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REVIEW

Skill acquisition in tennis: Research and current practice

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Summary Common to most tennis players is the desire to improve performance. Equipped with the necessary motivation, these players can spend countless hours rehearsing tennis' skills under the guidance of a coach. Often, these practices feature repetitous hitting, with little consideration given to the actual context in which the game's skills are expressed. Alternatively, training sessions that amount to little more than poorly structured game-play, devoid of any specific goals or objectives, are also discernible. Either way, player learning and long-term performance are unlikely to be optimised. So, where tennis coaches have long relied on certain instructional approaches and types of practices to enhance player performance, their efficacy is uncertain. Indeed, a growing body of research suggests that players stand to benefit from the earlier introduction of variable and random practices and feedback that is more intrinsic in nature rather than time-honoured overly prescriptive coaching. This review considers contemporary skill acquisition research in relation to current tennis coaching practice.

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Concurrent increases in the number of tennis players and their quality of play have, for the best part of 10 years, been goals of the Tennis Development Department of the International Tennis Federation (ITF). 'Producing more and better players' has been the catch-cry of the sport's governing body.[1] Achieving the latter of these two goals has seen sport scientists aggressively search for the ingredients that underpin elite tennis performance. Study of the biological sciences such as biomechanics and exercise physiology have been enthusiastically embraced. Examination of other behavioural sport science disciplines such as motor learning and psychology has however, received comparatively less research attention.

In a recent critique of soccer teaching methodology, Williams and Hodges[2] described a similar trend; one that likely stems from certain aspects of player preparation and development historically considered the coach's domain. Where fitness training has become increasingly sophisticated and individualised with advances in sports science, most tennis practices continue to be intuitive, emulative and coach-led with exiguous regard for the individual athlete. This paradox becomes all-the-more remarkable given that tennis coaching is widely recognised among the foremost contributors to enhanced player performance.[3]

Although it is well documented that reaching elite levels of performance or 'expertise' may require 10 years and some 10,000 h of sustained deliberate practice,[4,5] data detailing the microstructure of practice environments to facilitate the acquisition of this sporting excellence is sparse. However, there is now a mounting body of evidence to demonstrate the exposure to a variety of practice environments throughout an athlete's sport development can exert a powerful and enduring influence on the acquisition of expert skills. Current research on team sport athletes highlights that participation in other 'related' sports and unstructured activity, such as games with a peer group free of coach intervention, appears to expedite an athlete's sport-specific development, and ultimately, the attainment of sport-specific expertise.[6–8] The formative period for this exposure to other practice environments appears to span the ages of 8—14 years prior to an athlete's investment in deliberate-type practice in a single dedicated sport. This evidence contrasts with the notion that deliberate practice alone (i.e., highly directed sport-specific training) is optimal for player development. Importantly, deliberate practice for sport can also involve various types of 'off-field' training activities (e.g., weight training) as long as the sole intention is to improve sport-specific performance. It is acknowledged however, the research on team sport athletes may have limitations with respect to individual player development in tennis, and equally, it should be noted that following a purely deliberate practice approach may be just as beneficial when only skill acquisition is considered, regardless of the social, psychological and/or physical limitations of this approach. So, while the need for sustained practice is unquestioned in the pursuit of expert sport performance, and in light of the evidence from the sporting domain, deliberate practice (as strictly defined by Ericsson et al.[4]) may constitute the 'longer' road to expertise (see Abernethy et al.[9] for a critique of the deliberate practice framework).

Certain methodological approaches to tennis coaching have also been forwarded as beneficial from performance standpoints, yet research supporting their efficacy is equivocal. With this in mind, the purpose of this review is to bring the evidence-based considerations for expediting skill acquisition and the organisation of practice sessions into applied tennis settings.

Different instructional approaches in tennis

Collectively the fashion in which coaches present information, structure practice, and provide feedback comprises a considerable portion of what can be considered a 'coaching approach'. In tennis, the conceptualisation of different coaching approaches or philosophies has been confounded by disparate terminology and coaching parlance. For example, the ITF in its book, *Advanced Coaches Manual*, distinguish between teaching styles (i.e., command or discovery) and types (i.e., vicarious learning or formal teaching), teaching methods (i.e., global or analytic) and also leadership styles (i.e., authoratarian, cooperative and casual).[10] This has led to a certain ambiguity in global tennis coaches' education and exacerbated the extent to which the instruction of the game is anecdotally based.

