EXPLORING THE INFLUENCE OF PRACTICE DESIGN ON THE DEVELOPMENT OF TENNIS PLAYERS

by

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ABSTRACT

This thesis examined the efficacy of contemporary tennis practice for maximizing skill learning and transfer to competition performance. Theory suggests that experimental and practice tasks should be designed to promote emergent behaviours that are functional and adaptable to changing situations that occur during competition. Current evaluations of practice design in multiple sports, however, suggest that coaches do the opposite, prioritising tasks that promote mechanical consistency over adaptability. Practice in many sports may therefore be sub-optimal. To address this concern, Representative Learning Design (RLD) has been proposed as a framework for assessing the extent to which a task is representative of a situation of interest (e.g., an athletes competition environment). The terminology within the RLD framework, however, requires simplification for application by coaches in applied settings. Moreover, despite suggestions of its importance, no empirical work has assessed the longitudinal benefits of practicing in tasks more representative of competition contexts. This thesis combined the experiential and theoretical knowledge of experts in skill acquisition and tennis with concepts from RLD to design the Representative Practice Assessment Tool (RPAT). Application of the RPAT confirmed that tennis coaches prioritised tasks low in representativeness. This is a concern given it was also found that athlete behaviours observed in matchplay are best simulated in tasks that more closely represent matchplay contexts. Most importantly, this thesis provides empirical evidence which suggests that increasing the representativeness of a task does not simply imply enhanced skill learning, rather changes to task representativeness promotes different learning outcomes/adaptations that remain specific to how practice was conducted. To summarise, this thesis extended current knowledge of designing practice tasks for enhanced skill learning and transfer. Practitioners and coaches are recommended to individualise the representativeness of tasks to the specific needs of their

athlete in a manner which facilities the emergence of functional behaviours that are transferable to competition.

STUDENT DECLARATION

I, Lyndon Krause, declare that the PhD thesis entitled 'Exploring the influence of practice design on the development of tennis players' is no more than 100,000 words in length including quotes and exclusive of tables, figures, appendices, bibliography, references and footnotes. This thesis contains no material that has been submitted previously, in whole or in part, for the award of any other academic degree or diploma. Except where otherwise indicated, this thesis is my own work.

Signature: [redacted] Date: 26th April 2019

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As I write this section I reflect on the long, tiresome and exciting journey that was the four years of my PhD. It was an experience that I will treasure for the rest of my days and one of which I owe many thanks to the people who supported me and made this journey such a memorable one.

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I look forward to the next chapter of my life, fishing, frenchies, freedom.... Oh... and a wedding!

LIST OF PUBLICATIONS & PRESENTATIONS

Sections of this thesis have been published (or submitted for publication) and/or presented at relevant scientific and coaching conferences.

THESIS PUBLICATIONS

Chapter 1: **Krause, L.,** Buszard, T., Reid, M., Pinder, R. , Farrow, D. (2018). Assessment of elite junior tennis serve and return practice: a cross-sectional observation. *Currently under review in Q1 Journal of Sport Sciences.*

Chapter 2: **Krause, L.,** Farrow, D., Reid, M., Buszard, T., & Pinder, R. (2018). Helping coaches apply the principles of representative learning design: validation of a tennis specific practice assessment tool. *Journal of Sports Sciences*, *36*(11), 1277-1286. doi: 10.1080/02640414.2017.1374684

Chapter 3: **Krause, L.,** Farrow, D., Buszard, T., Pinder, R., & Reid, M. (2018). Application of representative learning design for assessment of common practice tasks in tennis. *Psychology of Sport and Exercise*, *41*, 36-45. doi: 10.1016/j.psychsport.2018.11.008

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OTHER PUBLICATIONS

The following work has also been published in peer-reviewed journals during candidature but are outside the scope of this thesis.

Buszard, T., Reid, M., **Krause, L.,** Kovalchik, S., and Farrow, D. (2017). Quantifying contextual interference and its effect on skill transfer in skilled youth tennis players. *Frontiers in Psychology,* 8, 1931. doi: 10.3389/fpsyg.2017.01931

Krause, L. M., Naughton, G. A., Benson, A. C., & Tibbert, S. (2018). Equity of physical characteristics between adolescent males and females participating in single-or mixed-sex sport. *The Journal of Strength & Conditioning Research*, *32*(5), 1415-1421. doi: 10.1519/JSC.0000000000001963

Tissera, K. M., Naughton, G. A., Gabbett, T. J., **Krause, L. M.,** Moresi, M. P., & Benson, A. C. (2019). Sex differences in physical fitness characteristics and match-play demands in adolescent netball: should male and female adolescents co-compete in netball? *The Journal of Strength & Conditioning Research*, *33*(3), 846-856. doi: 10.1519/JSC.0000000000002947

CONFERENCE PRESENTATIONS

The following thesis-related work was presented during candidature.

Krause, L. (2018). “Enhancing practice of the tennis serve through representative learning”. Presented at the 2018 Tennis Australia National Coaching Workshop, Melbourne, Australia.

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MEDIA RELATED WORK

The following media related opportunities were undertaken.

