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J Med Sci Tennis 2009; 14(2):20-25

“Tennis Coaching in the Era of Dynamic Systems”

The purpose of this article is to emphasise the importance of considering and studying tennis learning, coaching and training programs as dynamic complex systems that will help to develop a scientific paradigm of tennis alternative to the actual existing one. Tennis can be considered as an open, interdependent, dynamic, nonlinear, complex and multi-causal system. In order to try to fully understand tennis and tennis coaching it is important to use a systemic thinking approach. This approach takes into consideration the interaction of all relevant variables for the efficient functioning of the system.

Keywords: Tennis, coaching, dynamic systems, chaos theory

Introduction

Tennis coaching and training has traditionally been dominated by a mechanical concept of the player and the game (i.e. the consideration of the tennis player as a sum of different parts: mind and body; and the notion of the game as composed of different areas: technique, tactics, conditioning, psychology, etc.).¹ This ideological stream, known as “mechanicism”, imposed a fragmented and mechanical approach to the perception of the environment, and was originated during the industrial revolution in the 19th Century by emphasising the notion of progress and technological development.

This paradigm coupled with the traditional scientific method, which basically assumes that the understanding of the parts of a given system would provide the understanding of the whole, and is also known as “reductionism”. As such, this linear reductionist approach requires that the researcher isolates a variable or variables within the system under study for data collection at a specific time.

Sport sciences applied to tennis have followed the use of a reductionist philosophy (either deductive or inductive) which has been the predominant paradigm throughout the fields of science for centuries. This approach is a microscopic and not a macroscopic one since it investigates isolated parts of a system. It has also been called a linear (as opposed to non-linear), isolated (as opposed to integrated) and a reductionist (as opposed to holistic) approach.

Although the deductive or inductive approaches have contributed to our understanding of the game, the results

using these classical frameworks and methodologies have shown that it is difficult to understand complex sport behaviour. In fact, some research in sport science, such as the relationship between arousal and athletic performance has evolved from predicting linear relationships to considering curvilinear ones and to looking at multi-dimensional and nonlinear relationships.²

Modern approaches to tennis training and coaching have introduced the concepts of ecologic, holistic, total and global systems that generally understand both the game and the player as a whole.³ However, the practical application of these principles is far to be universally accepted and applied since the vast majority of tennis training and coaching programs are planned according to the traditional methods.

More macroscopic approaches for studying the complex, nonlinear system of sport behaviour, namely chaos theory, can be a useful alternative since chaos based research may yield patterns of behaviour which may provide a more functional understanding of sport behaviour.⁴

The purpose of this article is draw a general overview of the implications that dynamic systems theory can have in tennis as well as to emphasise the importance of considering and studying the learning and training processes in tennis as dynamic complex systems that will help to develop a scientific paradigm of tennis that can be an alternative to the actual existing one. Besides, we will try to justify the utility of the concepts and tools of the dynamic systems theory to optimise tennis training and coaching.

Tennis as a complex dynamic system

Human beings can consider reality taking into account their perceptions of the relationships between the different parts that make it. When we consider that the different variables are independent, we are using an analytic approach. Conversely, a systemic approach is used when it is considered that the variables are interdependent.

A system is a group of elements that are perceived as inter-related with a common goal. Systems can be mechanical (a ball machine), biological (the body of the tennis player), social (a tennis club) or ideological (the bylaws of a tennis academy or organisation). Besides, there are three fundamental aspects that can be applied to all systems: they can be rational, emotional or cultural.⁵ Human beings live in systems: family, friends, school, etc. Tennis is a system in itself: the club, the leagues, the teams, the training... the game. But tennis is also a complex system since neither the components nor the couplings are simple.

The dynamic systems approach tries to understand the behaviour of complex systems over time using the theory of complexity. A complex system is defined as a system whose properties are not fully explained by an understanding of its component parts. Complex systems consist of a large number of mutually interacting parts. The two most relevant features of complex systems are nonlinearity and universality. Nonlinear systems indicate that their behaviour is not simply the sum of its parts or their multiples. The chaos theory describes the behaviour of certain nonlinear dynamical systems that under certain conditions exhibit dynamics that appear to be random but they do not. Chaos is not about disorder, but about order in a seemingly chaotic system. In order to do this, chaos theory uses models to describe the behaviour of complex systems. Models are possible because all complex or chaotic systems have three defining characteristics; *deterministic* (e.g. simple laws determine their behaviour), *orderly* (e.g. patterns can be determined), and *sensitive to initial conditions* (e.g. minor initial changes can have considerable final consequences). From a systemic approach, tennis and tennis coaching can be considered as a socio-cultural complex system that has the following characteristics: *Contextuality*: They are open systems that can only be understood in relationship with their contexts. They do not exist in isolation. They have the capability of self-organisation and can create order from chaos. Each system is surrounded by another one and receives mutual influences. They are interrelated, hence their complexity. *Intentionality*: These systems have goals that respond to the reasons why they exist. *Continuity and dynamism*: Tennis coaching is not something that happens just once upon a time, it should be continuously reproduced. *Multidimensionality and multi-causality*: The assumption of the more training the better does not apply, since there are multiple dimensions that influence the system. *Contra-intuition*: even though tennis training is

directed to cause some effects, it can generate the opposite consequences. It clear seems than the relationships and the effects are not so obvious.⁶