Contemporary motor learning literature however, commonly describes two general coaching approaches: prescriptive and discovery, or variations thereof, which conceptually lie at either end of an explicit-implicit learning continuum. That is, depending on the type of instructional or practice environment, learning may occur by either explicit or implicit processes. At the explicit end of the continuum (e.g., prescriptive), specific instructions are given to the learner about the rules that underlie a stimulus, or movement pattern to assist learning (e.g., lateral ball toss displacement to the right-handed player's left may signal a player's intent to hit a kick serve). At the implicit end (e.g., discovery), no specific instructions are given, yet proficient learning of the underlying stimulus or movement pattern occurs.[11] Magill[12] operationally defined explicit knowledge as information that is consciously available to the performer and as a result can most often be verbally described or evidenced in some other way; and implicit knowledge as information that lies below the level of consciousness and is difficult, if not impossible, to verbalise. Improved performance accompanied by a lack of explicit knowledge is typically an indication of implicit knowledge acquisition.[13] In practical coaching environments, the learner will always be exposed to forms of explicit information (e.g., peers, parents, television, coaching magazines, etc.), so the likelihood of learning by purely implicit means is most unlikely.

Prescriptive coaching considers the coach to have all-encompassing knowledge, much of which should be passed on to the learner. It continues to be favoured by many on-court practitioners and is often characterised by superfluous extrinsic feedback and demonstration. Explicit instruction, which directs individuals' senses to specific cues, also features prominently. Indeed, Williams and Hodges[2] associate this instructional approach with coaches who feel the need to justify their existence and ''be heard''. Serious doubts have been raised regarding its effectiveness in long-term performance enhancement and learning, with recent research indicating that such tutelage develops skills that are less durable and resilient to psychological stress than skills learned through less prescriptive approaches.[14,15]

Discovery coaching approaches, in contrast, emphasise coaches as 'facilitators' rather than 'dictators' of the learning process. They encourage individuals to explore solutions to different movement problems which may encourage more implicit-type learning, therein developing a more robust skill set that is less reliant on higher level cognitive function, for both technical and tactical execution. These approaches are reported as more amenable to development of game intelligence (e.g., refs.[16–18]) or, in other words 'court nous'. Typically punctuated by more variable and random practices, some tennis coaches have unfortunately misinterpreted discovery approaches to de-emphasise the importance of technique and amount to nothing more than game play, devoid of informed instruction. Many of these same coaches fail to understand that discovery approaches were largely borne out of ecological psychology and dynamical systems theory, which suggests that individuals will adjust their behaviour, motoric or otherwise, to reflect the contraints imposed upon them.[19] This subsequently infers that players' on-court performances will be altered according to the behavioural constraints (i.e., characteristics of the player, task and environment) they encounter during practice. The importance of the coach manipulating the constraints to improve either technical or tactical proficiency is further supported from the dynamic systems perspective as game-play on its own can reinforce (create an attractor state) poor technique and/or tactical decision making. So rather than discovery practices representing game-play and a virtual time-out for the coach, designing them to elicit desirable performance (tactical, technical, psychological or physical) changes becomes infinitiely more challenging. Fig. 1 presents examples of constraint manipulation to facilitate the learning or improvement of a key mechanical characteristic of the serve.

Recent research has elucidated differences between prescriptive and discovery coaching approaches such that coaches are now better positioned to objectively evaluate the pedagogical efficacy of both. As afore-indicated, prescriptive and discovery coaching approaches shape behaviour differently through explicit instruction and the presentation of implicit learning opportunities. In the development of perceptual-motor skill, theorists argue that skill learning is largely implicit,[21] yet acknowledge that the distinction between explicit-implicit learning may never be absolute in practical settings.[22] Beek[21] justifies these statements with reference to Bernstein[23] in that only high level cognitive processes deal with explicit knowledge, and below this there are multiple other levels of organisation responsible for skilled performance that are inaccessible to conscious control or explanation. This debate may be somewhat mediated if implicit and explicit learning are not viewed as dichotomous states of knowledge but rather the end points on a continuum of knowledge representation as suggested by Magill.[12] Pragmatically, prescriptive coaching approaches provide individuals more explicit instruction to direct learning, while guided discovery and discovery learning are noted as two distinguishable forms of discovery coaching, which encourage individuals to learn more implicitly. More specifically, where both of these discovery approaches encourage individuals to achieve outcomes based on their own movement or behavioural responses, guided discovery, as the names suggests, may place greater constraints on behaviour than does discovery learning.[24]

