Original Article (short paper)

Nonlinear Pedagogy and the implications for teaching and training in table tennis

Larissa Rafaela Galatti[1,2], João Cláudio Machado[3], Mairin Del Corto Motta[1,2], Milton Shoiti Misuta[1,4], Taisa Belli[1]

[1]Universidade Estadual de Campinas, UNICAMP, Interdisciplinary Research Group on Racket Sports, GRIPER, School of Applied Sciences, Limeira, SP, Brazil; [2]Universidade Estadual de Campinas, UNICAMP, Sport Pedagogy Laboratory, LEPE, School of Applied Sciences, Limeira, SP, Brazil; [3]Universidade Federal do Amazonas, UFAM, Human Performance Laboratory, LEDEHU, Faculty of Physical Education and Physiotherapy, Manaus, AM, Brazil; [4]Universidade Estadual de Campinas, UNICAMP, Laboratório de Biomecânica e Instrumentação, LABIN, School of Applied Sciences, Limeira, SP, Brazil

Abstract — Aim: It is to propose a game-based and player-centred approach to teaching table tennis using nonlinear pedagogy insights. **Methods:** This is an essay which offers a well-reasoned articulated nonlinear pedagogy perspective on coaching and teaching table tennis issues **Results:** It offers the description of a propose based on a player-centred and game-based approach for table tennis supported by nonlinear pedagogy, illustrating examples of how to apply nonlinear pedagogical principles to design representative learning tasks in order to adapt them to learners' skills level. **Conclusion:** A novel perspective for teaching and training table tennis is presented here and we intend that this proposal may help coaches to design an effective learning environment.

Keywords: racquet sports; sports pedagogy; training/learning methods; athlete-centred approach; game-centred approach

Introduction

Table tennis is a sport comprising a high structural complexity with a wide range of technical-tactical elements, which the players need to develop to solve the match problems[1]. To achieve higher levels in table tennis, the player needs to improve important game skills[2], such as ball skills (dealing with ball flights and rotation), technical, tactical skills[1,3-5], mental skills[6], as well as concentration, anticipation and adaptive skills[7]. Also, game-intelligence[8] and physiological aspects[4,9] are crucial to reaching high levels of excellence. However, traditional approaches for teaching and training in table tennis appear to be limited to developing this entire body of competencies in players[7,8].

Historically, the coaching process in sports has emphasized traditional sports pedagogy. Learning has been understood as a linear process supported by the use of analytical and decontextualized exercises, i.e. training exercises that intend to stimulate an 'ideal' movement pattern prescribed by a coach to solve a specific task without respect real game situations[10-12]. However, recently, nonlinear and complex pedagogical approaches have emerged in sports scenarios, supported by the dynamic and nonlinear nature of learning[10,13]. This approach understands players as complex neurobiological systems, with the capacity to perceive relevant information flows within the game context, to self-organize under the influence of specific constraints and to transition between states of stability and instability[14,15]. Thus, this theoretical model can provide a framework for the emergence of creative and adaptive behaviours[12,14,15]. Therefore, the learning process must simulate these dynamic and complex features of both the learning process and the internal dynamics of the game.

Here we focus on presenting Nonlinear Pedagogy (NLP) as a theoretical model that can support a player-centred and game-based approach for teaching and training in table tennis, which may offer a training scenario with all of the dynamics, the structural and functional complexity of this sport. NLP emerges as an important pedagogical approach with the potential to assist coaches in the design of a player-centred and game-based process[10,15,16]. NLP uses nonlinear dynamics insights and an understanding that the functional movement patterns' learning (i.e. capacity to solve game problems using different movement patterns) emerges through the interaction of individuals, environment and task constraints (i.e. boundaries that shape our behaviors and decisions)[10,12,17]. In this perspective, a coach must carefully manipulate key tasks constraints (instructions, ball size and weight, table size, etc.) to encourage players to explore and find movement patterns that allow them to achieve tasks goals[14,15,18]. Moreover, NLP supports the use of representative training tasks, which stimulate functional information-movement coupling, where task constraints represent the competitive environment[10,12,19].