Feature article published by Chris Clarey in New York Times. This piece promoted Tennis Australia's 'Racquet Room', promoting my daily role with Tennis Australia. View article here: https://www.nytimes.com/2017/02/10/sports/tennis/smart-court-racket-australia.html?_r=0

TV presentation: Tennis Science, Scope Channel 11. March 26, 2018. Hosted a short segment related to using science to enhance the racquet and string selection process for tennis players. View segment here: https://youtu.be/-J4VHIXHEj8

Feature article published by Will Swanton in The Australian. This piece promoted Tennis Australia's and Victoria Universities 'Racquet Room', promoting my daily role with Tennis Australia. View article here: https://www.theaustralian.com.au/sport/tennis/the-bazooka-nadal-will-use-to-defend-french-crown/news-story/06aa33a8b2c542e3e880729c0b4c3055

Feature article published by Simon Briggs in The Daily Telegraph. This piece promoted Tennis Australia's and Victoria Universities 'Racquet Room', promoting my daily role with Tennis Australia. View article here: https://www.pressreader.com/similar/282660393166387

Feature article published by Vivienne Christie in The Australian Tennis Magazine. Interview discussing the intricacies of Tennis Australia's and Victoria Universities 'Tennis Lab' (formerly Racquet Room).

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CHAPTER 1

INTRODUCTION & OVERVIEW OF THESIS

1.1 Introduction

Consider for a moment that more than 90% of tennis grand slams have been won by male or female players with a current or former ranking of 1-5 in the world (ESPN, 2019), it is no surprise that the world remains fascinated by how such a small portion of athletes can be so dominant. The retrospective assessment of practice volumes across multiple sports confirms that expertise (e.g., winning a grand slam) is the product of an array of learnt skills (both physical and emotional) across an athlete’s lifetime (Ericsson, Krampe, & Tesch-Römer, 1993; Mann, Williams, Ward, & Janelle, 2007; Starkes & Hodges, 1998). Prominent among these perspectives is the requirement for large volumes of practice such as the 10,000 hour rule (Simon & Chase, 1988), the power-law of practice (Newell & Rosenbloom, 1981) and deliberate practice theory (Ericsson et al., 1993). Misinterpretation of this research (for example see Ericsson et al., 2013 and Gladwell, 2008) has however led coaches and practitioners to overemphasise the importance of undertaking extensive volumes of practice with less emphasis for the type or quality of practice. Major sport organisations such as Tennis Australia and the United States Tennis Federation certainly adopt this approach through the provision of information related to the ‘quantity or volume’ as opposed to the ‘quality’ of practice necessary to attain high levels of skill performance (Tennis Australia, 2007; United States Tennis Association, 2004, 2018)

More detailed descriptions of the specific types of practice being undertaken across a range of sports identifies a preference for the prioritization of drill-based practice tasks that emphasise the improvement of mechanical consistency over adaptability (Ford, Yates, & Williams, 2010; Low, Williams, McRobert, & Ford, 2013; Slade, Button, & Cochrane, 2015). Examples include the extensive use of repetitive drills (Travassos, Duarte, Vilar, Davids, & Araújo, 2012), ball machines (Pinder, Renshaw, Davids, & Kerhervé, 2011; Shim, Carlton, Chow, & Chae, 2005) and/or tasks completely removed from the context they are performed in competition (Barris, Davids, & Farrow, 2013; Reid, Giblin, & Whiteside, 2015). Researchers have, however, begun to identify that these common types of task may be sub-optimal for the learning and transfer of skills direct to competition given they do not simulate the context-specific situations an athlete is required to attend during competition (Barris et al., 2013; Pinder, Renshaw, & Davids, 2009; Travassos et al., 2012). More specifically, the movement solutions of an athlete competing in tasks considered 'more representative' of competition contexts (e.g., competing against a live opponent compared to a projection machine) leads to more desirable movement behaviours and/or solutions symbolic of what is expected during competition.

Intuitively, researchers are therefore beginning to advocate that the practice most conductive to skill learning and transfer is practice that (i) is focused toward achieving a specific goal and (ii) adequately simulates the context-specific information required for performance during actual competition (Araujo & Davids, 2009; Davids, Araújo, Hristovski, Passos, & Chow, 2012; Davids, Glazier, Araújo, & Bartlett, 2003). To assist practitioners and coaches in designing more representative experimental and practice tasks, Representative Learning Design (RLD) has been proposed (Pinder, Davids, Renshaw, & Araújo, 2011). RLD provides a framework for assessing the extent to which a task is representative of a situation of interest (e.g., an athletes competition environment). Currently, RLD has two key limitations: (i) no empirical work has assessed the longitudinal benefits of practicing in tasks more representative of competition contexts and (ii) it's terminology requires simplification to assist coaches in applying RLD in applied settings.

Ironically, there is incongruence between the contentions of contemporary skill acquisition literature and the practice actually being undertaken by athletes. That is, coaches appear to be prioritising drill-based practice tasks, which could be deemed low in representativeness and consequently may be sub optimal for skill acquisition and transfer. This thesis will progress our knowledge of practice design, with support from the RLD framework, in the skill-intensive sport of tennis. Tennis has been selected as the vehicle for this given previous acknowledgments that tennis practice is often based on tradition and intuition rather than empirical evidence (Reid, Crespo, Lay, & Berry, 2007).

1.2 Aims of the dissertation

1.2.1 General Aim

This thesis aims to examine the efficacy of contemporary tennis practice for maximizing skill learning and transfer of skills to competition performance. Additionally, this thesis aims to consolidate current theoretical literature as to enable coaches to better understand key principles for enhancing learning transfer via improved practice design in sport. Using tennis as the experimental vehicle, four specific aims were formulated.

