Sports teams as collective homeostatic systems: Exploiting self-organising tendencies in competition.

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Published version

SANTOS, Ricardo, RIBEIRO, João, DAVIDS, Keith and GARGANTA, Júlio (2023). Sports teams as collective homeostatic systems: Exploiting self-organising tendencies in competition. New Ideas in Psychology, 71: 101048.

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Running title: Sports teams as Collective Homeostatic Systems

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Abstract

This paper proposes how sports teams, conceptualised as homeostatic regulatory systems can continually self-organise their ongoing actions to maintain team functioning and organization during competitive performance. In the model, team performance is co-regulated as coordinated behaviours emerge between performers to adapt efficiently and effectively to satisfy emerging dynamical constraints of competitive environments. Understanding collective homeostasis in interpreting the self-organizing dynamics of sports teams facilitates the identification and analysis of adaptive behavioural responses of teams, sub-groups, and players. As a starting point, a biological model of collective homeostasis is composed of four critical components: a) players, b) set point, c) identifier, and d), adapter. Understanding the interrelated functioning of model components is fundamental to designing effective training for development of self-regulating team performance. In terms of performance analysis, identification and disruption of specific set points will provide insights for studying how to negotiate critical moments of game play.

Key Points

- Sports teams are conceptualised as collective homeostatic systems exploiting self-organisation tendencies in competition.

- The homeostatic model, aligned with ecological dynamics, explains the need for emergent adaptive behaviours of sports teams and enhances understanding of the self-regulatory tendencies emerging from players' interactions during competitive performance.

- The homeostatic self-regulatory model may assist coaches and performance analysts in elaborating better training methodologies and performance preparation models.

Manuscript word count: 2997 (max 3000)

1 Introduction

Current conceptualization and systematic analysis of performance in team sports, like soccer, considers it to be structured around phases of attack, defence, and transitions. There is a general idea that a team with ball possession is attacking and without ball possession is defending. When there is loss/recovery of the ball, teams enter a transitional phase between these phases of play. This perspective provides a fragmented, reductionist view of performance, in which the different phases of play are interpreted separately in isolation. Here we consider competitive performance in soccer, from a player-environment scale of analysis, predicated on a *continuous flow* of interactions in which teams display offensive and defensive behaviours at the same time. This systems orientation views adaptive readiness as essential for interacting with the dynamics of a demanding performance environment.

Considering performance-related questions like these facilitates the contemporization of training tools and methodologies, to enhance the functionality of athletes and teams at a systemic level. Adopting an ecological *player-environment perspective* is significant for developing coherent models for analysing and understanding competitive performance in sport. Utilising a systems perspective, sports teams have been conceptualised as *complex adaptive systems* composed of integral components (i.e., the players) [1]. System components interact within the performance environment in a dynamic, interdependent and functional manner, revealing emergent, self-organizing tendencies in behaviour to achieve task goals [2].

Understanding the nature of self-regulatory tendencies in complex adaptive systems (i.e., those sustaining the co-adaptive performance interactions of competing teams), is essential for developing methodologies for performance analysis. A potentially useful conceptualisation is the homeostatic regulation system, a model which has contributed so much to human development [3]. Here, we explore its potential merit in understanding how players, individually and in teams, can self-regulate collectively and adaptively within dynamic performance environments.

1.1 The concept of homeostasis

Homeostasis is a biological property for regulating the state of (bio)chemical and physical conditions maintained by all living organisms during ongoing interactions with the environment [4]. Organisms that exhibit innovative and efficient homeostatic tendencies (i.e., adaptation to constraints – see Newell, 1986 [5], for detailed information on the constraints model) enhance their capacity to survive, as these systems can quickly adapt to perturbations that threaten system functioning. Importantly, the homeostatic self-regulatory system has played a fundamental role in understanding natural selection and, consequently, the evolution of living organisms [3].