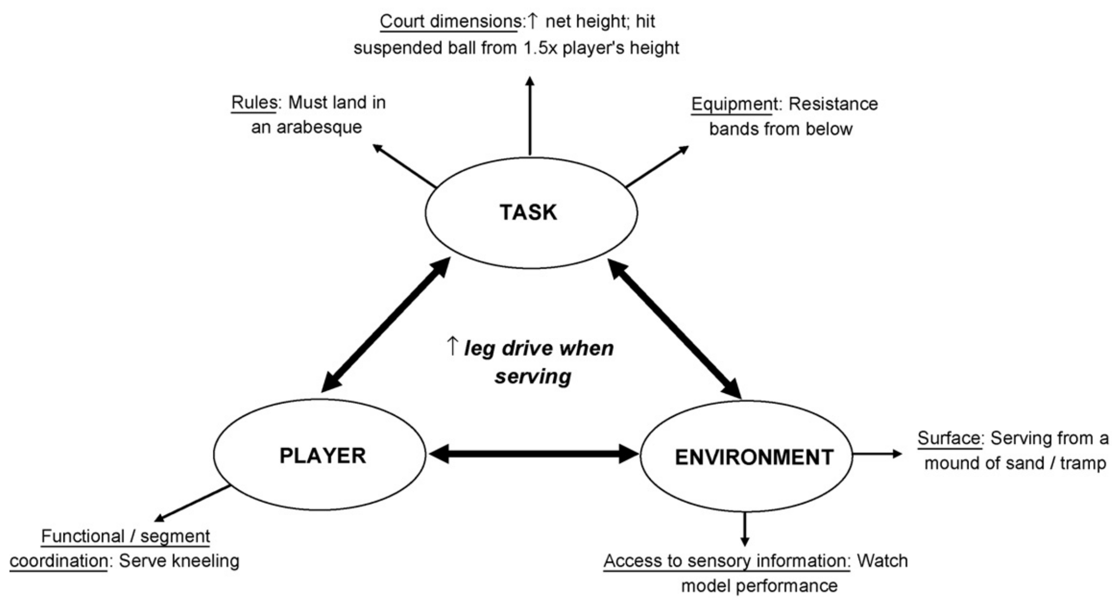

Figure 1 Examples of interventions to improve the leg drive in the serve (adapted from Newell[20]).

Influence of instructional approaches in the development of tennis-specific skill

To date, the effectiveness of different instructional approaches in tennis have only been evaluated by examining performers' decision-making and response accuracy. Farrow and Abernethy[25] compared explicit and implicit instructional methods in the training of anticipatory skill for the return-of-serve of intermediate players. The study sought to determine if the information utilised by expert tennis players could be used to train less skilled players. It was reported the implicit group significantly improved their on-court prediction accuracy after the training intervention with no improvement evident in the explicit, or placebo and control groups. In contrast, Williams et al.[26] demonstrated both explicit instruction (i.e., prescriptive) and guided discovery to be successful in improving decision time and response accuracy. Similar results were reported by Smeeton et al.[27] in their comparison of the influence of these same two approaches along with discovery learning on the anticipatory skill of young, intermediate tennis players. An interesting addendum however, was that players taught by explicit instruction exhibited significantly slower responses under anxiety-provoking conditions than players instructed with the guided discovery and discovery learning approaches. Such a finding is somewhat consistent with the work of Masters[15] and Hardy, Mullen and Jones,[28] which suggests implicitly learned motor skills to be more robust under stress. Furthermore, that the accuracy of the explicit-trained group's responses also deteriorated, effectively curbs any suggestion that the results were due to a speed-accuracy trade off alone. Rather, evidence suggests coaching approaches reliant on explicit instruction either predispose players to conscious thought during performance, and potentially poorer performance under stress (i.e., competition),[15,29] or to overload working memory capacity such that performance declines.[30]

Practical implications for the training of technique and tactics

The ability of players to successfully ascertain and then realise 'what to do' (tactics) and 'how to do it' (techniques) is central to high performance tennis play. Equally, coaching approaches and improvement strategies that facilitate the appropriateness of players' decisions are of comparable significance.[31] Indeed Raab et al.[32] highlight that most training methods emphasise the independent improvement of technical or tactical skills, despite such dichotomy being absent from sports performance.

So, although skilled performance relies on both motor skill execution and application of game knowledge,[33] traditionally, most tennis coaches have preferred to employ more prescriptive coaching approaches, where tactical information is often presented only after technique has been perfected. While such approaches may facilitate early skill acquisition (see part 4), their utility in helping players 'play' the game has been questioned (e.g., ref.[34]). Here, Turner et al.[35] highlighted a common by-product of such instruction: young players performing quite well during drills yet not being able to adapt their techniques to the demands of subsequent matchplay. In part, these scenarios have been responsible for recent popular support of less prescriptive coaching approaches, such as the game-based approach, at Federation level.[36]

Essentially a derivative of discovery coaching, game-based instruction is believed to promote decision-making and problem-solving in game situations such that players exhibit better game intelligence than players coached using the more prescriptive approaches.[37–39] Evidence supporting game-based coaching however remains equivocal, and the McPherson and French study[37] is a rarity to have quantified the proposed cognitive benefits of this coaching approach. Nonetheless, Turner[39] reports that game-based coaching, at the very least, offers a viable alternative for tennis instruction.

Expert players have been noted to make superior decisions, formulate better tactical responses and display greater game understanding than novice players[40–42]. Although McPherson[40] alludes to higher performance levels and more years of practice, coaching and tournament play contributing to the development of these enhanced cognitions, McPherson also concedes that the type of instruction players receive most likely impacts on their tactical tennis knowledge. Conceptually, it would appear appropriate for coaches to utilise instructional approaches and improvement strategies that challenge the technical and tactical skill development of their players.

Verbal and/or visual communication to facilitate learning?