The fact that modern tennis training theory has emphasised the importance of integrating the different components of tennis practice and play, as well as the need for a global or holistic view of the training and competition process has clearly shown the need for new approaches in the design of valid and effective training and competition plans. Several authors have already proposed this integration in different fields of tennis training.^{7,8,9,10,11,12}

Common conceptual challenges

The systemic approach is a mental model that implies a change in the perception of reality and that helps to better understand the reasons why things happen. Humans tend to understand reality as chaotic and complex because they use inappropriate concepts. That is why the systemic approach is also known as the “science of complexity”. This approach consists of perceiving complexity and trying to find an order and to simplify it as much as possible.

How can this be done? Coaches and tennis scientists can achieve this goal by designing training and competition models, structures and rules based on which decisions can be taken on the training and competition process. This perception of unpredictability and hazard derived from the chaotic nature of the game generating insecurity. Systemic thinking allows the creation and selection of systems and methodologies that help understanding and effectively dealing with these aspects of the game.

It is important to clarify that the systematic and multidisciplinary approaches to tennis coaching are not “*per se*” systemic concepts. These methodologies try to generate information from different perspectives, whereas the systemic approaches try to integrate different conclusions in a coherent whole that will allow for the interaction within the diversity and the contrasts and, finally, it will assist in the understanding of complexity. In some cases, the segmented analysis (analytic methodology) is perfectly valid and should be used.¹³ Likewise, coaches should understand that traditional and modern teaching methodologies are part of the same teaching continuum that evolves due to the interrelationships between two apparently dichotomic aspects.¹⁴

The systemic approach understands that due to the fact that contexts such as tennis and tennis coaching are complex, there are no unique, unilateral or simplistic solutions, but that simple methods should be used in simple situations and complex approaches in complex situations. Uncertainty can not be eliminated, but we can try to organise it. Then the global picture of the game can be observed and the relationships between its causes, effects, flows and circuits are better distinguished.

How can this approach be used in tennis coaching?

Coaches and tennis scientists should integrate the different aspects of the game, look for commonalities in the differences, and for the differences in those components that seem the same. This will help them develop models to explain and understand the game features. Some attempts made during the last years both in the applied and the research fields will be presented in the next sections.

Ecological and holistic approaches

The “ecological approach” to tennis coaching considers and emphasises the importance of large(r) interacting multifaceted systems that define a particular environment.¹⁵ Herein, “players” are understood to be both “shaped by” and “the shapers of” this environment, where learning is seen as a reciprocal relationship between players and their environment: the environment provides resources and opportunities for players, while players gain information from and act in the environment.

Ecological approaches provide insight into the dynamics of the game of tennis by examining the interacting constraints of player, environment, and game. It encourages empowerment, which increases players’ intrinsic motivation and self-confidence and improves their performance while decreasing problem behaviours.

“Ecological” approaches are similar to “holistic” approaches as both suggest that it is relatively more important to look at entire systems than to partition them and evaluate their component parts. They focus on the player’s interaction with the environment rather than on the deficits of the player. Ecological task coaching provides a framework that differs from the traditional coach-directed methods. It is designed to provide strategies for individualising instruction, to provide players with choices, to enhance decision making, to increase coach observation, and to foster discovery.

Holistic methods derive from the Greek word “holos”, which means whole. They consider their object of study (tennis) as an evolving dynamic whole, as opposed to the “atomistic” methods, which held a static or fragmentary view of the game. Holistic coaching is an approach that considers the importance of developing the player as a whole by using an individual, comprehensive, multifaceted and personal development program. The coach is seen as a facilitator that helps players to enlist all aspects of themselves in an integrated way to achieve their best possible performance. In keeping with these models, there is no better way to execute a particular motor skill; rather, movement form and outcomes are determined by goals, context, and individual constraints that continually change.

