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Theories of skill acquisition: Implications for tennis coaching

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ABSTRACT

This article discusses different theories of skill learning, including ecological dynamics, and their implications for coaching and practice design. Concerns with current beliefs about skill acquisition and the associated traditional practice methods will be discussed. The major tenets of ecological dynamics will be presented, followed by some practice design recommendations for coaches. The goal of this paper is to introduce coaches to a more contemporary theoretical framework of skill acquisition that will drive the exploration of new practice methods to maximize skill development across all ages.

Key words: Skill acquisition, motor skill learning, practice design, practice activities.

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INTRODUCTION

Skill acquisition theory is extremely important for coaches due to its foundational role in the development of skilled performance. However, many coaches either do not acknowledge their beliefs about skill learning, or attach themselves to traditional, sometimes unsupported explanations. The link between beliefs about learning and coaching methods is undeniable, therefore, methods should be grounded in evidence-based theoretical explanations of skill acquisition. The evidence in question, must be driven by academic research findings, and move away from a purely experiential knowledge-based rationale, as often cited by coaches (Reid et al., 2012, Anderson et al., 2021). This does not mean that experiential knowledge is somehow inferior, quite the opposite. It is coaching experiences that often inform research designs which study the efficacy of particular coaching methods. The findings of these studies either support or reject these methods as effective practices, which in turn should inform coaching behaviors. Unfortunately, this is not always the case with many coaching behaviors remaining unchanged even though our understanding of skill acquisition has advanced.

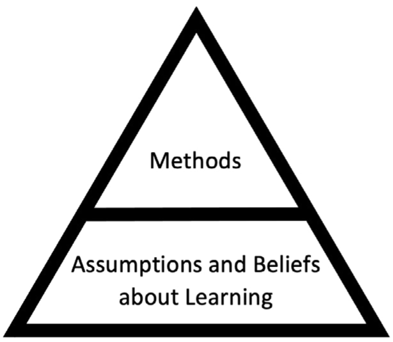

Figure 1. *Relationship between assumptions and beliefs about learning and chosen practice methods.*

Whether we articulate it or not, all coaching methods, practice activities and drills are driven by our underlying beliefs about skill learning (See Figure 1). All coaches believe that the drills chosen for practice "work", but, we must quantify what "work" means. In many instances it should mean the skills transfer to and are effectively applied in game situations.

TRANSFER OF LEARNING

Deciding whether a drill or practice activity "works", must be framed in the context of transfer to the game environment. If skills performed in practice drills do not hold up in games, those drills did not positively influence skill learning. Skill transfer is commonly defined as the influence of previous practice on the performance of the skill in a novel context or performance of a new skill altogether (Coker, 2017; Magill, 2010; Schmidt et al., 2018). This is where a number of drills and practice activities fall short, as they fail to make an effective transition into game performance. Tennis is dynamic and full of complex interactions between players in a variable performance environment, something that repetitive, prescribed drills do not replicate. Therefore, the question must be asked, does repetitive drilling of the "correct" technique positively transfer to the game? Although many coaches may believe that it does, the contemporary skill acquisition literature would suggest not (Renshaw, Davids et al., 2022; Renshaw, Davids & O'Sullivan, 2022; Pinder et al., 2011; Krause et al., 2018). It is more likely that game-like, representative practice experiences, that are unpredictable and variable in nature, is where transferrable skill learning occurs (Davids et al., 2013).

If this is true, why are repetitive, technical drills so prevalent in practice sessions? It comes down to how we define skilled behavior, as that is what directs our methods and approach to coaching.

DEFINITION OF SKILL

Traditional descriptions of skill include statements such as 'a task that has a specific purpose or goal' and 'the achievement of a high degree of proficiency' (Coker, 2017; Magill & Anderson, 2010). Both of these definitions highlight important elements of skilled behavior – performing in relation to a task goal, and the successful production of a functional movement solution (proficiency). Notice the lack of how the task goal is achieved in these definitions, such as a specific technique. The assumption that 'correct' or 'fundamental' techniques are requirements of skilled performance is presumptuous at best. Plainly put, technique and skill are different (Martens, 2012). So called 'textbook technique' is only one way to achieve a task goal. The technique a player uses, and its potential for success, is highly dependent on individual constraints and the context (game conditions) being faced.