In tennis, planning interventions to change motor or cognitive behaviour necessitate that information be conveyed to the player. Irrespective of the desired behavioural change — technical, tactical, mental or physical — the message is most commonly expressed visually, in the form of a demonstration, and/or verbally.

Studies evaluating the efficacy of demonstrations, or more broadly observational learning, have investigated how and what visual information is processed to facilitate learning.[43,44] Providing individuals with visual templates of desired movement patterns is commonly considered their primary goal,[45] and one pursued with vigor in most tennis coaching circles. And this, in spite of specific forms of visual demonstrations, like video-based modelling, only receiving ambiguous research support in instructional tennis settings.[44,46,47]

Factors such as task complexity, a coach's preferences, and the player's skill and motivation will also influence the prospect of behaviour change, yet the effectiveness of demonstrations are largely determined by their ability to direct learners to the specific goal (e.g., technical: velocity or precision; tactical: creating space vs. taking time away from an opponent). Indications are thus that when learning involves the precise replication of a technique, demonstrations may be at their most effective.[2] A player's motoric competence aside, further extrapolation to tennis contexts would suggest that they may be of similar benefit in the instruction of specific tactical patterns (i.e., shot sequences).

Successful tennis play however, is not diametrically dependent on the specific replication of technique, and herein, the value of demonstrations as compared to simple, verbal instruction is questionable.[2] To this end, concerns surround the overly constraining nature of some demonstrations, which may force individuals to reproduce mechanically inappropriate movement patterns. To negotiate this potential pit-fall and allow players to develop flexible but effective movement patterns, researchers have recommended that individuals be directed to observe, and then reproduce, the goal of the action or the movement's end point.[48,49] Respectively, in tennis practices, this may see coaches instruct players to attend and then reproduce either the ball trajectory or post-impact foot alignment of a specific shot (see Table 1 for more examples). Verbalising a skill's intended outcome rather than providing instructions as to how it should be achieved, may also facilitate learning in the absence of preceding or accompanying demonstrations.[45,50] A simple example of which would be for players in need of improving their use of court width to be asked to ''hit their shots so that all second bounces (of the ball) land outside the singles sideline''.

In assessing how best to present information to guide the learning process, it is clear that both visual and verbal strategies can be effective. Further, demonstrations and verbal instruction are not mutually exclusive and for the most part, can complement each other. However, coaches need to be aware that certain circumstances, or for that matter personalities, may dictate one method of con-

Table 1 Focus of demonstration, skill (task), what to observe, and desired behavioural change (solutions to the problem)

Focus of demonstration	Skill (task)	What to observe	Desired behavioural change
Goal of action	Topspin backhand lob	Ball trajectory	Low-high racquet trajectory; increase weight of shot
	Drop shot	Ball bounce	Develop high-low racquet trajectory, 'soft hands'
Movement end-point	Serve	Arabesque follow-through position	Improve back leg drive and trunk angular momentum (about X)
	Forehand drive	Alignment of feet post-impact	Increase separation angle; improve trunk rotation

veying information as more suitable. Establishing precisely what and when that is remains one of the fundmental challenges of all coaching.

Structuring practice for learning

Generally, training can be structured and skills practiced under constant (i.e., one skill, same conditions) or variable (i.e., different variations of the same skill) conditions, in a blocked or random manner. Fig. 2 presents some examples of drills to highlight these variations in the microstructure of typical tennis practices. Indeed the interpretation of related research points toward the arrangement of practice influencing performance in different ways. For example, support exists for the use of constant practice during the acquistion of new skills, yet variable practice is considered necessary if learning is to be most effectively transferred to game-play.[51] This latter proposal is consistent with the schema theory of Schmidt[52] and the dynamical systems approach to learning.[19] In general terms, both theories argue that variability in practice encourages learners to develop movement patterns that are more adaptable and better equipped to negotiate the largely unpredictable coordinative demands of competition.[19,53] Such theorising is not entirely foreign to tennis, for many high performance coaches have been noted to laud the importance of game-like training in producing versatile and 'smart' players.[16]

The blocked or random practice of skills reflects the degree of contextual interference encountered within a training session.[54] Blocked practices, where players may train one stroke, or two strokes independently, per session would typify sessions of relatively low contextual interference. In contrast, training sessions where the more random practice of several strokes or tactical patterns is scheduled would present players with greater contextual interference. In many ways, the proposed benefits of blocked and random practice parallel those aformentioned contrasting characteristics of constant and variable practice. That is, where blocked practice has been anecdotally noted to facilitate early skill acquisition,[55] an established yet surprisingly poorly disseminated body of research advocates the use of higher contextual interference practices to enhance long-term skill retention and learning.[56–58] Again, similar to the rationale used to explain the value of variable practice, theorists have suggested that random practice more actively engages learners in the construction, evaluation and adaptation of movement patterns.[59,60] Coaches of top international players have intimated that these benefits are not limited to technical or physical aspects of the game, but also contribute positively to the psychological and tactical development of players.[61] To our knowledge, only two studies have evaulated the effect of contextual interference in tennis, and indications are that both blocked and random practices can be of value but may need to be manipulated according to the skill level of the learner.[62,63]

