Milosavljević, V., Rajković, Ž., & Perišić, D. (2024). To the essential nature of the football game, part 1: approach to the game as a dynamic system, *SCIENCE International journal, 3*(3), 61-67.
doi: 10.35120/sciencej0303061m UDK: 796.33.06

TO THE ESSENTIAL NATURE OF THE FOOTBALL GAME, PART 1: APPROACH TO THE GAME AS A DYNAMIC SYSTEM

Voja Milosavljević[1], Željko Rajković[2], Dragan Perišić[1]*

[1] Football Academy, Belgrade, Serbia, e-mail: vojavojam@yahoo.com, dragan.perisic58@gmail.com
[2] Faculty of Sport and Physical Education, University of Belgrade, Serbia, e-mail: rajkoviczeljko@yahoo.com

Abstract: The aim of the article is to present the nature of the football game, which contemporaries approach as a dynamic system with a tendency to chaotic behavior, connecting it to several scientific disciplines. Relevant studies, which interactively connect football theory with several other disciplines, have pointed out important characteristics of the nature of the football game, which are not sufficiently visible through the prism of traditional science. The analysis of scientific articles highlights: dynamism, complexity, chaoticity, uncertainty, confrontation, reversibility, nonlinearity, flexibility, attractors, fractals, iterations, degrees of freedom. The team is seen as an open dynamic system that has the ability to self-organize and overcome itself. From the point of view of ecological psychology and dynamic systems, the athlete is a complex dynamic system whose subsystems are constantly interacting in order to make firm decisions . The player notices changes in the game scenario, existing constraints, predicts the possible course of the game and makes decisions from a wide range of possibilities that are sometimes unexpected. Speed of recognition of frequently repeated game states, appreciation of role in existing offensive and defensive matrices will enable more effective and efficient behavior at all levels of team organization in both phases. The ability to understand these deep processes of play is identified with sense of play.

Keywords: deterministic chaos, attractor, game configurations, matrix
Field: Social Sciences, and Humanities

1. INTRODUCTION

Our aspiration, to simplify the structure and to forecast the changes of complex phenomena, is the reason to explain the essence of the football game descriptively or on the basis of a linear view of causes and consequences (Čupić, 2009).

From the point of view of conquering the territory, football is a complex collective game in which, on a common surface, two opposing teams, directly and simultaneously, fight each other for possession of the ball, which they should throw into the goal on the opponent's field line and thus win a point that symbolizes success (Ferreira-Ruiz, García-Banderas, & Martín-Tamayo, 2022). The rules of the game regulate bans and thus guarantee equal opportunities for all teams and players. On the other hand, the rules give freedom to the players to find solutions in confrontation with the opponent on all three organizational and strategic-tactical levels: collective, group and individual (Sarthou, 2014). The essence of play should be sought in the intersection of limitations, freedom and conflict (Gréhaigne & Godbout, 2012).

2. MATERIALS AND METHODS

The paper used a combined research method that combines a historical approach to ideas, understandings and practical achievements in the past, with the method of theoretical analysis and the method of content analysis of scientific and professional literature that is not directly related to sports games. The causal method with logical inductive-deductive reasoning is presented using the author's practical experiences in the field of football.

In presenting his thesis in 1989, Grehaigne, (2018c) expressed his intention to contribute to the adoption of a systemic approach to the study of the essence of football. Reading the works he wrote over a period of 30 years was the impetus for writing this article. In order to understand the experiences so far and the possibilities of applying mathematics, social physics, the theory of dynamic systems and deterministic chaos, the paper explains terms that are less known and rarely used in the theory and practice of football.

*Corresponding author: vojavojam@yahoo.com

3. RESULTS

Areas of interest for competitive activities in football changed in parallel with the change of game dynamics and with the stages in the development of sports science. Then the interest was transferred to the examination of perceptual-cognitive and communicative-informational processes. In recent years, there has been a search for the nature of the football game, as a system in confrontation (Costa, Garganta, Greco, & Mesquita, 2009).