1.2.2 Specific Aims

1. Align the current practice approaches for developing tennis talent against the RLD framework.
2. Conceptualise and validate a practical coaching tool.
3. With support from objective motion capture ball and player movement data, implement the validated assessment tool to assess the representativeness of

common practice tasks considered useful for enhancing skill learning and transfer.

4. Assess benefits for learning and transfer of the tennis serve following increased exposure to either low, moderate or high representative practice tasks as classified by ratings from the assessment tool.

1.3 Chapter organisation

Chapter 1 provided an introduction to the topic of this thesis along with a brief rationale for the research. The specific aims of the thesis were also detailed.

Chapter 2 critiques the literature encompassing the study of skill learning and transfer by detailing the underpinning theoretical approaches to designing practice and experimental tasks. Implications for designing tasks more representative of competition, or a failure to do so, are discussed in detail.

Chapter 3 provides a descriptive analysis of the current practice approaches employed by elite junior tennis players to develop the two most important tennis skills, the serve and return. The specific constraints being implemented in practice (e.g., the presence of a returner, or requirement of players to continue the rally beyond the serve or return), along with the resultant behaviours displayed by the athletes as a result of these constraints (e.g., direction of serves or types of returns) are assessed. Results show that elite junior tennis players prioritise practice of the serve and return in tasks that do not closely simulate the constraints present during competition. As a result athletes displayed movement behaviours that may be considered less desirable in competition, inadvertently suggesting that tennis practice may be sub-optimal.

Acknowledging the current limitations of practice design in tennis, Chapter 4 presents the development and validation of an assessment tool for assessing and improving the design of tennis practice tasks. The tool was validated via seeking the opinions of leading expert skill acquisition researchers and international level tennis coaches. Consistent with the RLD framework, the underlying premise of this tool being that tasks must simulate the context-specific information presented during competition. This chapter provides practical examples of how the validated tool could be implemented to assist coaches and practitioners in enhancing the design of practice tasks to increase the likelihood for skill learning and transfer in tennis.

Chapter 5, expands on Chapter 4 by implementing the validated assessment tool and evaluating the representativeness of common practice tasks delivered in elite junior tennis programs. In addition to the qualitative evaluations via the assessment tool, motion capture ball and player movement data is presented for each task as well as for matches played by the same participants. The results highlight that the ball and movement characteristics presented within common practice tasks are not representative of those that are present during matchplay (e.g., players hit the ball faster but from deeper in the court during practice compared to matchplay). Similar to Chapter 3, these findings highlight that the specific constraints being implemented in practice require careful manipulation and even common practice tasks, often considered desirable for skill transfer by coaches, may be developing skills that are less desirable for transfer to competition.

Chapter 6, provides an empirical assessment of the longitudinal benefits of practicing tennis serving tasks considered more or less representative of competition. Pre- and post-serving performances of elite junior tennis players were assessed via a skill test and in-situ matchplay using manual notation and motion capture ball and player tracking, respectively. The results highlighted that changing the constraints of a task to be more or less representative of the constraints of matchplay alters an athletes behaviour in different ways. For example, practice in more representative tasks results in athlete prioritising placement over speed while practicing in lower representative tasks results in athletes prioritising speed over placement when serving 2nd serves in matchplay. This provides initial evidence to suggest that the relationship between increasing task representativeness and increased skill acquisition is not linear, rather the representativeness of a task should be carefully individualised to an athletes specific priorities.

The final chapter of this thesis (Chapter 7) provides a summary and general discussion of the studies conducted. Theoretical, methodological and practical implications of this thesis are considered along with future research directions.

Please note, that each of the chapters in this dissertation have been written with the intention to publish or in some cases have already been published (Chapters 4 & 5). Subsequently the definitions of key terms (e.g., representative learning design, action fidelity and functionality) have been repeated on several occasions.

CHAPTER 2

REVIEW OF LITERATURE

2.1 Introduction

It is common knowledge that athletes spend thousands of hours fine tuning their skills with the goal of enhancing their competitive performances (Ericsson et al., 1993; Macnamara, Moreau, & Hambrick, 2016; Ward, Hodges, Starkes, & Williams, 2007). A mismatch between contemporary theoretical concepts, evidence-based research and traditional coaching approaches is, however, coming to the fore with researchers questioning whether current practice approaches could more effectively simulate the demands (i.e., information and movement) of the competition contexts in which the athletes compete (Davids, Araújo, Correia, & Vilar, 2013; Pinder, Davids, et al., 2011). It is predicted that increased exposure to these types of practice environments will enable athletes to develop skills that are functional and adaptable to changing conditions (Farrow, 2013; Pinder, Davids, et al., 2011; Renshaw, Davids, Shuttleworth, & Chow, 2009).

This review firstly describes the importance of the relationship that an athlete shares with their environment by introducing concepts from ecological dynamics (Araujo, Davids, & Hristovski, 2006; Bernstein, 1967; Davids et al., 2012). Secondly, it considers the current approaches used by coaches to teach and transfer skills to competition and highlights key limitations of these approaches based on emerging research. Third, Representative Learning Design (RLD) is introduced as a tool for enhancing the design of practice tasks through more effectively simulating the demands of competition contexts. Lastly, current methods for assessing skill learning and transfer, namely in the sport of tennis, are evaluated. This analysis of literature demonstrates the importance of maintaining key aspects of the performance context in which an athlete competes (i.e., competition) in practice and discusses the potential consequences for skill acquisition research and coaching application.