In the last few years, initial investigations have focused study on the application of NLP and the use of a game-based approach in racket sports. Lee, Chow, Komar, Tan and Button[20] found that learners who participated in a learning process based on NLP improved the accuracy of their forehand stroke in tennis. Besides, players also present a greater variability of functional movement patterns and improve their capacity to adapt to the constant changes that occur in the games' dynamic context. In line with this, Zhang, Ward, Li, Sutherland and

Goodway[21] observed that table tennis players who participated in a game-based approach (i.e. Play Practice) showed a more effective improvement in their forehand (FH) attack and serving skills than players who participated in a traditional approach (i.e. skill-focused approach). These studies are the first steps to support the application of a player-centred and game-based approach for table tennis, which emphasizes the development of the tactical elements integrated with technical and motor skills learning.

This raises an important discussion about the teaching methods applied by the coach during sports initiation, since an early pleasant and diversified practice seems to contribute to the athlete's engagement throughout the later stages of his developmen process[22,23]. Based on the above statements, the aim of this study is to propose a game-based and player-centred approach for teaching and training table tennis that can help in providing players diversified tasks and experiences using NLP insights. Practical implications are shared on how representative training tasks based on a NLP approach can be delivered in table tennis learning.

Nonlinear Pedagogy as a pedagogical approach to design a player-centred and game-based teaching and training process

Considering Ecological Dynamics, NLP uses and applies the concepts of nonlinear dynamics in the coaching process in sports[10,24,25]. In the nonlinear pedagogical approach, players are understood as complex neurobiological systems composed of numerous components that are in constant interaction, moving between phases of stability and instability through self-organizing processes that are influenced and shaped by a large numbers of constraints in interaction (individual, environment, and task)[10,14,17].

The application of a nonlinear pedagogical approach is supported by a set of key pedagogical principles that assist coaches in creating an effective and representative learning environment (see Table 1). Atencio, Chow, Clara and Lee[26] and Chow, Davids, Button and Renshaw[10] highlighted that through the application of NLP, a coach should carefully **manipulate key constraints to design representative training tasks** in an attempt to ensure a **functional information-movement coupling** during the activity, and stimulate the emergence of a **variability of movement patterns**, which is important for stable patterns of movement acquisition[12]. Besides these principles, Chow[27] and Chow, Davids, Button and Renshaw[10] emphasize that coaches should carefully **plan the type of intervention** through instructions and feedbacks, facilitating the exploration of a similar real-game context by the players in order to discover movement patterns that allow them to achieve tasks goals, enhancing players' exploratory behavior. Therefore, the knowledge of the highlighted key pedagogical principles supports the design of an effective learning environment.

Table 1. Practical implication of Nonlinear Pedagogy principles for learning environment design[10,26].

Nonlinear Pedagogy Principles	Practical implications for learning environment design
Representativeness	Provide practical contexts that simulate competitive environment, respecting game dynamical context.
Functional information-movement coupling	Stimulate players to become attuned to key sources of information within game context, which regulate their actions and decisions.
Manipulation of constraints	Manipulate key tasks constraints in attempt to better adapt them to players' skill level and to training content.
Exploratory learning	Stimulate players to explore different game contexts in search of solutions to different game problems. Also, stimulate players to solve game problems in different ways (functional variability).
Attentional focus	Stimulate players' autonomy to explore different game contexts in search of different movement solutions, appropriate to their individual constraints. That is, coaches should avoid giving direct instructions that condition players' actions through predefined answers to game problems.

Understanding learning as an acquisition process of stable movement patterns that allow the achievement of specific performance goals (e.g. a stable FH drive attack at a half long service to put the ball out of the opponent's control) and that these behaviours emerge from the interaction of several constraints (individual, environment, and tasks), it is possible to realize how NLP will provide a design for a **player-centred approach**[10,18,27]. Through a set of pedagogical principles (Table 1), it is possible to design learning contexts that stimulate players to explore diverse movement solutions, assisting each one to find functional movement patterns that allow them to achieve tasks goals in their own way[10,14,24]. In other words, a nonlinear pedagogical approach enables individualized and creative learning, since the understanding of their own capacities for action provides players with the perception of specific actions' possibilities that allow them to reach performance goals and the high context variability allows the emergence of flexible movement patterns, permitting them to adapt to the constraints imposed by the game[13,18,24,27].