Each individual player can achieve the same, successful movement outcome with their own unique, body-scaled movement solution. The interpretation of proficiency should also be questioned, with many coaches believing it alludes to the repeated reproduction of a specific technique. If the skill "looks good" but does not successfully achieve the task goal, the technique is redundant – the focus must be on task goal achievement. If we look at skill through another lens, proficiency could be defined as the ability to continually adapt to changing task constraints, while achieving the task goal. We could also view proficiency as the ability to effectively perform in different environments, identifying adaptability as a key component of skilled performance. Take court surface for example, grass, clay, and hard courts require skill to be adaptable, suggesting skill is in the relationship between the performer and the performance environment, termed individual-environment mutuality (Araújo & Davids, 2011). Thus, the practice environment should be a very important consideration in the development of skill – ultimately context is key (Otte et al., 2021). Sterile practice environments, such as same ball feed, same court position, same movement solution, has separated the skill from the environment (performance context). Assuming that skills practiced in these sterile environments transfer into a completely different, dynamic performance environment, like a match, is difficult to swallow. Skill is embodied for each individual, meaning it is relative to their organismic constraints and action capabilities, and embedded within a performance environment. The movements performed are shaped by the performance context, it is an integral part of what skill is. Therefore, repetitive technique drills are practicing entirely different skills than those used in competition, as the performance context is vastly different. This means there is not one, correct textbook technique applicable to everyone in every context, and therefore, practitioners should coach accordingly (Gray, 2021).

Practicing a skill repeatedly, in a controlled environment, does not facilitate the development of the adaptable skills required in a match. In matchs, players have to make decisions and act based on information picked up from their opponent and the shot received. They also have to take into consideration game characteristics, such as the current score, which can act as psychological constraint on their decision making and performance. Each person responds to these constraints differently, therefore, the goal of coaching should not be to develop textbook, technical skills, but rather adaptable, functional ones (O'Sullivan et al., 2021). Because a coach's beliefs about skill acquisition drive practice methods, addressing them has to be the main focus if positive changes to practice design are desired.

TRADITIONAL VIEWS OF SKILL ACQUISITION

Two common beliefs about skill learning persist among coaches in all sports, muscle memory and mental representations. Both of these ideas have flaws that should caution coaches from using them as rationale for practice drills and activities.

Muscle Memory

Muscle memory is often used in coaching circles as a rationale for the drills selected for practice, for example "we repeat this technique over and over to ingrain it in muscle memory". The concept of muscle memory is often thought of as an explanation of skill acquisition (it is not) and is generally interpreted in one of two ways:

1. Following significant repeated practice of the correct technique, muscles remember what to do.
2. Following significant repeated practice of the correct technique, skills become automatic and can be performed without conscious processing (Smith, 2018).

Take note of how beliefs about muscle memory is linked to specific coaching methods and practice drills, such as repetitive drilling of technique. Neither of these explanations are supported by the skill acquisition research literature, and therefore, the use of practice drills based on this belief is problematic. Ivancevic et al., (2012) put it quite bluntly in the following excerpt:

> *"from the scientific perspective, the common term "muscle memory", so popular with coaches and players is shear nonsense".*

The truth is, the skill acquisition literature does not even entertain the idea as there is simply no evidence to support it. This does not mean that the term and associated assumptions do not permeate coaching practice, far from it. Roetert et al. (2018) identified the problem with the use and belief in the term in their commentary on Smith's (2018) paper:

> *"The colloquial phrase "muscle memory" is simply inaccurate and could certainly be misunderstood since it promotes the notion that somehow our muscles can store memories which are a brain function".*

If coaches believe that their practice drills develop muscle memory, and that assumption is false, the associated methods, such as repetitive, technical drills, must be questioned.

Mental Representations

A more traditional theoretical approach to skill acquisition is based on the premise that significant practice helps to develop internal, mental representations of movements in the brain that can be recalled in the future. This concept is a key element of schema and motor program theory developed by Schmidt (1975). Although more robust than muscle memory, it still perpetuates a troubling idea, the myth of one correct, repeatable technique (Gray, 2021). If the 'one correct technique' idea is true, every tennis player should perform shots identically. Serena Williams, Rafa Nadal, Naomi Osaka, and Novak Djokovic should all serve, volley, and hit groundstrokes in the exact same way, which they clearly don't. What their performance does demonstrate is that they have each found an optimal way to perform based on their unique organismic constraints and the environmental context they are performing in.