2.2 The nature of skill

The development of expertise in sport has remained a keen interest of researchers for decades (for a review see Baker and Farrow, 2015) In light of this interest, researchers have begun to suggest that expert performers consistently display three common traits independent of their domain: (i) they can identify the most critical information sources at the right point in time (i.e., perceive and anticipate), (ii) they can process this information efficiently before deciding on the best course of action (i.e., decision-making) and (iii) they have an ability to perform the specific physical skills fundamental to success in a player's given sport (i.e., superior motor skill execution).

While debate as to how these skills are specifically acquired exists, a commonly held view is that they are developed through prolonged exposure to context-specific information specific to the domain in which they perform. That is, the performer shares a close coupling with their environment (Brunswik, 1943; Davids et al., 2012; Newell, 1986). This is certainly supported via research highlighting that differences between experts and their less-skilled counterparts are not related to physical and/or cognitive abilities but rather learned capacities resulting from their considerable experience playing their sport (see Abernethy & Russell, 1987; Allard & Starkes, 1980; Williams & Davids, 1998). For example, it has been highlighted that there is greater likelihood of identifying the advantages (e.g., reduced anticipatory response times and superior decision-making) that experts possess over their less-skilled counterparts when conducting investigations requiring performances that more closely simulate actual competition environments (Abernethy, Thomas, & Thomas, 1993; Mann et al., 2007; Williams & Davids, 1998). That is, larger differences in expert advantage are reported when the performer is submersed in field-based environments, followed by watching video recordings of competition, and then looking at static images of competition scenarios (for a meta-analysis see Mann et al., 2007). Above all else, this research highlights that the relationship an athlete shares with their environment is critical to the development of sport-specific skill and expertise.

In an attempt to improve the understanding of the relationship that a person shares with their environment behavioural psychologists have operationally defined skill. Namely, Guthrie (1935) was one of the first to define ‘skill’ (p. 162):

“Skill consists in the ability to bring about some predetermined results with maximum certainty, and the minimum outlay of energy.”

Over time however, researchers have suggested that this and similar definitions (Johnson, 1961; Knapp, 1963; Whiting & Zernicke, 1982) are inadequate given they reflect only the emergent properties of skill behaviour and do not capture the organizational properties of the motor system, relative to the performance environment, which is required for skilled performances. Rather Newell (1985) suggested that the ecological approach of Bernstein (1967) and Kugler, Kelso, and Turvey (1980) should be operationalised (i.e., move away from mathematical functions) to provide a more in depth understanding of how skills are acquired.

The general theoretical approach proposed by Newell (1985) suggests that movement solutions should be viewed as emergent features of various constraints imposed on action, rather than as a prescription for action specified in advance of movement execution. Using this approach it is predicted that skill expertise is developed through progressive increased attunement to context-specific information and subsequent opportunities to optimise successful movement outcomes over time (Flach, Lintern, & Larish, 1990; Newell, 1985). Ecological dynamics combines ideas

(Flach, Lintern, & Larish, 1990; Newell, 1985). Ecological dynamics combines ideas from ecological psychology and dynamical systems theory, to provide an explanation of how individuals interact with ever changing environments (Araujo et al., 2006; Davids et al., 2012; Passos & Davids, 2015). Application of ecological dynamics to a sporting context requires that the individual (i.e., athlete) and their environment be considered as one interacting system, whereby functional patterns of athlete behaviour emerge from interactions with their performance environment over time (Araujo, Davids, & Passos, 2007; Gibson, 1979). Worded in another way, it is predicted that the perception of information available to an athlete within their performance environment provides context-specific affordances (i.e., opportunities for action) that continuously shape their behaviour. An athletes' movement behaviour therefore emerges from the self-organisation of a wide range of interacting constraints (i.e., the boundaries or features that promote or limit movement).

Newell (1986) proposed that there are three categories of constraints that interact to determine opportunity for emergent behaviours: organismic (individual), environmental and task constraints. Specifically, organismic constraints refer to characteristics of the athlete such as their age, gender, physical capacities, which precludes the performance of skills (e.g., one player may not be capable of hitting a tennis serve as fast as another player due to having less muscle mass or a less efficient technique). Environmental constraints refer to the characteristics of the environment in which the movement is performed (e.g., the behaviours of an opponent/teammates, weather conditions and/or crowd noises). Task constraints are physical constraints placed upon a task (e.g., goals of a specific task, rules of the sport and/or equipment being used in that sport). Importantly, the interactions of these constraints determine any number of affordances an individual can perform whilst continuously shaping patterns (Davids, Araújo, Vilar, Renshaw, & Pinder, 2013; Gibson, 1979; Newell, 1991). For example, in soccer, an unmarked teammate may afford the opportunity to make a pass for the ball carrier, however, the distance and difficulty of the pass may limit such a passing option to only some athletes (i.e., a young developing athlete is unlikely to have the same physical strength or skill to pass a ball 20-30m that a professional soccer player has – thus making this affordance redundant relative to their own set of skills).