Garganta, (1997) highlights the importance of several personalities who have built concepts for the study of sports games. Teodorescu (2013), who in the 1970s headed the Department of Sports Games at the Institute of Physical Education in Bucharest, dealt with various theoretical and methodological problems and determined the postulates of the theory of sports games. The adoption of a common language that enables the transfer and understanding of the players' intentions was discussed by Teissie as early as 1954 (Garganta, 1997).

Theoretical discussions on strategy and tactics based on the cybernetic model of individual tactical action proposed by Friedrich Mahlo in the 1960s, gave rise to new models that study the process sequence: perception - cognition - motor – memory (König & Memmert, 2019).

Gréhaigne opposes the deductive mirroring of dynamic system theory to sports games and methodological reductionism that sees the system as a simple sum of its parts. Causal approach, inductive reasoning and heuristic methods based on experience, allow following the evolution of the game step by step (Gréhaigne, 2010).

Garganta concludes that the nature of football is dominated by values associated with strategic-tactical dimensions: simultaneous use of space, simultaneous form of actor participation, direct form of struggle over ownership of the ball, control of ownership and the path of the ball's movement, and the oppositional nature of the conflict (Garganta, 1997).

The high level of uncertainty, which arises due to the "pressure of space and time", is reduced if there is a quality process of information and a certain degree of freedom of the player to make a decision quickly (Serra-Olivares, Clemente, & González-Víllora, 2016).

This attitude is close to the theory of action (Argyris, & Schön, 1997), the theory of games and the theory of deterministic chaos. Game theory represents a mathematical theory and methodology that deals with quick decision-making about behavior during conflicts between opposing parties such as in the game of football.

Since 1975, the phrase deterministic chaos has been used in science as the name for a theory that has the task of investigating and determining how disorder arises from order and how order can be restored from such a state. It seems nonsensical that determinism and chaos are interconnected. Determinism is a teaching that believes that every event and human behavior follows precisely regulated laws and can be explained by previous causes (Berčić, 2004). In general the term linearity denotes changes that take place in a uniform sequence and are graphically represented by a line.

Kolaković and Vrankić, (2004) believe that the theory of deterministic chaos is a conceptual and methodological tool for understanding the surprisingly complex behavior of seemingly simple structures. Chaoticity is an important and inevitable feature observed in any dynamic system: from the behavior of a pendulum to the natural swarming of bees outside the hive. Chaos theory cannot be separated from the word dynamics, which refers to movement and transition from one state to another. Some theories and practice cannot explain the apparently unusual behavior of the system. However, chaos theory introduces the term attractor, which denotes a set of states through which a chaotic dynamic system moves in a phased, often multidimensional space (Oestreicher, 2007). Attractors can be classified according to different criteria, but for us the division according to regularity is sufficient. Regular attractors are simple sets shown as points or curves. Irregular attractors are complex paths of special types of oscillations, which have a different, irregular shape, chaotic dynamics and are called fractals (Ivanović, 2009). The repetition of a procedure in which the result of the previous procedure is the starting point for the next repetition is called an iteration. In pedagogy, iteration is used to describe a teaching process in which a student repeats the performance of a task until he acquires knowledge or masters a skill (Gojkov, 2007). The number of repetitions tends to infinity, so the following reduced or enlarged versions of the fractal can be endlessly sequenced.

Kuzmanović et al. (2013) believes that if a system has many degrees of freedom, then random movements can occur that not belong to chaotic behavior. Gojkov (2008) takes the position that there is no true science of deterministic chaos, but that there are different social scientific and metatheoretical paradigms that can be applied in social practice with varying degrees of reliability and validity.

The scenario method is used to predict the sequence of changes in non-linear events with a focus

on the causes and the decision-making process. The probability that the scenario will come true increases when possibilities and limitations are taken into account. Depending on the set of variables and conditions that make up the functional unit, taking into account the goal threat, soccer game scenarios can be critical or non-critical (Martins, Mesquita, Mendes, Santos, & Afonso, 2022).

4. DISCUSSION

The game always tends to take the most likely configuration that has many authentic features that temporarily do not change (Gréhaigne, 2007). Each part of the configuration has its own will and a certain degree of freedom to choose ways to achieve its goal. However, the degree of autonomy is limited and conditioned by the needs of interconnected and dependent parts of the organization of the game, which consists of: teams in conflict, team, groups of players, duel-game and individuals (Gréhaigne, Marle, & Caty, 2015).