Moreover, a learning process supported by NLP requires a **coach's effective** participation. The coach should be understood as a facilitating agent who plays an important role in acquiring functional movement patterns since his extensive knowledge on table tennis, and on key pedagogical principles of NLP, will enable him to effectively manipulate key task constraints[10,14,27]. In table tennis, understanding that the perception of relevant sources of information regulates players' actions through the information-movement coupling, coaches must carefully

manipulate informational constraints to guide the players in the execution of movement patterns that allow them to solve game problems[10,24,27]. For example, coaches may question what players can do to avoid an opponent's preferred strokes during the match.

Thus, players need to explore, in learning environments, training tasks that represent performance context[10,14,19]. In this way, during practice, players will become attuned to the essential sources of information and that regulates their actions[10,27]. A key feature of NLP is the use of representative training tasks to facilitate the development of a self-organization process and information-movement coupling in a **game-based approach**, where tasks must simulate specific performance constraints[10,14,18,19]. Therefore, following the key principles of NLP, the training tasks should stimulate functional movement patterns of service, return, attack, counterattack, defence and block, by means of games/activities that simulate the high level of complexity of the match, and offer players a wide range of changes during these games/activities to improve their capacity to solve game problems.

In this perspective, the use of traditional teaching and training approaches based on a linear sports pedagogy, which uses decontextualized tasks and focuses on 'ideal' movement patterns prescribed by coaches too much, has been widely criticized in motor learning and sports science literature[11,20]. Therefore, in an attempt to escape from these traditional approaches to teaching table tennis, NLP can be understood as a functional and applicable pedagogical approach that supports a player-centred and game-based teaching and training process.

Nonlinear pedagogy and the designing process of tasks to enhance learning in table tennis

Generally, learning in table tennis occurs by a traditional sports pedagogy (e.g. McAfee[28]), which contradicts the nonlinear and complex nature of the game. If traditional tasks do not maintain key sources of information contained in the competitive environment (i.e. stimulates an information-movement decoupling through decontextualized training exercises), it is necessary to move towards representative tasks in coaching process[10,21,27]. According to Renshaw, Oldham and Bawden[12] and Chow, Davids, Hristovski, Araújo and Passos[29], it is crucial for coaches to understand that information and action act to constrain each other. Pinder, Davids, Renshaw and Araújo[19] sustain as a representative task those who seek to maintain within the context key sources of information that will regulate players' actions, allowing the establishment of functional information-movement couplings, where tasks constraints represent the competitive context (i.e. game-based activities). However, in an attempt to enhance learning and stimulate a functional coupling between information and movement, training tasks must be appropriate to players skills level and training content which the coach intends to emphasize. Therefore, we support that not every game activity will be a representative training task since it will depend on the player who is playing and the tactical problem that the coach wants to emphasize.

Moreover, the use of representative tasks in training sessions stimulates players to explore a diverse set of movement patterns, allowing them to find the one that is most appropriate for their individual constraints[10,12,27]. This environmental variability in training sessions cannot be neglected since it allows the emergence of co-adaptive behaviours through self-organizing processes[24]. In line with this, the ability to adapt to the dynamic and nonlinear changes that occur in the competitive environment appears as an important competency for a table tennis elite athlete[2,7]. Applying the principles and concepts of NLP may thus contribute in the design of the learning environment to enhance learning in this sport through a player-centred and game-based teaching and training process[12,14,24,29].

However, we also need to discuss the designing process of representative training tasks (game-based activities) which intend to promote effective learning. Based on Atencio, Chow, Clara and Lee[25] and Serra-Olivares and Garcia-Rubio[29] works, we highlight *Teaching Games for Understanding* (TGfU) pedagogical principles to help coaches to design representative training tasks in table tennis: *sampling*, *representation*, *exaggeration and tactical complexity*[26,30]. Even knowing that TGfU model was proposed based on a different pedagogical approach, we corroborate with the literature that the insights of nonlinear pedagogy can help coaches apply these principles effectively in the designing process of representative training tasks[25,29]. That is, we are not here proposing the use of TGfU, but only highlighting that these principles can support the design of representative training tasks.