Another weakness of this theory is that is does not clearly consider the important role of the environment, and the information present, in the performance of sport skills. The performer and environment have a shared mutuality, meaning skills are continuously influenced by the environment in which they are performed (Woods, McKeown, O'Sullivan et al., 2020). Performance changes as a function of the playing surface. Grass, clay or hard courts are significantly different due to the player-environment (surface) interaction. For example, players dive for shots significantly more on grass in comparison to hard courts, supporting the idea that skill is in the relationship between the individual and the environment.

In this theory, memories or motor programs are stored in the brain, are retrieved in the moment prior to movement execution. It is unclear why stored representations of movements would be more beneficial than real-time, context-specific information offered by the environment. This theory would suggest that information in the environment, such as movement of opponent or ball flight, is somehow impoverished and therefore must be interpreted and supplemented with these mental representations. More contemporary theories, such as ecological dynamics, would disagree and suggest information embedded in the environment is all we need to act effectively. It is logical to think that interacting directly with, and attuning to, the rich, real-time information in the environment would be preferable for successful action control (Otte et al., 2021). This highlights one of many key differences between traditional and contemporary skill acquisition approaches and has broad ramifications for how we coach and design practice.

Ecological Dynamics: A New Lens

Ecological dynamics is a theoretical approach to skill acquisition combining ideas from ecological psychology, dynamic systems, and complexity sciences (Davids et al., 2013). The theory is grounded in concepts, reviewed below, that fundamentally change how we view skill and its development.

Individual-Environment Mutuality

The performance environment has a direct influence on the individual, it is the mold that shapes how skills are performed. Araujo & Davids (2009) put it best "To do is always to do something, somewhere" emphasizing the functional relationship with the environment that must be realized to be skillful. Skill is not a quantity that we acquire and store as mental representations, it is embedded in the reciprocal, adaptive relationship between the performer and their environment (Araujo & Davids, 2011, Gomez, 2015). This has huge implications for coaching as it suggests the practice context and its representativeness is integral in the development of skilled game performance (Araujo & Davids, 2011; Davids, Araújo et al., 2012; Yearby et al., 2022).

Constraints

A central tenet of this approach is that of constraints and their influence on how we perceive and act in the world. Newell (1986) identified three categories of constraint, labeled organismic, environmental and task, which interact influencing the perception-action cycle, leading to functional movement behavior (see Figure 2).

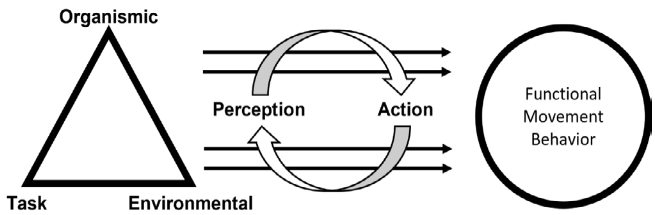

Figure 2. *The Constraints Model (Newell, 1986).*

Organismic constraints are categorized into structural, for example height, strength, flexibility and functional, that are more psychological in nature such as anxiety and confidence. Environmental constraints can be the performance context, for example playing surface, weather conditions, or socio-cultural constraints such as societal perceptions of gender, and socially imposed values. Finally, task constraints are broken down into task goals, rules, and objects, which can be most easily manipulated by coaches in practice. Task goal constraints direct the search for movement solutions as they are ultimately what we are trying to achieve. Instructions are considered task goal constraints as they guide the performer toward certain solutions and away from others (e.g., powerful vs. accurate). Task rule constraints include the dimensions of the court, net height, and game rules, such as serves must bounce in the service box. Task rule constraints can be modified in practice to directly or indirectly encourage the search for individualized, functional movement solutions (Fonseca-Morales & Martinez-Gallego, 2021).

For example, the practice area can be designed to be deep and thin (e.g. rallying on a half court), encouraging long and short shots versus utilizing court width which is no longer afforded. By focusing on achieving the task goal within the rules of the game or practice activity, unique, effective solutions will emerge. This focus on task goal achievement can explain the recent prevalence of underhand serves in top level competition, which are clearly effective. In practice, game conditions (e.g. no bounce zones) and incentivized scoring (e.g. more points for certain actions) are also common task constraints that can guide performance instead of prescribing a specific technique or solution. Finally, task object (and implement) constraints are related to the equipment used, namely racquets and tennis balls. Farrow & Reid (2010) and Buszard et al. (2014) showed that body-scaled racquets and stage-appropriate tennis balls have a positive effect on performance and learning, especially in young players. When taking into consideration the organismic constraints of the individual and appropriately implementing task constraints to suit, positive behavioral consequences emerge. Fitzpatrick et al. (2018) noted as much, showing stage-scaled courts, racquets and tennis balls resulted in greater rally length, shot variety, and serve success. Buszard et al. (2016) echoed this sentiment, finding full size courts and higher compression balls resulted in fewer hitting opportunities and fewer chances to use a variety of different shots. However, we must be aware that constraint manipulations may facilitate some objectives but possibly not others, it is a fine balance (Reid et al., 2012; Reid & Giblin, 2015). This highlights the importance of constraining to afford by presenting opportunities to solve the movement problem in the activity.