The team behaves as an open dynamic system with a large degree of freedom, so a large number of parameters are needed to reveal the core of the game (Gréhaigne & Dietsch, 2015).

The more complex the system is, the more open it is to the input of information from the environment, and thus the degree of freedom that is the cause of spontaneous changes in the system increases.

From the approach of ecological dynamics (Araújo, Davids, & Hristovski, 2006), football is a superorganism in which there is a continuous exchange of information that is the basis of spatial-temporal interaction at all levels of organization (Duarte, Araújo, Correia, & Davids,2012; Travassos, Gonçalves, Marcelino, Monteiro, & Sampaio,2014). The organizational parts of the game appear as a whole as a collective of dynamic interactions that is self-organizing from within and possesses a self-similar nature that is a fundamental feature of fractals. The parts of the fractal are (according to some characteristic) "similar" to the whole (Ivanović, 2009). Sometimes the notion of self-organization is understood as an emergent phenomenon, which means that the system spontaneously moves to a higher level of complexity through self-surpassing.

In order to achieve this type of continuity and structural integrity, the system should be as flexible and adaptable as possible. It seems counterintuitive that the greater the confusion, the more stable the system. By reaching a critical level of fluctuation (movements or repetitive processes) and perturbation (disruption of proper movement), the system jumps into a new stable state. Then, the degree of entropy, as a measure of the system's tendency to spontaneously move into a state of greater disorder, begins to rise again. As soon as the balance between the two teams is established, player circulation becomes more important than ball circulation (Gréhaigne, Zerai, & Caty,2009). The established order among the attackers is a favorable condition for the opponent to "read the game" and take possession of the ball, and too much disorder increases the risk of mistakes (Gréhaigne, 2010).

From the point of view of ecological psychology and dynamic systems, the athlete is a complex dynamic system whose subsystems are constantly interacting in order to make firm decisions and perform movement patterns during the game (Travassos, Araújo, Vilar & McGarry, 2011).; Serra-Olivares et al., 2016).

Players think and make decisions that can change the course of game development, which is not always in accordance with the needs of a hierarchically higher entity that does not have the ability to control behavior.

Decision making is the player's ability to make the most effective choice from different game scenarios (Silva, Ramirez-Campillo,Sarmento, Afonso, & Clemente, 2021). Exceptional players make seemingly paradoxical decisions because they see what average people don't and combine things that are incompatible for other people.

Tactical behavior in soccer is assessed by tracking the positioning and movement of players on the field and translates into patterns of cooperation between players and teams. By monitoring the oscillations between the centers of gravity of the teams, it is possible to better understand the balance between the teams on the field, the variations during the game and the level of coupling between the teams (Travassos et al., 2014). The center of gravity of the team is the space around the ball in the shape of a circle, with a radius of 9.15 m (Costa at al., 2009). Remote and directly involved players behave according to the phase of the game: they cause instability in the defense with attacking movements, and they neutralize the danger of a goal with defensive activities.

The self-organization characteristic of the game manifests itself in oscillations that disrupt the stationary state, periodically return to the stationary state, or develop events that tend to restore such a state (Gréhaigne, & Godbout, 2012). In real game conditions energy is spent on movement and overcoming the opponent's resistance. Bringing additional energy to the game (often related to motivational actions of

the players, related to personal volitional characteristics or the dynamics of communication transactions in a team) would encourage forced oscillations, which in a burst of energy can become progressive: to cause a breakdown of the opponent's resistance, or the cessation of oscillation due to a complete loss of energy. In that case, either the result changes, or the rhythm and tempo of the game changes.

Prototypical configurations are temporary stable states of the game that are most often repeated in certain time intervals, so they are considered periodic phenomena (Gréhaigne, & Godbout, 2014). Configurations are grouped according to similar properties, geometric shape and time relations (Grehaigne, 2007) and allow the structure of the game to be revealed through invariants. Based on the philosophical opinion about the unity of opposites, the invariant explains the immutability of the observed object during transformations. On the other hand, variations mean essential changes of the object (Leung, 2023).