Homeostatic systems combine an ability to maintain integrity over time with a functional capacity for interactive adaptive behaviours. Like many other organic systems (e.g.,[6, 7]), the collective homeostasis associated with sports teams captures the collaborative processes necessary to maintain the functional integrity of teams, supported by individual homeostasis (i.e., interactive, goal-directedbehaviours of individual players for co-adapting within the performance environment[8]).

In this opinion piece, we consider how a homeostatic regulation model could conceptually frame how players and teams continually (re)adjust their ongoing actions during competitive performance to dynamical constraints. These ideas on collective homeostasis underpinning self-regulation in team sports are well aligned with the key concepts in ecological dynamics [9]. The proposed framework may provide novel insights for coaches, practitioners, and performance analysts regarding the design of training environments to enhance team organisation and functioning.

2 Conceptualizing Sports Teams as Collective Homeostatic Systems

Collective behaviours of sports teams are underpinned by homeostasis, with a purpose of self-regulation in order to maintain structural integrity within the parameters of *survival* in a sporting context. This specific understanding of ‘survival’ corresponds to effective behaviours adjusted to different contexts of competitive performance that emerge at different levels of complexity (i.e., from micro-meso-macro relations).

Considered at a micro scale of analysis (i.e., interactions between a player and environment), homeostasis allows an individual to adjust their behaviour to the emergent contingencies of competition. System information in the form of specific values of interpersonal distances between competitors, speeds of approach and/or distance from teammates and opponents, need adjusting to maintain performance functionality [10, 11]. These information sources support system self-organization tendencies that emerge for performers to exploit and (re)organise functional responses to emerging disturbances in the environment, which can be internal or external in nature. Progressing to meso-scales of increasing complexity, in sectoral, intersectoral and collective terms, to be successful, players will have to effectively coordinate actions and behaviours (i.e., build functional synergies) to avoid compromising a requisite level of collective functional organizational. Thus, inherently adaptable properties underlying team organisation and functioning mirror those of collective homeostatic systems. The former emerge from the collaborative, synergistic processes developed by players to achieve performance goals during practice and competitive performance.

2.1 The importance of collaboration in sport

Collaborative processes are key for system functioning and adaptation, requiring teammates to coordinate goal-directed behaviours to deal efficiently and effectively with the dynamics of performance constraints in competitive environments. It has been argued that cooperation is indispensable to understand particular aspects of evolution [12, 13]. According to this line of thought, enhancement of collaborative behaviours can explain some changes in team performance. For example, competitive dynamics in soccer have adjusted towards increased teamwork and less individual performance behaviours over the last 30 years [14]. Hence, understanding collaboration has become increasingly important for understanding the functionality of the homeostatic nature of self-regulation tendencies in sports teams, particularly the implicit communication processes that channel player interactions as system components.

Since collective homeostasis emerges from a group of autonomous individuals who form a sports team, the design of training programmes has tremendous importance in the development of the collective homeostatic system. The adjusted configuration of training sessions can provide necessary tools for enhancing self-regulation tendencies in teams, impacting on their organization and functioning. Understanding the events that lead to the emergence of different system states of order, disorder, and transitions between them, as adaptive behaviours [15], is needed to identify the contexts in which the congruence between states of order/disorder is broken, shaping competitive outcomes [16].

Conceptualizing sports teams as collective homeostatic systems might help to understand the evolutionary tendencies of teams, enriching our understanding of performance dynamics. Although the timescale of sport performance is not the timescale of evolution it is important to recognise that the same principles of homeostasis underpin the dynamics behind the necessary adaptations that emerge in sports organisations and evolving systems.

3 The Homeostatic Model

Homeostasis is a fundamental property of complex adaptive systems, to regulate environmental functioning, maintaining system stability through multiple dynamic balance adjustments, adapting to perturbations through self-regulatory tendencies [17].

Although self-organisation tendencies already have a biophysical theoretical explanation in Kelso's (1995) [18] framework of coordination dynamics, the concept of homeostasis may provide a useful foundation for understanding how collaborative processes function for maintaining performance stability in a (collective) biological system like a sports team. Indeed, homeostasis may provide a foundation for understanding how inherent self-organisation tendencies function in athletes and sports teams conceptualised as dynamical systems [19].