There is always a danger of over-constraining practice tasks leaving only one viable solution - traditional prescriptions of one specific technique is an example. The goal of this approach is not to find the “correct” technique or solution. Instead, each performer is encouraged to search for functional movement solutions that are adaptable to the ever-changing constraints that are imposed. These theoretical ideas have spawned an exciting methodology, the Constraints-Led Approach [CLA] (Renshaw et al., 2010; Renshaw & Chow, 2019), which has been discussed as an excellent approach to develop skilled tennis players (Pill & Hewitt, 2017; Hewitt et al., 2018).

Direct Perception of Affordances

The nature of perception is a common distinction between traditional and more contemporary theories of skill acquisition. Ecological dynamics is grounded in work by J. J. Gibson who proposed that we could directly perceive information from our environment and act upon it without the need for internal mental representations (Gibson, 1979). Directly perceiving environmental information to guide action has significant ramifications for coaching drills and activities. Therefore, the goal as coaches must be focused on helping athletes attune to task relevant information in the environment. In tennis, players perceive opportunities to act, or affordances (Gibson, 1979), such as whether a ball is hittable, returnable or the opponent is passable. These affordances are a function of the player’s individual action capabilities. If players do not have the action capability to act effectively, they do not perceive the affordance, despite being a property of the individual-environment system. This is where carefully designed practice activities can be beneficial.

A common occurrence in coaching is when the coach sees an opportunity to act but the player does not. This occurs because they are each perceiving affordances based on their own, embodied action capabilities. A short player may not see approaching the net as an affordance as they could easily get lobbed, whereas a tall player may perceive it very differently. This exemplifies how constraints influence the perception-action cycle, including the presence of affordances, resulting in very different movement behaviors between (See Figure 2). This is also true to for task constraint manipulations in practice, as they will present some affordances but remove others. Helping athletes pick up the potential affordances offered to them will encourage the development of adaptable, functional solutions that are robust when exposed to the changing demands of the game.

As coaches we must be comfortable in the fact that the best source of information to control action does not reside in a player’s head (or even worse, the coach’s head), but instead within the information-rich performance environment. In tennis, the best sources of information to guide action are the movements of the opponent and the movement of the ball, demonstrating the relationship between how we move and the information we perceive.

Information-Movement Coupling

The relationship between environmental information and our movements is an important consideration for coaches when designing practice activities. As Gibson (1979) put it "*we perceive to move and we move to perceive*", showing that movement changes the information and affordances we perceive, but also perceiving that information changes how we move. From an Ecological Dynamics perspective, it is the information-movement relationship that transfers between a faithfully simulated practice task and a competitive performance environment (Davids et al., 2013; Pinder et al., 2011). Therefore, in sport contexts, the attunement of an athlete’s attention to these action-relevant sources of information must be a key component of practice. Practice task design must authentically include this dynamic information-movement relationship to develop skilled performers. This alludes to the need to shift away from repetitive drill-based practice to a more representative game-based approach, encouraging players to find effective, functional movement solutions.

This is just a brief overview of a complex theoretical approach to skill acquisition with a description of a few of its key components. A significant benefit of this approach is that you can see it reflected in movement behavior, meaning the performer-environment and information-movement relationships can be directly observed. It is also important to note that adopting an ecological dynamics rationale to support your practice design does not reduce your coaching toolbox, far from it. A common misconception of this approach and associated methodologies such as the constraints-led approach, is that instructions are prohibited. As mentioned previously, instructions are task constraints and can help guide the search for movement solutions. The issue is with the provision of over-prescriptive instructions emphasizing the repetitive production of a specific technique. In this approach, the role of instruction changes in comparison to more traditional views. You should instruct athletes what to do, meaning the task goal, making them aware of task constraints and incentives, just not how to do it. Players must be provided the opportunity to search, explore and adapt (Chow et al., 2016) to the changing task constraints of the game.