The Effective Game Space (EGS) is an easy-to-use tool for extracting reliable game data (Grehaigne & Godbout, 2014). The surface of this space is bounded by lines whose vertices are determined by the players' positions in the game area at a given moment. By monitoring the following criteria over time, the evolution of the game can be detected (Gréhaigne & Dietsch, 2015): 1) position on the field and EGS area; 2) position and trajectory of the ball; 3) positions and dynamics of the offensive and defensive playing area; 4)defense matrices and 5) compression/extension.

It is possible to define an offensive (EOS) and a defensive (EDS) effective space that intertwine and provide details of power changes during the match (Gréhaigne at al., 2015). The position of the first striker (the player in possession of the ball) can be behind, forward, in the middle, or on the side of the EOS. EDS appears in the form of an obstacle or a race for the ball. The occupied area of play (OAP) is a surface consisting of a series of EGS occupied by attackers and defenders during an attack.

Depending on whether the EGS takes place on the defensive, maneuvering or attacking side of the field and on which line (front, middle or back) within the EGS the ball is won, a corresponding initial action occurs, the logic of which is found in all subsequent actions (Gréhaigne et al., 2015). Mouchet (2014) uses the term "mother phases", for the initial scenes of attacks from which future forms of attacks arise.

These stages of the game arise at the point where the battle for the ball return was strongest. If the players do not master the large amount of information that appears in that phase in a short period of time, there will certainly be an imbalance in the game and mistakes by attackers or defenders that have further consequences (Duprat, 2019).

Typical ways of ball circulation within the EGS are (Gréhaigne et al., 2015): 1)exchanging the ball on the periphery. 2) guiding the ball on the periphery. 3)long ball through the EGS. 4) exchanging passes through the EGS. 5) guiding the ball within the space of the EGS.

If the attacking team loses possession of the ball behind the EGS (the side closer to their goal), the danger of a goal is obvious. On the other hand, if the ball is lost in front of the EGS forward line, the team moves into the defense phase with more players placed in front of the ball (Duprat, 2019).

By combining the different possibilities of interaction between teams in attack and teams in defense, which are arranged in three different forms: in width, in depth or equally in width and depth, Gréhaigne (2010) presented a theoretical matrix in 1989. which consists of nine different instances of game configurations.

The nine displayed matrices are a set of functionally and logically connected lines that simplify the complex nature of the football game.

Defensive and offensive matrices are simple constructs that can be adapted to the opponent's changes to stop any form of his attack - in the defense phase, or to choose an appropriate way to deceive the opponent's defensive order - in the attack phase (Gréhaigne & Godbout, 2014).

The defense matrix boils down to two patterns: defense in the form of an obstacle or defense in pursuit. Obstacle defense occurs if players of the defending team are placed between the ball and their own goal. In such a situation, attackers organize a slower, positional attack (Gréhaigne, 2010). A more dynamic variant of this matrix is organized by a stepped order of players covering each other while simultaneously marking the opponent, moving axially in the space in front of the goal and in front of the ball (Gréhaigne, 2018b; Duprat, 2019). The pursuit defense most often appears on the counter attack when the attacker with the ball is in front of the EGS with the opposing defensive players chasing after him. It requires the first defender (the player who puts pressure on the ball) to maneuver to slow down the attack, which would give teammates more time to position themselves between the ball and the goal (Gréhaigne, 2018c).

The term reversibility means that the game goes both ways and that a situation of double effect emerges (Gréhaigne, Godbout, & Bouthier, 1999). Before getting possession of the ball, the defending team plans how, with the help of teammates placed forward, they will organize the next (counter)attack. On the other hand, when the first attacker loses the ball, the other attackers (teammates who supported

the first attacker during the attacking phase) form the first line of defense in front of the ball.

The offensive matrix is created by choosing a way to bypass or penetrate the opponent's defensive system and can have the following characteristics (Gréhaigne, 2010; Gréhaigne et al., 2015): 1) the players are spread out wide. 2) the ball is on the periphery and in front of the EGS. 3) the ball is passed from the back line quickly shifts in front of the front line EGS.