The *sampling* principle states that during the learning process, players must experience a diversity of game-play with tactical elements in common[10,26,30]. When these tactical elements are well assimilated by the players, this learning can be transferred to another game that has a similar dynamics[26]. In table tennis, it is possible to plan sessions with practical tasks that emphasize specific skills (e.g. ball skills)[5] and that have common tactical elements (e.g. to plan the ball placement)[1] by means of a diversity of games activities (e.g. hit the target, numbered table, etc.). Thus, by correctly applying this pedagogical principle, coaches can design tasks that have similar dynamics in an attempt to facilitate the learning transfer between both games/tasks[10,26,30].

The second pedagogical principle highlighted is *representation*. Coaches must design/select training tasks that maintain key sources of information that will support players' actions, allowing a functional coupling between information and movement, besides simulating competitive environment demands[10,26,30]. Thus, it is important to reflect on the teaching proposals commonly used in table tennis, which stimulate task decomposition, providing a decoupling between the information and the action, in search of a predetermined movement pattern by coach[10,11,14]. In table tennis, it is very common to believe that there is an ideal movement pattern for specific game situations. However, from the application of a nonlinear pedagogical approach, a coach will enable the design of representative tasks that allow the development of players' game comprehension and tactical performance, in line with the individualised technical improvement[12,31,32].

The principle of *exaggeration* supports that a coach must have the capacity to emphasize a specific game's component (physical, technical or tactical) throughout the manipulation

of key task constraints[10,26,30]. As an example, when designing a task aimed at having the players deal with ball rotation/spin, the coach should manipulate key task constraints (instructions, ball size, table size, etc.) that emphasize technical skills (e.g. FH drive attack or footwork) or tactical skills (e.g. to put the ball out of the opponent control).

The last pedagogical principle highlighted is tactical complexity. This principle supports the need for the training task to be appropriate to the skill level or learning stage of the players[10,26,30]. For example, the coach can increase the net's size to decrease game dynamics[14], or the coach can manipulate the racket's size (increase the contact surface with the ball), the size and weight of the balls (use larger and softer balls), among other things, to facilitate the emergence of functional movement patterns[10,14].

Design of representative training tasks: An example of table tennis

According to the strategies for the design of representative training tasks suggested by Serra-Olivares and Garcia-Rubio[30], tactical problems should guide the process, since it can be understood as the set of essential task constraints that influence the contextual dynamics of the game. Thus, the design of representative tasks based on tactical problems will enable players to perceive relevant information for the development of specific functional behaviours that will allow them to solve game problems[24,30]. Therefore, tactical problems can be considered a key task constraint that will influence the dynamics of the game and the sources of information that will be provided by the players and for the players[30].

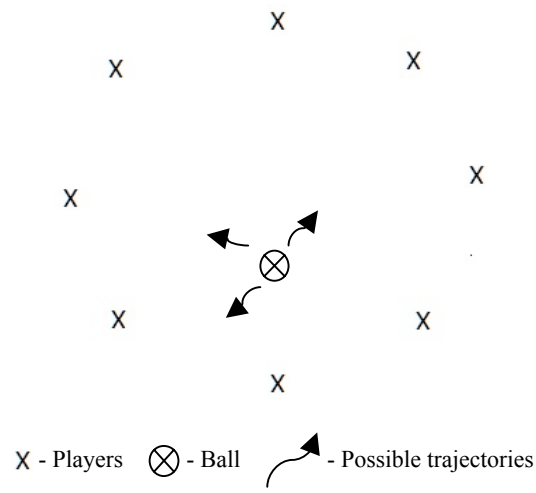
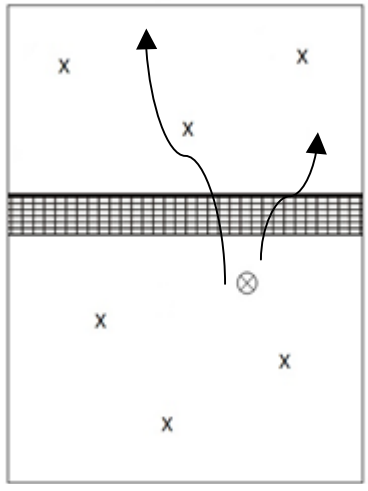
To better exemplify our proposal of teaching and training table tennis through a player-centred and game-based approach supported by a nonlinear pedagogy approach, we have selected the ball spin as a tactical problem to be emphasized in the representative training tasks (Table II). Munivrana, Petrinović and Kondrič[1] evidenced ball speed, ball placement and ball spin as basic tactical means for players to realize their own tactical ideas. Ball speed and ball spin, which is often used during the strokes to increase the accuracy of ball placement, are interrelated and restricted each other[33.] In line with this, although we emphasized ball spin, the ball speed and ball placement also appeared in an integrative perspective in practical examples. Ball spin is among the most effective means to keep the ball out of the opponent's control, or even use it as a weapon to cause the opponent to make mistakes[34-36]. Thus, dealing with ball spin, performing functional strokes with a spin component, reading and dealing with an opponent's ball spin, and being able to apply a diversity of ball spins according to tactical intentions during the match are relevant player competencies to be developed during teaching and training table tennis. We focused these technical/tactical competencies to design our examples of representative tasks.