As coaches we have to be confident that with appropriately designed practice activities using constraints, players will self-organize a functional coordination pattern to achieve the task goal (Gray, 2021). By utilizing methods grounded in this approach, such as representative design and task simplification, coaches can design practice tasks that faithfully represent the actions and information sources present in a game. Obviously, a switch toward this approach from a traditional one has important connotations for coaching and practice design.

IMPLICATIONS FOR COACHING AND PRACTICE DESIGN

Adopting an Ecological Dynamics approach dramatically changes the traditional role of the coach, from a provider to a designer and facilitator (Woods, McKeown, Rothwell et al., 2020). The coach helps cultivate a rich performance environment to facilitate growth exemplified by the following quote:

> *"The gardener cannot actually grow tomatoes, squash or beans, she can only foster an environment in which they do so"* (McChrystal et al., 2015).

Non-linear pedagogy, a method aligned with ecological dynamics, outlines five principles for the design of practice tasks: representativeness, constraints manipulation, task simplification, informational constraints, and functional variability, broadly discussed below.

Design Representative Tasks

Practice tasks should authentically represent features of the game. Representative design includes two components, action fidelity, meaning movements from the game are present in practice tasks, and functionality, meaning the information sources used to control those actions are also present. A key outcome of good representative design is the functional coupling between perception and action (Pinder et al, 2011). For tennis practice, ball feed location, speed and spin are important considerations when designing representative practice tasks as the ball and its movement is an excellent source of information (functionality). The presence of an authentic opponent is also important if we are to achieve high levels of representativeness. However, it is important to note that representative design does not mean just playing the full version of the game. Coaches can select slices of the game and then design practice tasks that accurately represent the movements and information sources required for success in competition.

Constrain to Afford

When applying task constraints, we want to avoid over-constraining, pushing them toward one specific solution or technique. Constraints set problems for the player which they must solve in order to be successful. When implementing constraints in practice activities, it is important that they present relevant affordances. Affordances are opportunities or invitations for action offered by the environment or task (Rudd, Pesce et al., 2020). Quality practice design can present, eliminate and/or incentivize particular actions. For example, if the goal is to work on the overhead smash, I can add an incentive constraint to their opponent by offering an extra point for a successful lob, which in turn will present varied opportunities to smash.

Simplify skills, don't break them down

A common, traditional coaching practice is to break skills down into parts, termed task decomposition, the assumption being they can be put back together effectively later. Remember, skills are shaped by the context in which they are performed. Information-movement coupling is where skill exists, therefore this relationship must be preserved in practice tasks. Task simplification, achieves this by modifying games to meet the performance level of the player, including scaled equipment, the dimensions of the playing space, or game rules. The format of the LTA's mini-tennis program is a notable example of task simplification with scaled equipment, smaller courts, and modified game rules to facilitate learning (Fitzpatrick et al., 2018).

Repeat problems not solutions

Bernstein (1967) coined the phrase "repetition without repetition", noting that even in basic, stable movements (e.g. drawing a line back and forth), trial-to-trial variation exists. We simply don't perform an idealized movement pattern each time, emphasizing that skill is in the ability to adapt to changing task constraints (Otte et al., 2021). By introducing variability, players have to attune to better sources of information to guide their action selection. Match-based practice activities, ensure functional variability is present, encouraging players to continually solve the movement problem in front of them. Not only is this more engaging (and fun), it significantly increases the transfer of these skills to the game.

In conclusion, to enhance skill transfer, practice design should mirror the dynamic nature of the game. We simply don't perform the same skill over and over, eloquently described by Nadal:

> *"You might think that after millions and millions of balls I've hit, I'd have the basic shots of tennis show up, that reliably hitting a true, smooth clean shot every time would be a piece of cake. But it isn't. Not just because every day you wake up feeling differently, but because every shot is different; every single one. From the moment the ball is in motion, it comes at you at an infinitesimal number of angles and speeds, with more topspin, or backspin, or flatter or higher. The differences might be minute, microscopic, but so are the variations your body makes – shoulders, elbows, wrists, hips, ankles, knees – in every shot. And there are so many other factors – the weather, the surface, the rival. No ball arrives the same as another; no shot is identical"* (Nadal & Carlin, 2011).

Every shot is different, design practice with that in mind.

CONFLICT OF INTEREST AND FUNDING

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