The elasticity of the system is monitored through the movement of the ball and player in compression/expansion and through the static state of the player in concentration/dispersion, in EGS (Grehaigne, 2018c). The compression model appears in a game in a limited space near an attacked or defended goal with a high density of players and slow ball transfer. As soon as a long, or short and quick pass is made outside this field, the game model in expansion (stretching) is created. When the game in the attack zone stabilizes, a form of compression occurs again in front of the goal that is being attacked (Gréhaigne, 2018c).

Concentration and dispersion refer to the number of players who are active in a certain space. When playing in front of the goal, there is concentration (accumulation) in the central axis, and dispersion (scattering) on the periphery of the field. We can consider dispersed systems as a prototype of nonlinear dynamic systems (Gréhaigne, 2018a; Gréhaigne, 2018b).

If, at least in one direction, instead of compression, there is a stretching of the phase space, initially close points will be far away from each other over time, which results in the fundamental indeterminacy of their position and the appearance of chaos (Ivanović, 2009). Variations in the distance between the center of gravity of the players on both teams and among the stretch indices provide accurate information about how the offensive and defensive teams expand and contract relative to each other during the game. This makes it possible to understand the occurrence of scoring opportunities (Duarte et al., 2012; Travassos et al., 2014).

5. CONCLUSIONS

The purpose of this article is to present a discussion of dynamical systems theory and its application to the study of the nature of the soccer game. The text explains concepts that appear in works from the field of sports games, but are used to a greater extent in mathematics, general and social physics.

A football game is conceptualized as a dynamic system in which human behavior can be predicted by monitoring the flow of information and ideas.

The organizational segments of the game have their degrees of freedom to decide which action they will take to continue the game in order to achieve their goal, so the football match is viewed as an open, complex, dynamic, non-linear system that often behaves chaotically. It is a paradoxical fact that maintaining the integrity of the game requires flexibility, instability and change. The greater the perturbations of the game, the more stable the game becomes and moves to a higher order of complexity. In fact, modeling football processes by discovering prototypical configurations - recurring situations, setting up a theoretical matrix of the game is essential for meaningful interpretation and prediction of the future behavior of the structural parts of the game. Despite the research done, our understanding of the game is still very limited.

In the end, the question arises, should we expose a phenomenon whose uncertainty brings a lot of excitement?

REFERENCES

Araújo, D., Davids, K., & Hristovski, R. (2006). The ecological dynamics of decision making in sport. Psychology of Sport and Exercise, 7(6), 653–676. https://doi.org/10.1016/j.psychsport.2006.07.002

Argyris, Ch., & Schön, D. A. (1997). Organizational learning: A theory of action perspective. Reis, 77/78, 345–348. https://doi.org/10.2307/40183951

Berčić, B. (2004). Determinizam i sloboda volje [Determinism and free will]. Godišnjak za filozofiju. 1-66. https://www.academia.edu/76898693/Determinizam_i_sloboda_volje

Costa, I. T., Garganta, J., Greco, P. J., & Mesquita, I. (2009). Princípios táticos do jogo de futebol: conceitos e aplicação [Tactical principles of Soccer Play: Tips and Application]. Motriz, 15(3), 657-668.
https://www.researchgate.net/publication/283529457_Princ%27ipios_Taticos_do_Jogo_de_Futebol_conceitos_e_aplicacao_Os_Princ%27ipios_Taticos

Čupić, D. Ž. (2009). Nelinearna dinamika u primenjenim fizičko-hemijskim procesima [Nonlinear dynamics in applied physical-chemical processes]. Hem Ind, 63(5a), 445-454. DOI: 10.2298/HEMIND0905445C

Duprat, E. (2019). L'opposition au coeur de l'analyse des sports collectifs [The opposition at the heart of the analysis of team sports]. eJRIEPS, 44, 26-50. https://doi.org/10.4000/ejrieps.397

Duarte, R., Araújo, D., Correia, V., & Davids, K. (2012). Sports teams as superorganisms: implications of sociobiological models of behaviour for research and practice in team sports performance analysis. Sports Med. 42(8), 633–642. doi:

10.2165/11632450-000000000-00000
Ferreira-Ruiz, Á., García-Banderas, F., & Martín-Tamayo, I. (2022). Systematic review: Technical-tactical behaviour in small-sided games in men's football. Apunts Educación Física y Deportes, 148, 42-61. https://doi.org/10.5672/apunts.2014-0983.es.(2022/2).148.06
Garganta J. M. da Silva (1997). Modelação táctica do jogo de Futebol, Estudo da organização da fase ofensiva em equipas de alto rendimento [Tactical modeling of soccer games, study of the organization of the offensive phase in high-performance teams], (dissertação no ramo de ciências do desporto, Universidade do Porto, Faculdade de Ciências do Desporto e de Educação Física). http://hdl.handle.net/10216/10267
Gojkov, G. (2007). Kvalitativna istraživačka paradigma u pedagogiji - prilozi kvalitativnim istraživanjima u pedagogiji [Qualitative research paradigm in pedagogy - contributions to qualitative research in pedagogy]. Visoka škola strukovnih studija za obrazovanje vaspitača.
Gojkov, G. (2008). Metodološki problemi istraživanja darovitosti [Methodological problems of giftedness research]. Visoka škola strukovnih studija za obrazovanje vaspitača "Mihailo Pavlov".
Gréhaigne, J. F., & Godbout, P. (2012). À propos de la dynamique du jeu… en football et autres sports collectifs [About the dynamics of the game… in football and other team sports]. eJRIEPS, 26 130-156. https://doi.org/10.4000/ejrieps.3380
Gréhaigne, J. F. & Godbout, P. (2014). Dynamic systems theory and team sport coaching. Quest. 66(1), 96–116. https://doi.org/10.1080/00336297.2013.814577
Gréhaigne, J. F. (2010). Des outils et des concepts pour modéliser les aspects tactiques en sports collectifs [Tools and concepts for modeling tactical aspects in team sports],37-64. Available on January 4, 2024, at https://dokumen.tips/documents/des-outils-et-des-concepts-pour-modeliser-les-aspects-tactiques-en-sports-collectifs.html?page=1
Gréhaigne, J. F., Godbout, P., & Bouthier, D. (1999). The foundations of tactics and strategy in team sports. Journal of Teaching in Physical Education, 18(2), 159–174. https://doi.org/10.1123/jtpe.18.2.159
Gréhaigne, J. F. & Dietsch, G. (2015). L'opposition et ses concepts associés en sports collectifs [Opposition and its associated concepts in team sports]. eJRIEPS, Hors Série N° 1, 92-108. https://doi.org/10.4000/ejrieps.1308
Gréhaigne, J. F. (Ed.). (2007). Configurations du jeu, débat d'idées et apprentissage des sports collectifs [Game configurations, debate of ideas and learning of team sports]. Presses de l'Université de Franche-Comté.
Gréhaigne. J. F. (2018a). Le temps, le mouvement et la compréhension de l'organisation du jeu [Time, movement and understanding the organization of the game]. eJRIEPS, Hors-série N° 2, 32-42. https://doi.org/10.4000/ejrieps.506
Gréhaigne. J. F. (2018b). Le jeu en mouvement : avance / retard - barrage / poursuite - pénétrer / contourner [The game in motion: advance / delay - barrage / pursuit - penetrate / bypass]. eJRIEPS, Hors-série N° 2, 43-52. https://doi.org/10.4000/ejrieps.507
Gréhaigne. J. F. (2018c). En préambule [In preamble] Gréhaigne. J.F. (ed.) eJRIEPS, Hors-série N° 2, 2. https://doi.org/10.4000/ejrieps.501
Gréhaigne, J. F., Marle, P. & Caty, D. (2015). L'apport de la notion de configuration du jeu pour analyser les rapports d'opposition [The contribution of the notion of game configuration to analyze opposition relationships]. eJRIEPS, Hors Série N° 1, 13-53. https://doi.org/10.4000/ejrieps.1277
Gréhaigne. J. F., Zerai, Z., & Caty, D. (2009). Prototypic configurations of play in handball in physical education: A strategy to promote student understanding in team sports. In T. F. Hopper, J. Butler, & B. Storey (Eds.), TGFU. Simply good pedagogy: Understanding a Complex Challenge (pp. 53–64). Physical and Health Education Canada.