However, a recognisable yet unfortunate characteristic of modern coaching sees some coaches evaluate player improvement, or the effectiveness of the training session, based on what is immediately observable. A problem further compounded by parents who expect immediate 'bang for their buck'. Consequently, to avert impending discontent, coaches often employ constant, blocked practices in the knowledge that they are less likely to negatively affect short-term performance. Others, find further comfort in structuring practice in this way as it is easier to administer and a virtual 'no-brainer' for those who learned the game accordingly.[64] Nevertheless, when learners are presented with novel versions of what has been practiced, as would be expected in matchplay,

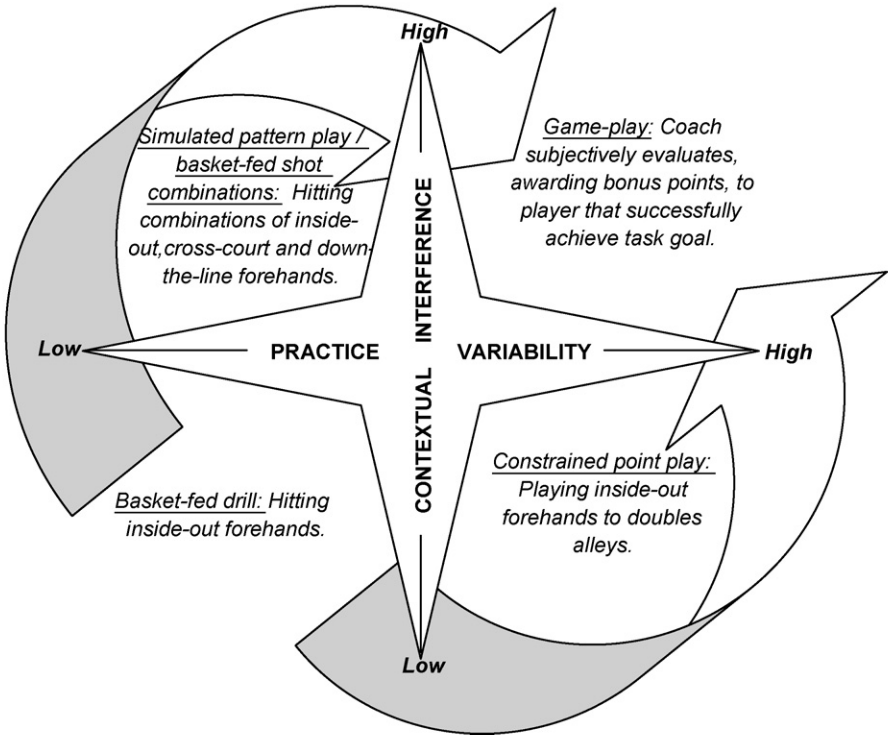

Figure 2 The microstructure of different tennis-specific practice activites.

skills learned though random-variable schedules are likely more rigorous, especially among young players.[65] Yet rather than side with the detractors of certain practices, optimal learning most likely exposes players to various practice structures throughout their development (Fig. 2). It may be that as players progress a greater percentage of training time is still spent on conditioned games or matchplay but the point of issue is that players will likely benefit from participation in random and variable practices earlier than is currently prescribed.

Type and timing of feedback

Stand at the rear of a tennis court on which a coaching session is being conducted and it wont be long before one hears 'step in', 'good depth', 'more racquet-head speed' or similar. Feedback can be provided in many ways, and when effective is noted to facilitate learning, guide skill development and maintain or improve an individual's motivation. So too, will it provide players with knowledge of their result (i.e., the serve was wide) and/or performance (i.e., the serve's ball toss was too low).

Feedback can be gained intrinsically as players feel, see or hear the consequence of their action, and/or extrinsically as provided, in potentially different detail, by the coach. As alluded to above, observation of some tennis lessons will see coaches, consciously or otherwise, provide feedback that lacks specificity; while others are concise but provide it all too frequently. Indeed, the provision of too much extrinsic feedback is suggested to breed an over-reliance on the coach, and impair an individual's ability to independently process and evaluate information.[2,66] This may manifest on-court with some players becoming anxious at the prospect of having to problem-solve without direct, extrinsic feedback or guidance. Empirically, such situations are noted as more common among female players[67]: a potential by-product of the findings of female players' preference for more autocratic coach behaviour.[68] To thwart the likelihood of this problem arising, Swinnen,[69] Swinnen et al.[31] and Liu and Wrisberg[70] have recommended interventions such as lengthening the interval between the action culminating and a coach's provision of feedback, to afford players greater opportunity to intrinsically evaluate their own performance. The use of questions by the coach during this time may further direct players to review specific performance cues, while Rhea et al.[71] have shown that players can effectively evaluate selected aspects of their performance through post-match video analysis.