In this paper, we refine a model proposed earlier [20] that reflects the function of homeostatic regulatory tendencies, including four critical components: a) **players**, as self-regulating agents who succeed by coupling perception and action; b) **set point**, a set of principles which guide a sports team's performance style, pertaining to a specific game model (which educates intentions of athletes); c) **identifier**, a set of aggregating ideas and intentions (related to the game model); d) **adapter**, that facilitates emergence of functional variability in systems within sport performance contexts.

These sub-systems function by perceiving a change or disturbance in a regulated (informational) variable with respect to bandwidth tolerances. A value of a key system variable, outside of the acceptable bandwidth, facilitates the search for a change in system behaviour to restore the regulated variable towards tolerance limits for its set point value (negative feedback systems).

3.1 How the negative feedback system explains co-adaptive dynamics of sports teams

One of the fundamental properties in a homeostatic regulatory system is the use of negative feedback to guide search for more functional solutions. This process provokes a mediating change in relation to a perceived system perturbation or disturbance which acts as information to guide re-organisation of system degrees of freedom [21] that seeks to address effects of a perturbation.

This model of self-organisation clarifies how a sports team can adjust its behaviours to satisfy different constraints emerging from the performance environment dynamics. In this way, a collective system can counteract perturbations and disturbances that might threaten the stability of its collective structure. In the same way that thermoregulation is a functional way of adapting body temperature in biological organisms, a sports team can regulate collective performance by teammates using surrounding information sources, for example by co-adapting distances between themselves.

This type of regulatory tendency in sports teams can help them to *survive* (defined as successfully competing in a sport context) by adapting to a dynamic performance environment. Indeed, a sports team can also evolve (defined as enhancing performance to compete successfully over a longer timescale) using these information-regulation processes to enhance actions. Facing adversity in competition, a team needs to develop collaborative processes that strengthen the collective system's adaptive interactions in order to maintain system survival (maintain collective performance stability in sport contexts). An important aspect in this self-regulatory tendency is the need for a team to exploit division of labour [22], in which players can take on different roles and tasks during competitive performance (e.g., in attack, a team with ball possession may have the majority of players focusing on creating defensive imbalances in opposition organisation to complete a scoring attempt). At the same time, other teammates are concerned with covering key spaces in case the ball is suddenly lost. In this way, a homeostatic conceptualisation of team organisation in phases of play avoids fractured and reductionist analyses of competitive performance because, while a team is attacking, some players may adopt a more defensive role to sustain momentum in attack if possession is conceded to counter the threat of a counterattack. For this reason, it may be better to analyse collective system performance in terms of agent roles (attacking or defending) rather than positions (attacker or defender) [23].

Figure 1 illustrates this regulatory process, the ecological model of the homeostatic process in a sports team and its components.