The four main pedagogical principles of TGfU for designing representative training tasks must be considered in all training activities (*sampling*, *representation*, *exaggeration and tactical complexity*). We highlight those most evident in each example of a representative task. Finally, in order to check whether the task is appropriate for NLP assumptions, we designed three examples of representative training tasks for beginner players to relate movement patterns with key sources of information that are present within the game context, which might contribute to a functional information-movement coupling[10,14,24,27].

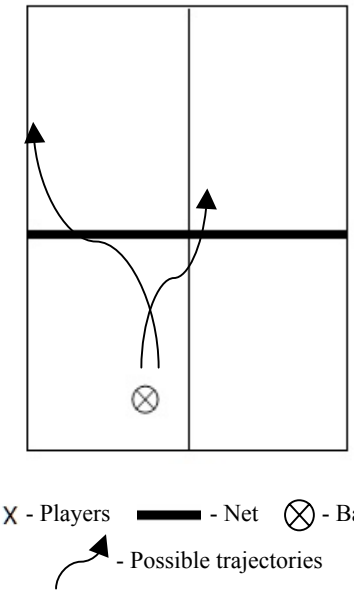
In table tennis, the ball has a small dimension (40 mm) and can reach about 150 r/s[33], and it is difficult for beginners to visualize what type of spin was played by the opponent to interact properly. Thus, the first task occurs with larger balls until reaching the table tennis ball to allow the learners' perception of the game complexity. Here the emphasis is about players learning how to deal with the various types of ball spins, from applying it to reading the ball spin and effectively putting the ball out of the opponent's reach (i.e., representativeness) in a wider setting (i.e., large-sized scenario) without the use of racket and net.

The second task is structured in the context of dealing with ball spin with the use of the racket in order to return the ball to the other side of the net in order to move the opposing team off the court. The scenario is still broader (court vs. table), but racket use and field delimitation, across the net, allow players to explore functional movements/strokes involving ball spin as well as to play a diversity of ball spins according to tactical ideas during the game. Finally, the third task presents the real game scenario (the table) and the goal of playing a match using the ball spin to win the points. As players are beginners, some constraints can be manipulated by the coach to facilitate this game (e.g., to offer slower or even colored balls for learners to better understand the ball spin).

Table II. Design of representative training tasks focused on ball spin skills for beginner players of table tennis.