Clearly there is a delicate balance between providing too much or too little feedback as a coach. The goal becomes to provide sufficient input so as to facilitate performance and motivate the learner, while not dominating such that independence of thought and strategy are impaired.[26] To this end, Wulf et al.[72] relate the frequency of feedback to the individual's stage of learning, and suggest that with novice players or during the learning of complex tasks, coaches may be required to provide more frequent feedback to improve performance. However, motor learning literature implores feedback to become less frequent as skills develop[69,73]; elevating the role of intrinsic feedback to greater prominence. A comparable shift in feedback content and precision is also recommended to accompany player development. More specifically, researchers differentiate between feedback being descriptive (i.e., players would be alerted to the error committed) or prescriptive (i.e., players are informed of how to correct the error). Again, the inference is that appropriate feedback should become increasingly descriptive[73] and precise[74] as skill and/or learning improves. In application, this may serve the dual purpose of further developing the problem-solving prowess of skilled tennis players,[72] while concurrently streamlining sometimes-subtle refinements to their games.[74]

Conclusion

If coaching is indeed as important to player development as the sport would have us believe, efforts to investigate and then disseminate knowledge pertaining to motor learning in tennis need to be enhanced. Indeed, to realise one of the ITF's goals to improve player performance-coaches should consider embracing less prescriptive approaches to coaching, and thus the efficacy of variable and random practices and the importance of intrinsic feedback. This is not to say that more prescriptive coaching approaches have become obsolete; rather they should be used more selectively. For this paradigm shift to be accomplished however, players, parents, and administrators may first need to be reminded or educated regarding its philosophy and long-term benefit. Who knows ... the use of these more player-centered approaches to coaching may even assist the ITF achieve the former of its goals!

Practical implications

- Clear delineation of discovery and prescriptive instructional approaches in relation to tennis coaching should permit organisations to better deliver evidenced-based pedagogical messages throughout their coach education programs.
- Elaboration of contemporary skill acquisition research as it relates to tennis coaching may help to reduce the disparate and, at times, misplaced use of certain concepts and methodologies across international tennis coach education curricula.
- As compared to overly prescriptive coaching, indications are that tennis players would benefit from earlier introduction to variable and random practice designs and the accompanying increased opportunity to intrinsically evaluate their own performance.

References

1. ITF. *Marketing of the Game: The Drive for Growth*. London: ITF Ltd.; 2004.
2. Williams AM, Hodges NJ. Practice, instruction and skill acquisition in soccer: challenging tradition. *J Sports Sci* 2005;**23**(6):637—50.
3. ITF, ITF Coaches Commission Minutes, Antalya; 2005.
4. Ericsson KA, Krampe RT, Tesch-Römer C. The role of deliberate practice in the acquisition of expert performance. *Psychol Rev* 1993;**100**:363—406.
5. Helsen WF, Starkes JL, Hodges NJ. Team sports and the theory of deliberate practice. *J Sport Exerc Psychol* 1998;**20**:12—34.
6. Baker J, Côté J, Abernethy B. Sport-specific practice and the development of expert decision-making in team ball sports. *J Appl Sport Psychol* 2003;**15**:12—25.
7. Berry J, Abernethy B. Expert game-based decision-making in Australian football. How is it developed and how can it be trained? *Res Report Aust Football League* 2003.
8. Côté J, Baker J, Abernethy B. From play to practice: A developmental framework for teh acquisition of expertise in team sports. In: Starkes JL, Ericsson KA, editors. *Expert Performance in Sport: Recent Advances in Research on Sport Expertise*. Champaign: Human Kinetics; 2003. p. 89—113.
9. Abernethy B, Farrow D, Berry J. Constraints and issues in the development of a general theory of expert perceptual-motor performance: a critique of the deliberate practice framework. In: Starkes JL, Ericsson KA, editors. *Expert Performance in Sport: Recent Advances in Research on Sport Expertise*. Champaign: Human Kinetics; 2003. p. 349—69.
10. Crespo M, Miley D. *ITF Advanced Coaches Manual*. London: ITF Ltd; 1998.
11. Berry DC, Broadbent DE. Interactive tasks and the implicit-explicit distinction. *Br J Psychol* 1988;**79**:251—72.
12. Magill RA. Knowledge is more than we can talk about: implicit learning in motor skill acquisition. *Res Q Exerc Sport* 1998;**69**(2):104—10.