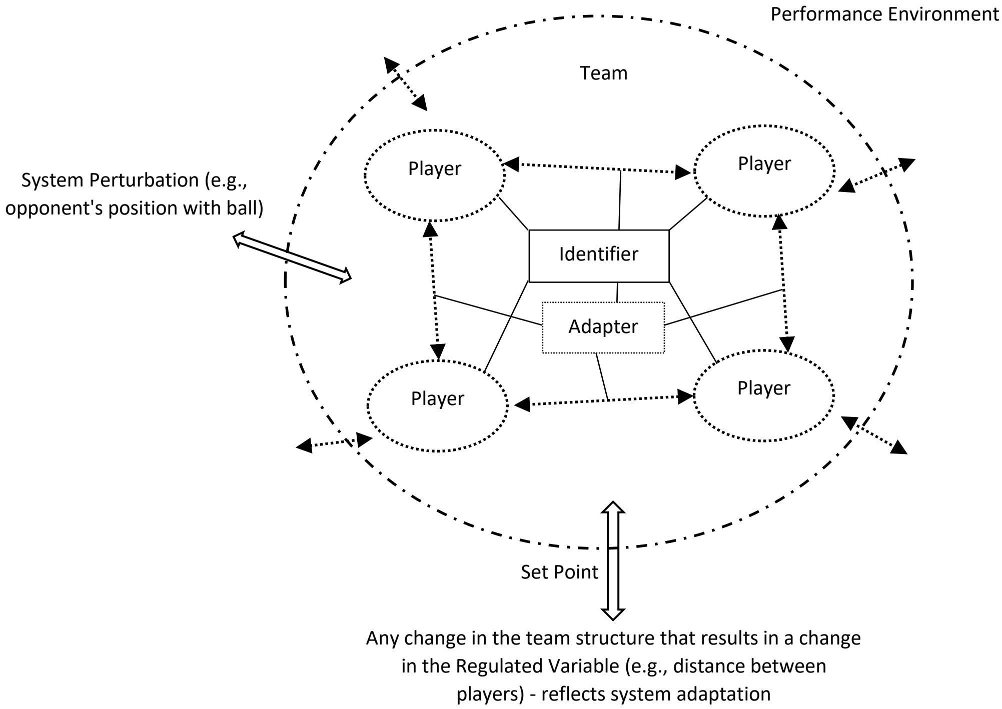

Fig.1. Homeostatic regulatory model in a sports team

3.2 Players

In this model, the players represent the highly attuned, information-seeking agents of the team through their continuous interactions, attending to perceiving and using key information sources for affordances in the surrounding environment (e.g., the location of the ball, the player in possession of it, available space). The player acts as a perception–action coupling agent in the team, in which each individual can perceive the value of key collective, performance-regulating variables (e.g., distance between teammates, interpersonal distances with immediate opponents) [24, 25]. Individual actions contribute to shaping the dynamic values of key performance variables to maintain collective system stability. Each player can exploit system actions/behaviours harnessing the reciprocal compensatory system in the team (e.g., covering a gap left by a teammate). In coaching, from an ecological dynamics perspective, this idea aligns with processes of ‘education of intention’ (clarifying collective system performance goals) and ‘education of attention’ (individual performers becoming attuned to relevant information sources in their surrounding performance environment during practice to continuously monitor and regulate their goal-oriented actions) [26, 27].

In the collective homeostatic system, team cooperation emerges from the continuous co-adaptation of all the players guided by surrounding information and framed by collective system intentionality [28]. This is essential for sharing affordances (invitations for collective actions) and intentions (performance goals), and to reinforce that collective homeostasis is more than the sum of individual homeostasis (i.e., in each player), although collective system functioning is dependent on the unique contributions of each individual, since each player has singular characteristics (e.g., skill set, decision-making, experience, emotions, tactical knowledge) which are adjusted and integrated to enhance whole system functioning.

Importantly, collective system self-regulation is dependent on a degenerate (i.e., multiplicity of different performance solutions from the same components of the system [29]), self-organising, control system distributed amongst all players, predicated on adaptive homeostatic information regulation tendencies, regardless of individual components (e.g., when a player is injured and replaced, or a tactical substitution is made).

3.3 Set Point

In biophysical systems the set point corresponds to information of the intended values in a regulatory feedback sub-system, as in regulating temperature or pressure. In a sports team, the set point can be equated with key informational variables associated with tactical principles of play (e.g., at a moment of defensive transition, a team can pressure the opposition ball carrier and the surrounding space, with the objective of re-gaining possession, preventing long passes or assuming defensive organization for closing down space between defensive lines). In this example, the set point of the team can act as an informational variable at a specific moment in the game, facilitating a sudden change in organisational function (i.e., offensive to defensive) and a decrease in players` interpersonal distances values at the moment where ball possession is lost.

3.4 Identifier

The identifier component corresponds to the capacity of the team, as an entity, to perceive and act upon information received through each player, for the shared affordances implied by the game model. The game model encompasses a set of guiding principles, captured as overarching intended performance outcomes, defined at different scales of complexity, and for different moments of the game [30].

