that *metastability* is crucial for players to co-adapt behaviours. The dynamics of a metastable region of performance landscape can be exploited, for instance, when players continuously transit among different stages of block-defence organisation according to opposition attacking contexts. This aspect of practice design allowed the team to maintain functional performance integrity required to exploit tactical advantages within challenging competitive environments. Moreover, the highest ST observed over the third AR-cycle underlines the importance of players being embedded within specific-didactical and representative practice programmes for long time-periods to improve their attunement to relevant informational constraints translated, in terms of performance, by the (re)emergence of ST.

As hypothesised, the influence of opposition attacking context on ST was progressively reduced. The strategical game-plan introduced, from the second AR-cycle, might explain this finding. This strategy involved constructive discussions between players with the coach, who sought to stimulate the players' tactical understanding. Players were invited to interpret the opposition's strategy exploring possible strategies to gain tactical advantages during competition (e.g. establishing block-priorities). Afterwards, as proposed by

Woods and colleagues (2020), the learning tasks were co-designed following the principles defined by the strategical game-plan (i.e. encompassing the same information offered by competition – representativeness (Pinder, Davids, Renshaw, & Araújo, 2011)). For instance, adaptation tasks were rule-constrained according to opposition features of play with questioning being used to reinforce tactical understanding (e.g. Did you see the block open? So why did you dig there?).

A limitation of the study was that the TACTO software did not allow us to directly collect data on positional coordinates at a three-dimensional scale of analysis. Hence the ball coordinates were not included in the study. Since players co-adapt their positioning according to ball location it could add valuable information. Moreover, our analysis was focused on the "phase" of the ST. The trajectory of a dynamical system (e.g. volleyball team ST) consists of a combination of "phase" and "amplitude" data, meaning that a movement in a different direction and/or velocity, produced as a consequence of another player's movement, cannot be quantified as a synchronised.

Conclusion

This study emphasised the benefits of integrating ecological and constructivist approaches to develop ST during defensive and offensive counterattacking-subphases. The data encourage coaches to design representative and specific-didactical learning environments, predicated on the team's tactical needs and strategical ideas from a game-plan (framing player intentionality). Results supported the integration of complementary pedagogical approaches that enable development of team co-adaptative processes. Findings endorsed use of questioning strategies to narrow the players' attentional focus in searching practice landscapes, stimulating perceptual attunement to relevant competitive performance constraints. Results suggested that complex tactical organisation cause reductions in collective coordinative structures, with the (re)attainment of functional synchrony made feasible by integrating CLA-SGA principles. Methodologically, the insider-AR provided contextualised insights for a coaching intervention focused on improving collective ST.

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