Ivanović, Z. A. (2009). Pregled savremenih metoda koje se koriste u analizi vremenskih serija nelinearnih dinamičkih sistema [Overview of modern methods used in the analysis of time series of nonlinear dynamic systems]. Hem. Ind. 63(5a), 467- 475. doi: 10.2298/HEMIND0905467I
König, S. und Memmert, D. (2019). Taktik und taktiktraining im sport [Tactics and tactics training in sport]. In: Güllich, A., Krüger, M. (eds) Bewegung, Training, Leistung und Gesundheit (1-17). Springer. https://doi.org/10.1007/978-3-662-53386-4_52-1
Kolaković, M., & Vrankić, I. (2004). Teorija kaosa [Chaos theory]. Zbornik Ekonomskog fakulteta u Zagrebu 2(1), 85-96. https://hrcak.srce.hr/file/41436
Kuzmanović, D., Vasović, N., Kostić, S., Simić, S., Franović, I., Grozdanović, I., Todorović-Vasović, K., & Ranković-Plazinić, B. (2013). Uvod u teoriju haosa [Introduction to Chaos Theory]. Univerzitet u Beogradu, Saobraćajni fakultet, Rudarsko-geološki fakultet.
Leung, A. (2023). A pedagogical reflection on the interplay between variation and invariant: Variational thinking. Asian Journal for Mathematics Education, 2(3),261-273. https://doi.org/10.1177/27527263231203056
Martins, J.B., Mesquita, I., Mendes, A., Santos, L., & Afonso, J. (2022). Current understanding of critical game scenarios in team sports: Systematic review. Hum Mov., 23(2), 1–11. https://doi.org/10.5114/hm.2022.109068
Mouchet A., (2014). Intelligence tactique en sports collectifs [Tactical intelligence in team sports]. In J. F. Gréhaigne (Ed.), L'intelligence tactique : des perceptions aux décisions tactiques en sports collectifs (55-71). Presses universitaires de Franche-Comté. https://doi.org/10.4000/books.pufc.10513
Oestreicher, C. (2007) A history of chaos theory, Dialogues in Clinical Neuroscience, 9(3), 279-289. https://doi.org/10.31887/DCNS.2007.9.3/coestreicher
https://volley4all.files.wordpress.com/2015/10/039_045-056_es.pdf
Sarthou, J.J., (2014). Développement de l'intelligence tactique et entraînement : un exemple au rugby [Development of tactical intelligence and training: an example in rugby]. J. F. Gréhaigne (ed.) L'intelligence tactique. (155-179). Presses universitaires de Franche-Comté.
Serra-Olivares, J., Clemente, F. M., & González-Víllora, S. (2016). Tactical expertise assessment in youth football using representative tasks. SpringerPlus, 5 (1), 1-9. https://doi.org/10.1186/s40064-016-2955-1
Silva, A. F., Ramirez-Campillo, R., Sarmento, H., Afonso, J. & Clemente, F. M. (2021). Effects of training programs on decision-making in youth team sports players: A systematic review and meta-analysis. Front. Psychol. 12, 1-15. https://doi.org/10.3389/fpsyg.2021.663867
Teodorescu, L. (2013). Principes pour l'étude de la tactique commune aux jeux sportifs collectifs et leur corrélation avec la préparation tactique des équipes et des joueurs [Principles for the study of tactics common to team sports games

and their correlation with the tactical preparation of teams and players]. eJRIEPS, 28, 99-117. https://doi.org/10.4000/ejrieps.2934

Travassos, B., Araújo, D., Vilar, L., & McGarry, T. (2011). Interpersonal coordination and ball dynamics in futsal (Indoor football). Human Movement Science, 30(6), 1245–1259.
https://doi.org/10.1016/j.humov.2011.04.003

Travassos, B., Gonçalves, B., Marcelino, R., Monteiro, R., & Sampaio, J. (2014). How perceiving additional targets modifies teams' tactical behavior during football small sided games, Human Movement Science 38, 241–250. https://doi.org/10.1016/j.humov.2014.10.005