Sport practitioners have begun to adopt a 'constraints-based' approach to improve the design of practice tasks arguing that skill transfer between contexts occurs due to the similarity between a learned behaviour and a behaviour required in a new context to achieve the task goal (Davids et al., 2012). Contributing to this theory, researchers have evaluated the interactions an athletes shares with their environment, through the observation of athlete responses to a variety of off-field (e.g., visual anticipation tasks – Broadbent et al., 2013; Farrow, 2013) and in-situ sport-specific tasks (e.g., eye tracking and movement outcomes – see Oppici et al., 2017) across a wide range of skill levels. More specifically, research has highlighted that when the constraints imposed on an athlete more closely simulate the constraints of competition the athletes responses will more closely the simulate those required during competition performances. Specific examples can be found in cricket (Pinder, Davids, et al., 2011), diving (Barris et al., 2013) and soccer (Travassos et al., 2012). These findings remain consistent with the approach that the athlete and their environment should be considered as a dynamical system (Warren, 2006). Moreover, it is also worth to noting that small changes to even a single constraint, such as reducing the size of a playing area, can result in significant changes to an athlete's performance (e.g., increase in decision-making due to greater player-to-player densities – see Timmerman, Farrow, & Savelsbergh, 2017).

The ability of an athlete to perceive and act (often referred to as perception and action) remains a critical factor for sporting success (Le Runigo, Benguigui, & Bardy, 2005; Warren, 2006). For example, the availability of an opponents movement kinematics in interceptive sports such as cricket or tennis provides critical information required to ensure movement to the correct spot, at the correct time, to make appropriate ball contact (Davids, Kingsbury, Bennett, & Handford, 2001; Loffing & Hagemann, 2014). Equally, sailors are required to constantly adjust their actions relative to changing weather conditions (Pluijms, Cañal-Bruland, Kats, & Savelsbergh, 2013). Alternatively, as a case in point, Correia et al. (2012) assessed the emergent decision-making and actions of youth rugby players in a 1 attacker vs 2 defender task to provide an example of the relationship an athlete shares with their environment. This was investigated by manipulating the starting point (i.e., distances between) each attacker and defender relative to the try-line. Interestingly, as distance increased between the defenders and attackers, defenders showed a greater tendency to stay close to the try-line. When the distance between attackers and defenders decreased, this trend was reversed, with defenders more likely to advance towards the attacker away from the try line. Lastly, when the distance between the two defenders was increased, the defenders showed a tendency to move towards each other to close the gap available to the attacker to pass through. Similar has also been shown in tennis whereby players are known to couple the direction and angle of their serve away from their opponent (Whiteside & Reid, 2016) and also couple their own court positions to the relative position of their opponent (Carvalho et al., 2013). These studies provide critical insights into the interpersonal interactions a performer shares with their opponents and teammates. Concurrently, it is hypothesised that failing to represent similar relationships in practice could hinder the transfer of learnt skills to competition (Davids, Araújo, Correia, et al., 2013; Pinder, Davids, et al., 2011). A common example of this is in tennis, whereby serving practice is often isolated without a returner, despite as highlighted above, the returner being a critical source of information used by the server to couple their serving behaviour.

To summarise, this thesis will therefore consider 'skill' as the requirement for a learner to: (1) learn to perceive and process the most critical information sources from their performance environment and (2) develop stable coordination patterns that can be adapted and performed in a functional and economic way under dynamic environments with changing informational sources (Davids et al., 2012). With support from the ecological dynamics framework (Araujo et al., 2006; Davids et al., 2012; Davids, Araújo, Vilar, et al., 2013) this thesis proposes the following definition of skill:

"The refinement of adaptive processes, achieved by perceiving key properties from the performance environment in the scale of the performers own body and action."

Moreover, consistent with recommendations proposed by ecological psychologists that an athlete and their environment are a dynamical system, a general recommendation for teaching skills is to provide opportunities for athletes to perceive and act as they would during competition (Brunswik, 1943, 1955; Davids, Araújo, Correia, et al., 2013). More specifically, when manipulating the constraints of a practice task, only constraints available during age and skill-appropriate competition performances should be altered. Altering other constraints may result in an athlete becoming perceptually attuned to affordances that may not be functional during competition (Correia et al., 2012; Pluijms et al., 2013). To promote enhanced learning and transfer of skills, this thesis will therefore advocate that practice tasks should be designed to provide athletes the opportunity to become attuned to the specifying information sources available in their performance environment.

2.3 Understanding of current practice designs

Initial attempts to quantify the practice required to develop expertise has lead researchers and practitioners to unintentionally over-emphasise the 'quantity' rather than the 'type or quality' of practice required to reach expert levels of performance (see – deliberate practice theory; Ericsson et al. 1993). For example, a benchmark of 10,000 hours of deliberate practice was initially discussed as a requirement for a performer to reach expertise (Ericsson, 2013; Gladwell, 2008; Güllich, 2014). This benchmark, however, remains contentious given that the deliberate practice theory always articulated that the quality of practice (albeit via very general guidelines) should not be overlooked (Ericsson, 2013; Ericsson et al., 1993). More recently Hambrick et al. (2014) undertook a meta-analysis of the two most widely researched domains in expertise research (music and chess) and identified there to be an enormous amount of variability in the hours of deliberate practice undertaken by performers before reaching expertise. Using chess as an example, some players took <2,500 hours to reach a level considered to be 'expert' while other players took >22,500 hours of practice. As such, the practice required to develop expert performance is dynamic and remains highly dependent on the quality of practice tasks not just quantity, as has previously been interpreted.