Ecological task analysis as a coaching framework derived from the ecological approach in the area of adapted physical education.¹⁶ Like the above approaches, it is designed to provide strategies for individualising instruction, providing players with greater choice, to enhance decision-making,

to increase coach observation, and to foster discovery. In keeping with these types of models, it is agreed that there is no one best way to execute a particular motor skill; rather, movement form and outcomes are determined by goals, context, and individual constraints that continually change. Ecological approaches stand in sharp contrast to the prescriptive, coach-directed, directive and categorical coaching approaches that punctuate most tennis lessons.¹⁷ These models provide an insight into the dynamics of movement behaviour through the examination of the interacting constraints of performer, environment, and task. They emphasise player empowerment and intrinsic motivation, help to foster self-confidence, improve player performance while decreasing problem behaviours, and challenge decision-making capabilities.

Tennis training model design

According to the dynamic systems approach, tennis can be defined as a game sport since two parties (teams or players) try to achieve their goals and avoid that the opponent achieves his one.¹⁸ Tennis is, then, an interaction process.

Tennis performance can be better understood as the emergent result of this interaction process instead of the display of skills and abilities of the players. This interaction process is dynamic due to the nature of tennis. The process changes throughout the match as the players are always searching for a successful behaviour based on their strategy according to the score or the actions of the opponent.¹⁹

As aforementioned, systemic thinking is borne out as a reaction against reductionist and mechanistic theories that have emphasised the concept of tennis, the tennis player and the tennis training as pure mechanisms with interchangeability (one aspect or piece can be changed by another and the system-player will keep working), transferability (the pieces can be used in other mechanisms-players), and independence (the parts can work without depending on the others). Tennis training, as a socio-cultural system, is not a mechanism. It is not even an organism, it is an organisation.

When trying to elaborate training and competition models for tennis it is important to recognise the particular challenge the tennis coach and the sport scientists face due to the complexity of the game. There can be two or four players, but they play in an enormous variety of game situations, tactical intentions, court surfaces, tournament formats, playing conditions, ball types, variety of strokes, types of effects, psychological states, physical conditions, etc. The challenge in coaching tennis remains in the need for effective handling all these alternatives required by the demands of the changing situations.²⁰

The dynamic nature of tennis implies that the traditional coaching and performance analysis methods should be superseded in order to look for new approaches that will help to understand individuality, singularity and dyna-

mism of this interactive process.

From the dynamic system approach, all training and competition models created by coaches and tennis scientists designed to try to explain and understand the game should meet a series of requisites. *Applicability*: It should allow for the generation, application and distribution of the adequate training and competition loads depending on the demands of the game. *Knowledge*: It should provide information, knowledge and understanding of the game, its training and competition. *Values*: It should formulate and present a set of values that adjust to those of the coach, the player and the training team. These values will set the principles and limits of the ethics of the process. Values such as honesty, confidence, integrity, responsibility and care for the player as a human being will legitimate to the model. *Management*: It should establish principles or rules by which all the model will operate including responsibilities, roles, tasks, relationships, hierarchies, dependences and interactions among all constituents of the model. These models should have goals, characteristics and limitations that define them. Their quality will be defined by their form, functionality, efficacy, efficiency, internal logic, coherence and balance between ends and means.²¹

Tennis research and dynamic analysis, studies, applications and future directions

There have been numerous scientific advances sport sciences applied to tennis using the traditional approach. In this section we will try to present some of the most relevant studies. It is important to note the growing body

of research in fields such as medicine, conditioning, biomechanics and psychology, to name a few, that have helped enormously the progress of tennis coaching and training. However, conducted research following these principles seems to find difficulties to investigate and explain the rationale behind training systems and teaching methodologies applied to complex systems such as tennis performed by players who are living systems that interact with the environment in an integral fashion.^{1,3,4}

Dynamic systems, chaos and self-organization theories have been applied to tennis in some studies. Their main goal has been to try to provide an understanding of the complexity of our game.² This is sought by the definition, identification and measurement of the vast amount of variables both individual and contextual that influence tennis. The kinematics of the tennis forehands and the backhands have been studied as continuous hitting movements modeled from the perspective of dynamical systems with temporal input.²³ Results have suggested that these strokes have a hierarchical fractal structure, as expected, from the theory of dynamical systems with external temporal input.²² When examining the influence of a similar complex hitting action on performance with novice tennis players and when comparing two hitting conditions: alternative forehand and backhand strokes (complex) versus repetition of the same stroke (continuous), results revealed that players showed better performance under the complex when compared to the continuous hitting condition. Results suggested that when more than two different types of new movements have to be acquired, the combination of



movements that benefits from the stroke inertia would be more effective than repeating each stroke individually. Derived from the previous studies, the dynamical systems approach to the learning of a new action pattern tries to focus on the concept of order-order transitions between different modes of a coordinative structure. Disorder-order transitions precede this process since the movement space has to be established and gradually developed as a self-organizing information system for an adequate performance. A complex training condition has revealed to be more efficient by exploiting the trunk rotation inertia produced by the hitting action of the previous stroke. This suggests that a dynamical systems approach can describe complex human movement such as a forehand or a backhand tennis stroke, and also offer practical applications to motor learning in a practical training condition by effectively using the physical, task and environmental constraints.^{24,25} Self-organization theories have also been used to study the on-court movement of tennis players in match play situations. It was considered that players show continuous to-and-fro displacements about a reference position located at the centre of the baseline. This constitutes an informational linked system formed by two coupled oscillators.²⁶ Results showed two movement patterns: in-phase (players moving in the same direction) and anti-phase (moving in opposite directions). Movements towards or away the net showed the in-phase pattern being more stable than anti-phase, whereas lateral movements showed mainly the anti-phase pattern.