Emphasis	Task description	Constraints manipulated by coach
- Dealing with ball spin - Reading opponent's ball spin - Applying a diversity of ball spins according to tactical ideas during the game - Large-sized scenario, - Without racket, - Without ball-over-net	 X - Players ⊗ - Ball - Possible trajectories - Learners play by themselves. Thus, the opponents are any of the other players standing in the circle. The players are positioned in a circle shape, as evidenced on the illustration. - The aim of this game is to have one player throw the ball with a spin inside the circle area, and the opponents in the circle must let the ball bounce on the floor before catching it. - The player must focus on keeping the ball out of the control of the opponents to win the game (i.e. *representation* – information-action coupling).	- Offering different types of balls (e.g. Swiss ball, volleyball ball, tennis ball) in order for players to experience a diversity of game-play with tactical elements in common (i.e. *sampling*). In addition, bigger balls may decrease the *tactical complexity* of the task and facilitate the emergence of functional movement patterns (and vice-versa). - Increasing the amount of balls during the game increases the *tactical complexity* of the task. - Challenging the players to explore the different types of ball spin (e.g. backspin, sidespin, top spin), and challenging how they reflect about the application of each ball spin and its consequences during the game. - Asking the players which ball spin they are able to use to cause the opponent make mistakes, and emphasise a tactical skill. Alternately, the coach can ask the players to focus on how they are able to throw the ball with spin and emphasise a technical skill. (i.e. *exaggeration*)
- Dealing with ball spin - Reading and dealing with an opponent's ball spin - Performing functional strokes with a spin component - Applying a diversity of ball spins according to tactical ideas during the game - Ball placement - Large-sized scenario, - With racket, - With ball-over-net	 X - Players - Net ⊗ - Ball - Possible trajectories - 2 Teams of 3 or more players. One team for each side of the net. - The aim of this game is to play ball-over-net with ball rotation. The opponent players must let the ball bounce on the floor before returning the ball. - The player must focus on moving the opponents out of the field area to win the game.	- Offering different types of rackets (e.g. tennis, table tennis, etc.) and balls (e.g. soft/slower ball, tennis ball, table tennis ball) based on sampling and *tactical complexity* principles. - Challenging the players to recognise which ball spin may be played in specific places in the opponent's field (i.e. ball placement) to move the other team out of the field area (information-action coupling). - Delimiting a target zone within the field to be advantageous (i.e. players earn more points if they hit the ball in this zone and the opponent's team makes a mistake). - Challenging the players to explore different types of ball spin to put the ball in this target zone, and ask them: 'Why is this area advantageous?'; 'If this field mimicked a table in table tennis, why is this area a risk area?'

(To be continued)

Emphasis	Task description	Constraints manipulated by coach
- Performing functional strokes with a spin component - Reading and dealing with an opponent's ball spin - Applying a diversity of ball spins according to tactical ideas during the game - Ball placement - Full-sized scenario, - With racket, - With ball-over-net	 - This aim of this game is to simulate an official single match of table tennis and emphasise that the players play the ball with rotation. In line with this, if the players earn the point by means of a ball spin, they earn two points instead of one point.	- Offering soft/slower balls or increasing the net height during the game. These manipulations decrease the ball speed and facilitate the players dealing with an opponent's ball spin and make them perform functional strokes with a spin component. Painting part of a ball in table tennis to facilitate the players reading the opponent's ball spin. All of these interventions may decrease the *tactical complexity* of the task. - Challenging the players put the ball with spin out of an opponent's control or cause the opponent to make mistakes (information-action coupling). - Delimiting a target zone within the table to be advantageous (i.e. players earn more points if they hit the ball in this zone and opponent make a mistake). These target zones may be related to different spin on the balls. For example: delimiting a target zone on the side areas of the table to stimulate players to play with side spin in order to cause the opponent to make a mistake.

The games presented here are not a lesson in sequence, and the principles of TGfU are not hierarchical, as in traditional pedagogy, i.e. tasks that emphasize sampling do not necessarily need to precede an exaggeration principle, for example. The tasks' design is based on the players' needs and requirement to be constantly reviewed, since each training session the players learn and develop, and therefore, need more representative tasks appropriate to the 'new' intrinsic dynamics.

Conclusion

This study proposes a novel perspective for teaching and training table tennis based on NLP as the pedagogical approach, which may offer a framework in accordance with all of the dynamics, the structural and functional complexity of this sport. Our proposal focuses on the game, the player and mainly on the interrelation between one another from representative training tasks. It is from this interrelation that new demands emerge from the complex process that is the teaching-training pathway. Herein, we present a series of strategies to design representative learning tasks in table tennis and the important role of the coaches during this process. Finally, we share the practical implications of our proposal from the ball spin as an example. Future investigations may focus on evaluating the effect of NPL on teaching and training table tennis, opening a new research avenue in this field.

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Corresponding author

Larissa Galatti
Address: School of Applied Sciences, University of Campinas. Pedro Zaccaria Street, 1.300, Jardim Santa Luiza, Postal Code 13484-350, Limeira, Sao Paulo, Brazil.
Email: larissa.galatti@fca.unicamp.br

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