In this way, the game model can frame the coherence and meaning for players and teams, substantiating a collective intentionality, influencing ways of thinking, perceiving, and acting in the performance environment. A game model is not a mental model (which may contain *information about affordances* [31]), but is highly dependent on shared *information for affordances* [31] that sustains emergent interactions of team members with a performance environment. This approach emphasises the importance of firmly establishing a "local to global" direction of synergy formation to harness in collective system performance [32]. Thus, the identifier component in the shared team control processes, distributed among all players, perceives the difference between indicative set point values and the actual values of an information variable that emerges during performance interactions (e.g., a team starts with clear performance intentions – shared intentions to seek affordances – to maintain ball possession to unbalance the opposition, seeking to circulate the ball to find, create and exploit gaps and open spaces in the opposition defensive structure).

3.5 Adapter

Like the identifier, the functioning of the adapter is predicated on self-organising tendencies in the team. The self-organising system adapter continuously receives information from the players, depending on the identifier of the team, promoting the search of a field of intended adaptive responses. The adapter initiates an appropriate team response to an *opportunity for (inter)action* emerging in an affordance field from a system perturbation highlighted by information from a regulated variable. This information source enhances the capacity of the team to perceive and act on available opportunities for action that can be utilised in performance. Moments of disturbance and perturbations are opportunities for interaction in which the team must act in order, for example, to reduce or increase the distance between sectors, thereby making the team more or less compact in a certain area of the field, depending on context. In this case, information on inter-sectoral space (weak area of the team that can be exploited by an opponent) can be perceived individually, or collectively (as intended) for the team to act on, based on this opportunity for interaction (to compact space or open up the field for an attack).

In order to provide appropriate responses, there is a need for shared affordances by the team [33], sustained by framed intentions, common goals and cooperative tendencies to achieve team success. These shared intentions enable the creation of specific information by acting in performance [34] that promotes skilled intentionality or effective coordination according to performance objectives. The ability to perceive information for affordances, and share the latter, is a performance tendency that emerges during practice,establishing skilled intentionality to enhance collective self-regulatory homeostatic tendencies.

3.6 Regulated Variable

A regulated variable is a collective system property needed to maintain system functionality, adjusted to the demands of ‘competitive survival’ in a sporting sense. Examples of a regulated variable include the interpersonal distance values between players in competition, players’ fatigue levels, co-positioning of players according to essential informational references in the performance landscape (e.g., ball, line markings or scoring area). These specified information variables can be manipulated in training to promote the collective, homeostatic regulation of interactions between players and teams. Specified *information for* affordances enables emergence of effective homeostatic regulatory processes during competitive performance.

First, it is important to emphasize that, regardless of specific regulated performance variables, their analysis will always have to be undertaken according to the functional organisation of a specific team. Because each sports team has its own game approach, there are no recipes to be generalized to other teams. Even in analysing performance of a team, measurement of a regulated variable can provide different insights at different moments. Hence, a regulated variable should not be understood as a closed and rigid entity within an open system. In this respect, the set point can help coaches to analyse performance of their own team, based on what they observe and what is desirable or adjustable according to specific performance contexts.

Therefore, collective homeostasis should not be conceptualised as a measure that oscillates between values or limits that indicate whether a performance behaviour is correct or not. Rather, collective homeostasis, through efficient communication and coordination, provides a platform for adapting effective performance responses.

4 Conclusions and Future Implications

In this paper, we discussed how the homeostatic regulation system could be used to explain the functioning of self-organisation tendencies in different sport performance contexts.

Homeostatic regulation allows team members to organise adaptive responses to performance dynamics in constant evolution. This may be facilitated by the training of sports teams to prepare them to attack and defend simultaneously, in order to maintain a balanced system state as long as possible in different game phases. Future research is needed to empirically elaborate on this homeostatic model by further analysing self-regulatory properties of sports teams during practice preparation and competitive performance.

Funding: This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Conflict of interest: The authors declare no conflicts of interest.

Availability of data and materials: Not applicable

Acknowledgements Not applicable

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