In a quest to better understand the types/qualities of practice most critical to an athlete's development, the opinions of elite athletes and coaches have been sought (Deakin & Cobley, 2003; Slade et al., 2015). Of particular interest is the acknowledgement that elite and sub-elite figure skaters identified that practice activities highly related to actual competition performance are most critical to their improvement (Deakin & Cobley, 2003). Similar, ideas have also been shared in the sport of field hockey (Slade et al., 2015), whereby senior international coaches cite: *"practice structure needs to reflect what we see happening in the game"* (Slade et al., 2015, p. 663). Intuitively, these learning's highlight that elite coach and player perceptions align closely with the key principles of ecological dynamics (i.e., practice closely aligned to competition is more likely to result in superior skill learning and transfer (Davids et al., 2012; Davids, Araújo, Vilar, et al., 2013; Renshaw et al., 2009)).

In contrast to the abovementioned elite athlete and coach opinions, observations of the actual practice being undertaken by youth athletes (sub-elite to elite level) highlight that over two thirds of an athlete's total practice time in a variety of sports is spent in 'drill-based' practice tasks (i.e., tasks that typically do not simulate the same information available to an athlete in competition). Specifically, Figure 2.1 provides example breakdowns of practice times in the sports of soccer and cricket, but similar trends have also been shown in wrestling, field hockey, ice-skating and soccer (Starkes, 2000; Starkes & Hodges, 1998). Problematically, these findings highlight a significant gap between what coaches, athletes and researchers acknowledge as the most important type of practice to increase learning and transfer and what is being applied in the field. A major limitation, however, of these practice evaluations is that they did not assess the specific design of individual tasks (i.e., how closely they simulate competition contexts) and instead used broad definitions capturing only two types of task (i.e., drill- and game-based) that lack validation. Nonetheless, it appears there is a need for researchers to provide tools and ideas for improving current practice designs which align more closely with the needs of a coach (i.e., time-efficient on-court assessments).

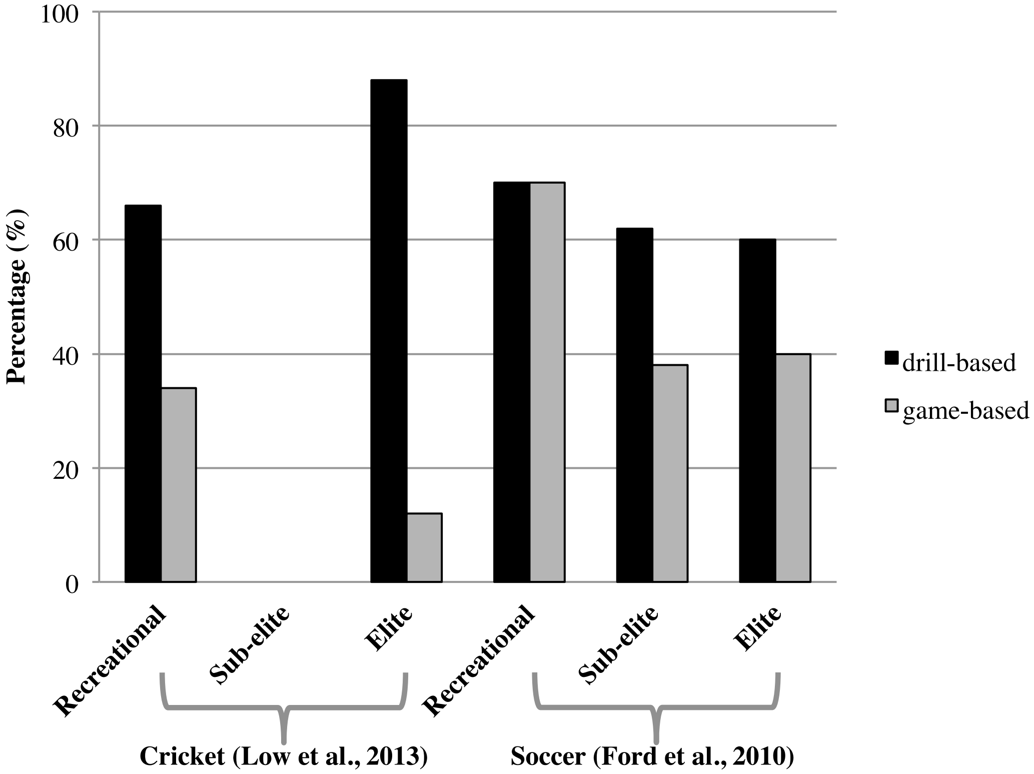

Figure 2.1 Percentage of practice time spent in drill-based versus game-based practice tasks by sub-elite and elite 9-17 year old athletes.
Note, presented results have been summarised from Low et al. (2013) and Ford et al. (2010); drill-based tasks = fitness activity, technique or skill practice; game-based tasks = phase of play or small-sided games/conditioned games).