13. Berry DC, Broadbent DE. On the relationship between task performance and associated verbalizable knowledge. *Q J Exp Psychol* 1984;**43A**:881—906.
14. Abrams M, Reber AS. Implicit learning: robustness in the FACE of psychiatric disorder. *J Psycholinguist Res* 1988;**17**:425—39.
15. Masters RSW. Knowledge, knerves and know-how: the role of explicit versus implicit knowledge in the breakdown of a complex motor skill under pressure. *Br J Psychol* 1992;**83**:343—58.
16. Charlesworth R. Designer games. *Sports Coach* 1994;**4**: 30—3.
17. Launder AG. *Play Practice: the Games Approach to Teaching and Coaching Sports*. Champaign: Human Kinetics; 2001.
18. Pressley M, Snyder BL, Cariglia-Bull T. How can good strategy use be taught to children? Evaluation of six alternative approaches. In: Cormier SM, Hagman JD, editors. *Transfer of Learning: Contemporary Research and Applications*. San Diego: Academic Press; 1987. p. 81—120.
19. Davids K, Williams AM, Button C, Court M. An integrative modelling approach to the study of intentional movement behaviour. In: Singer RN, Hausenblas HA, Janelle CM, editors. *Handbook of Sport Psychology*. New York: Wiley; 2001. p. 144—73.
20. Newell KM. Constraints on the development of coordination. In: Wade MG, Whiting HTA, editors. *Motor development in children; aspects of coordination and control*. Boston: Martinus Nijhoff; 1986. p. 341—60.
21. Beek PJ. Toward a theory of implicit learning in the perceptual motor domain. *Int J Sport Psychol* 2000;**31**:547—54.
22. Reber AS. Implicit ruminations. *Psychon Bull Rev* 1997;**4**: 49—55.
23. Bernstein N. *The Coordination and Regulation of Movement*. Oxford: Pergamon Press; 1967.
24. Jackson RC, Farrow D. Implicit perceptual training: how, when, and why? *Hum Movement Sci* 2005;**24**:308—25.
25. Farrow D, Abernethy B. Can anticipatory skills be learned through implicit video-based perceptual training? *J Sports Sci* 2002;**20**(6):471—85.
26. Williams AM, Ward P, Knowles JM, Smeeton N. Anticipation skill in a real-world task: measurement, training, and transfer in tennis. *J Exp Psychol* 2002;**8**:259—70.
27. Smeeton NJ, Williams AM, Hodges NJ, Ward P. The relative effectiveness of various instructional approaches in developing anticipation skill. *J Exp Psychol* 2005;**11**:98—110.
28. Hardy L, Mullen R, Jones G. Knowledge and conscious control of motor actions under stress. *Br J Psychol* 1996;**87**:621—36.
29. Liao CM, Masters RSW. Analogy learning: a means to implicit motor learning. *J Sports Sci* 2001;**19**:307—19.
30. Eysenck MW. Models of memory: information processing. *Psychopharmacol Ser* 1988;**6**:3—11.
31. Swinnen S, Schmidt RA, Nicholson DE, Shapiro DC. Information feedback for skill acquistion: instantaneous knowledge of results degrades learning. *J Exp Psychol: Learn, Mem Cognit* 1990;**16**:706—16.
32. Raab M, Masters RSW, Maxwell JP. Improving the 'how' and 'what' decisions of elite table tennis players. *J Hum Movement Sci* 2005;**24**:326—44.
33. Dexter T. Relationships between sport knowledge, sport performance and academic ability: empirical evidence from GCSE physical education. *J Sports Sci* 1999;**17**:283—95.
34. Jones D. Teaching for understanding in tennis. *Bull Phys Edu* 1982;**18**(1):29—31.
35. Turner A, Crespo M, Reid MM, Miley D. The games for understanding teaching approach in tennis. *ITF Coach Sport Sci Rev* 2002;**26**:2—14.
36. ITF. *ITF Coach Sport Sci Rev* 1999:19.
37. McPherson SL, French KE. Changes in cognitive strategies and motor skill in tennis. *J Sport Exerc Psychol* 1991;**13**:26—41.
38. Thorpe R, Bunker D. A changing focus in games education. In: Almond L, editor. *The Place of Physical Education in Schools*. London: Kogan Page; 1989. p. 42—71.
39. Turner A. A comparative analysis of two approaches for teaching tennis: games for understanding approach versus the technique approach. In: *Proceedings of the 2nd International Conference: Teaching Sport and Physical Education for understanding*. Melbourne; 2003.
40. McPherson SL. Tactical differences in problem representations and solutions in college varsity and female tennis players. *Res Q Exerc Sport* 1999;**70**:369—84.
41. McPherson SL, Thomas JR. Relation of knowledge and performance in boys' tennis: age and expertise. *J Exp Child Psychol* 1989;**48**:190—211.
42. Nielsen TM, McPherson SL. Response selection and execution skills of professionals and novices during singles tennis competition. *Percept Motor Skills* 2001;**93**(2):541—55.
43. Horn RR, Williams AM. Observational learning: is it time we took another look? In: Williams AM, Hodges NJ, editors. *Skill Acquisition in Sport: Research, Theory and Practice*. London: Routledge; 2004. p. 175—206.
44. Scully DM, Newell KM. Observational learning and the acquisition of motor skills: toward a visual perception perspective. *J Hum Movement Stud* 1985;**11**:169—86.
45. Hodges NJ, Franks IM. Modeling coaching practice: the role of instruction and demonstration. *J Sports Sci* 2002;**20**:1—19.
46. Miller C, Gabbard C. Effects of visual aids on acquisition of selected tennis skills. *Percept Motor Skills* 1988;**67**(2):603—6.
47. Van Wieringen PC, Emmen HH, Bootsma RJ, Hoogesteger M, Whiting HT. The effect of video-feedback on the learning of the tennis service by intermediate players. *J Sports Sci* 1989;**7**(2):153—62.
48. Matatic MJ, Pomplun M. Fixation behaviour in observation and imitation of human movement. *Cognit Brain Res* 1998;**7**:191—202.
49. Wulf G, Lauterbach B, Toole T. Learning advantages of an external focus of attention in golf. *Res Q Exerc Sport* 1999;**70**:120—6.
50. Weeks DL, Anderson LP. The interaction of observational learning with overt practice: effects of motor skill learning. *Acta Psychol* 2000;**104**:259—71.
51. Lee TD, Magill RA, Weeks DJ. Influence of practice schedule on testing schema theory predictions in adults. *J Motor Behav* 1985;**17**:282—99.
52. Schmidt RA. A schema theory of discrete motor skill learning. *Psychol Rev* 1975;**82**:225—60.
53. Schmidt RA, Lee AT. *Motor Control and Learning: A Behavioural Emphasis*. Champaign: Human Kinetics; 1999.
54. Battig WF. The flexibility of human memory. In: Cermak LS, Craik FIM, editors. *Levels of Processing in Human Memory*. Hillsdale: Lawrence Erlbhaum Associates; 1979. p. 23—44.
55. Shea CH, Kohl R, Indermill C. Contextual interference: contributions of practice. *Acta Psychol* 1990;**73**:145—57.
56. Goode S, Magill RA. Contextual interference effects in three badminton serves. *Res Q Exerc Sport* 1986;**57**:308—14.
57. Hall KG, Domingues DA, Cavazos R. Contextual interference effects with skilled baseball players. *Percept Motor Skills* 1994;**78**:835—41.
58. Landin DL, Herbert EP. A comparison of three practice schedules along the contextual interference continuum. *Res Q Exerc Sport* 1997;**68**:357—61.