A discrete nonlinear model for the kinematics of ball-racquet contacts was developed to investigate the task of rhythmically bouncing a ball in the air. As predicted, that the racquet trajectory should be decelerating prior to ball contact to achieve a dynamically stable performance. Results showed that players use the stability properties of the task but when perturbations arise, they can adjust their racquet trajectory to correct errors and maintain a stable bouncing pattern.²⁷

Tennis as a dynamic interaction process between two coupled parties has also been studied by considering the movements in tennis as movements of two subsystems, the players that exchange strokes.¹⁹ The positional interaction between the two players has been suggested to be described by a relative phase that, considered together with the speed of the strokes, it indicates some aspects of the tactical interaction in tennis.

Future directions of research in tennis using the dynamic system approach suggest the development and test a model addressing the outcome of tennis matches that would consider the psychological laws that determine successful tennis performance and find out patterns that predict the overall behaviour of players.² It has also been proposed that a movement pattern of a tennis serve can be interpreted as one point in a multi-dimensional state-space of

all possible tennis-serve patterns.⁴

The tactical analysis using a dynamic systems approach can be described by mathematical models which will help the linkage of relative phase to tactical behaviour in the court by closely examination rallies of players at different levels.^{18,19} Other research fields such as competition structure, periodisation, social issues and player development could also be investigated using these theories.²⁰ From a tennis training perspective several authors have emphasised the importance of lifelong differential learning and peripheral self-organising patterns instead of drill training and technical models for efficient tennis stroke production and movement patterns.^{10,11} Differential learning (learning from differences) implies a combination of possible movement technique adaptations and compares the execution of movements with possible solutions to "errors". Players can learn from differences by using variety in training. Here, the information found in the transition between different movement patterns (e.g. the change between hit, touch, etc.) is crucial.

A determining factor for skill acquisition becomes the players' ability to extend their range of possible solutions during match play. The player will then have the possibility to select the movement techniques/patterns they will use whether it be consciously and/or unconsciously. Specific self-organising patterns can be learned by the player if technique adaptations are enforced during the skill acquisition and automating phase movement.²⁸

Conclusion

The basis of the modern approaches to tennis coaching discussed in this article is the belief that tennis training does not occur in isolation, but it rather takes place in a dynamic environment that is influenced by the different elements that determine tennis play. Coaches then need to use this approach to coaching by integrating their professional experience, the game-performance determining factors and all the knowledge derived from sport science research¹³. From a complex systems perspective the role of a coach is not only that of the guiding the player but he also has the option of changing the environment itself by having a good understanding of the goal function. Modern tennis training takes into account the importance of tennis as a whole, a holistic approach to coaching, and the principle of integration vs. isolation. Terms like "integrated, total or complex" tennis training are very close to each other are more common among coaches of all levels. These terms refer to a global vision of tennis training in which all components are integrated and are put into practice using a "complex" training approach. The concept of integrated training for tennis states that the traditional distinction between technique, tactics, conditioning, and mentality is more artificial than real. In practice, it is not only possible, but probable, that when working technique

there is simultaneous – albeit secondary, even subconscious – development of some decision-making, physical fitness and/or mental capacity. This interrelation between capacities is common to most highly directed, specific on-court work (i.e. regardless of primary goal). That is why a lesson should have a versatile character its goals should concern more than just tactics and technique.¹⁷

The key concept of tennis coaching from a systemic perspective is the development towards a new level of integration and differentiation. Mechanical-technical explanations are outdated, especially in complex, unstable systems such as the ones in which human beings take part, such as tennis. Tennis coaching should be regarded as process of collective learning designed to assist the player and its context. By doing this, it will imply an improvement and

balanced process that will lead to the total development of the player. The tennis coaching and training with all its complexity should be at the core of the whole process of change.

Coaches and the tennis scientists should be willing to create training models that will help to control, flow and value the different parameters that affect the existence and functioning of tennis training as a system. Further research is needed to validate these findings in the practical field and discover if there is a “hands on” application of these principles to tennis. Much is still to be done, however, it is hoped that the analysis of the dynamic complex systems theories will provide both a theoretical paradigm and a practical basis to develop a specific and efficient training and competition science for tennis.

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