Consistent with the above observations, the sport of tennis also provides practical examples of these concerns, whereby it is acknowledged that tennis practice is based on tradition and intuition rather than empirical evidence (Reid et al., 2007). Reinforcing such claims is current coaching tools, such as Tennis Australia's athlete development matrix (Tennis Australia, 2007) and the United States Tennis Association's coaching philosophy guidelines (United States Tennis Association, 2004). These resources primarily provide information related to the 'quantity or volume' as opposed to the 'quality' of practice necessary to attain high levels of skill performance. In particular, there appears to be an overemphasis on describing the attributes of a quality technique in isolation as opposed to the quality of practice design required to develop such techniques. Furthermore, when inferences are made to the types of task recommended for developing sport-specific skills they often align with tendencies considered reductionist under an ecological framework (Davids, Araújo, Vilar, et al., 2013). That is, recommendations mostly highlight a preference for drill-based tasks to be designed in a simplistic and highly controlled manner that focus on technical outcomes, generally of one skill at a time. For example the USTA provide the following recommendation for a task to work on 'volley technique':

"Drill 2…. Hitting firm volleys with good footwork and proper technique without swinging. 5 minutes each on 1 side doing different volley patterns" (United States Tennis Association, 2018, p. 22).

This is particularly concerning given the USTA (and Tennis Australia) are often considered world leaders in coach education, with other smaller tennis federations likely using these programs as a resource to guide their own 'best practice'. Moreover, consistent with the concern of researchers (Farrow & Robertson, 2016; Reid et al., 2007) origins of such tools appear to be founded on emulation and anecdote, often highlighted among popular culture (Coyle, 2010; Gladwell, 2008; Kottke, Halpern, Easton, Ozel, & Burrill, 1978). This raises the prospect that current practice in tennis across the globe is potentially inefficient, sub-optimal and therein inadvertently impeding skill learning and transfer. To date, however, no comprehensive evaluations of the specific microstructures of practice undertaken by tennis players exist. Accordingly, it is difficult to substantiate the above claims that tennis coaches prioritise drill-based practice tasks over tasks considered to be more representative of competition.

2.4 Types of drill-based practice

Drill-based practice tasks are often referred to as displaying one or more of the below key traits: (i) tasks de-couple critical information required for perception and action of practiced skills in competition, (ii) complex motor skills are decomposed into their smaller constituent parts and/or (iii) skills are scheduled to maximise repetitions of the same skill versus changes between skills or variations within the same skill. While the reason coaches tend to design tasks in this way remains unsubstantiated it is predicted that coaches believe emphasizing mechanical consistency (over adaptability) will produce more stable solutions in the performance context (Farrow, Baker, & MacMahon, 2013; Reid et al., 2015; Reid, Whiteside, Gilbin, & Elliott, 2013). Alternatively drill-based tasks may remain favoured by coaches and athletes due it being easier to explicitly focus on performing a single solution (i.e., technical outcome) and/or elicit greater in-task performance, which consequently reflects positively on the coach and the athlete's confidence (Handford, Davids, Bennett, & Button, 1997).

In opposition to coach ideology, researchers have highlighted that variable movement solutions are functional facets of performance, even among athletes competing at the highest-level in their respective domains including, grand slam tennis (Reid, Whiteside, & Elliott, 2010; Whiteside, Giblin, & Reid, 2014), Olympic long jumping (Wu, Porter, Partridge, Young, & Newman, 2012) and Olympic spring board diving (Barris et al., 2013). The development of consistent movement solutions therefore appears counterintuitive. Certainly at least this is consistent with research which has shown that practice in repetitive drill-based tasks aimed at 'perfecting' movement outcomes can contribute to undesirable movement solutions (Barris et al., 2013; Pinder et al., 2009; Reid et al., 2013). Intuitively, over practicing in drill-based tasks may pose significant implications for learning, each of which are discussed in detail below.

2.4.1 Decoupling of perception-action vs. task simplification

A prevailing concern among researchers is that coaches continue to deliver practice tasks that are devoid of the contextual information sources required for performance of the practiced skills in competition (Davids, Araújo, Vilar, et al., 2013; Pinder, Davids, et al., 2011; Renshaw, Oldham, Davids, & Golds, 2007). One common example is the use of ball machines in interceptive sports such as tennis, cricket and baseball to supplement increased volumes of hitting practice, particularly when no opponents are available. While the use of these machines may be necessary in some contexts (e.g., managing concerns for overload of bowlers in cricket) their use removes perceptual pre-flight cues (e.g., opponents kinematics) used by the performer to coordinate their movements, which may subsequently reduce the acquisition of functional movement patterns (Gibson & Adams, 1989; Pinder et al., 2009; Shim et al., 2005). For example, Pinder et al., (2009) investigated this issue by conducting a cross-sectional assessment of the timing and coordination of forward defensive and forward drive strokes among elite developing cricket batsmen when facing a machine and live bowler. It was found that batting against a ball machine led to significant differences in the movement timing and initiation of bat backswing, front foot movement/placement and bat downswings. To summarise, players adopted a more defensive approach against the machine compared to a live bowler, which is considered less functional for performance during actual competition.