59. Handford C, Davids K, Bennett S, Button C. Skill acquisition in sport: some applications of an evolving practice ecology. *J Sports Sci* 1997;**15**:621—40.
60. Lee TD, Magill RA. Can forgetting facilitate skill acquisition? In: Goodman D, Wilberg RB, Franks IM, editors. *Differing Perspectives in Motor Learning, Memory and Control*. Amsterdam: Elsevier; 1985. p. 3—22.
61. Martens S, Bastiaens K. A ''working'' concept for coaching and athlete development. In: *Proceedings of the 14th ITF Worldwide Coaches Workshop*. Antalya: ITF Ltd.; 2005.
62. Hebert EP, Landin D, Solmon MA. Practice schedule effects on the performance and learning of low-and high-skilled students: an applied study. *Res Q Exerc Sport* 1996;**67**:52—8.
63. Farrow D, Maschette W. The effects of contextual interference on children learning forehand tennis groundstrokes. *J Hum Movement Stud* 1997;**33**:47—67.
64. Roetert EP, Crespo M, Reid MM. How to become a model. *ITF Coach Sport Sci Rev* 2003;**31**:12—3.
65. Kerr R, Booth B. Specific and varied practice of motor skill. *Percept Motor Skills* 1978;**46**:395—401.
66. Salmoni A, Schmidt RA, Walter CB. Knowledge of results and motor learning: a review and critical reappraisal. *Psychol Bull* 1984;**95**:355—86.
67. Rastaad E. Key issues in developing female tennis players. *ITF Coach Sport Sci Rev* 2004;**34**:14.
68. Riemer HA, Toon K. Leadership and satisfaction in tennis: examination of congruence, gender, and ability. *Res Q Exerc Sport* 2001;**72**(3):243—56.
69. Swinnen SP. Information feedback for motor skill learning: a review. In: Zelaznik HN, editor. *Advances in Motor Learning and Control*. Champaign: Human Kinetics; 1996. p. 37—66.
70. Liu J, Wrisberg CA. The effect of knowledge of results delay and the subjective estimation of movement form on the acquisition and retention of a motor skill. *Res Q Exerc Sport* 1997;**68**:145—51.
71. Rhea DJ, Mathes SA, Hardin K. Video recall for analysis of performance by collegiate female tennis players. *Percept Motor Skills* 1997;**85**(3):1354.
72. Wulf G, Shea CH, Matschiner S. Frequent feedback enhances complex motor skill learning. *J Motor Behav* 1998;**30**:180—92.
73. Wulf G, Shea CH. Understanding the role of augmented feedback: the good, the bad, and the ugly. In: Williams AM, Hodges NJ, editors. *Skill Acquisition in Sport: Research, Theory and Practice*. London: Routledge; 2004. p. 121—44.
74. Magill RA, Wood CA. Knowledge of results precision as a learning variable in motor skill acquisition. *Res Q Exerc Sport* 1986;**47**:277—91.