In contrast to decoupling perception and action opportunities in practice, it has been proposed that coaches instead design tasks that require the performer to practice the desired skills in environments that simplify the contextual information presented to the athlete (Renshaw et al., 2016). This supports the performer to use information that is functionally relevant to their decisions and to perform actions that are expected and desirable in competition performances (Pinder, Davids, et al., 2011; Pinder et al., 2009). Examples of task simplifications exist in many sports and are often achieved through the manipulation of task rules (Renshaw, Chow, Davids, & Hammond, 2010), equipment (Araújo, Davids, Bennett, Button, & Chapman, 2004; Buszard, Farrow, Reid, & Masters, 2014; Timmerman et al., 2015) and/or player densities (Timmerman, Farrow, & Savelsbergh, 2017). Terms commonly used by researchers and coaches to describe these type of tasks are 'small-sided' or 'modified' games (Davids, Araújo, Correia, et al., 2013).

Fundamentally, the main benefit of task simplification is the ability to maintain and manipulate the relationship that exists between an athlete, their opponent and other teammates (Davids, Araújo, Correia, et al., 2013). For example, in soccer (Silva, Garganta, Santos, & Teoldo, 2014), 3v3 games promote more aggressive decision-making behaviours that result in 1v1 duels and subsequently make it easier for players to beat defensive lines. Alternatively, 6v6 games encourage safer behaviours encouraging more collaborative team actions to beat the opponent's defense. Similarly, an increase in the number of teammates from 3 to 7 (3v4, 5v4 and 7v4) also promotes more offensive actions (Torrents et al., 2016), while decreasing the number of teammates from 7 to 3 (7v4, 5v4 and 3v4) results in players becoming more defensive with their own actions and being more attentive to their opponents' behaviours (Ric et al., 2017). Knowledge of such outcomes can assist coaches to strategically plan practice tasks that maintain key perception-action couplings but also promote behaviours that are competition-ready (e.g., attacking or defensive behaviours). In individual sports, the dyadic relationship that the player shares with their opponent remains equally as important given that a simple interruption to the dyad can impact the outcome of the point (Carvalho et al., 2013). The frequency in which these tasks are used, however, remains infrequent.

2.4.2 Task decomposition

In an effort to simplify the learning process coaches will often decompose more complex motor skills into smaller less complex parts (Davids et al., 2001). The main aim of task decomposition is to improve the consistency of each smaller part, so that when re-assembled the consistency gained in each part is carried over to the larger more complex movement itself (Davids et al., 2003). Specific examples of decomposing complex motor skills is practicing the ball toss without actually striking a ball in volleyball (Davids et al., 2001) and/or practicing the run-up separately to the jump in the sport of long jumping (Montagne, Cornus, Glize, Quaine, & Laurent, 2000). The decomposition of complex motor skills in this manner is thought to result in athletes reconstructing movements considered arbitrary in relation to those required for competition performance (Renshaw et al., 2007).

As a case in point, Barris et al. (2013) evaluated how a diver's movement kinematics differed when required to dive into a foam pit versus water – a task typically used by divers to practice smaller components of a dive before reconstructing them in full in the aquatic environment. In this study, a typical practice environment was emulated through the delivery of two tasks with each task requiring the athlete to perform the same springboard takeoff phase. The aerial component of the dive (i.e., after take off to landing), however, was adjusted to allow for a feet-first land in the foam pit (single somersault) as opposed to a wrist-first landing into the water (2 ½ somersault). As predicted, the kinematics of athletes performing each dive differed significantly with the aquatic dives typically displaying greater step lengths, jump heights and board depressions – of which were likely due to the additional 1 ½ somersaults required in the aquatic condition. Nonetheless, this study confirms that decoupling tasks from key elements of the performance environment (i.e., replacing water with foam), and decomposing parts of the movement (i.e., landing feet-first versus wrist-first) results in movement solutions that are less generalisable and transferable to a competition context.

The decomposition of complex motor skills is also common in tennis. In tennis, no motor skill is more complex than the serve. Traditionally one way coaches have taught this skill is by rehearsing the ball toss independent of the swing and vice versa (Reid et al., 2010). It has been shown that when the ball toss is practiced alone, athletes toss the ball significantly higher and with more peak rotation than when they complete the full service action inclusive of ball contact (Reid et al., 2010). Equally, the variability of the throw actually increases when practiced in isolation from the swing - directly opposing the reason that athletes utilise this activity (i.e., to improve ball toss consistency (Reid et al., 2010; Whiteside et al., 2014)). Similarly, when practicing the service swing in isolation (without a ball) athletes use less aggressive trunk and lower limb involvements compared to performing the full service action (Reid et al., 2010). Other tennis-specific examples include isolating the upper body from leg drive by serving from a kneeling position (Reid et al., 2013) and even using the overarm throw in an attempt to infer skill transfer to the serve (Reid et al., 2015).

The unconditional use of skill decomposition by coaches and sport practitioners therefore remains a concern given the clear mismatch between the movement kinematics presented in decomposed versions of a skill and those required during actual competition performances. The routine use of skill decomposition is therefore predicted to hinder, rather than promote, the development and transfer of skills to competition (Davids et al., 2001; Reid et al., 2010; Renshaw et al., 2007). Nonetheless, a current limitation of assessments is they have typically used small homogenous samples (i.e., elite senior or elite developing athletes) and have only appraised the immediate biomechanical effects of task decomposition rather than exploring implications for learning and transfer over longer time scales.

2.4.3 Distribution of practice

It is well acknowledged that the arrangement and/or practice sequencing of skills within a task can elicit improved learning outcomes when appropriately tailored to the proficiency of an athlete (Barreiros, Figueiredo, & Godinho, 2007; Van Rossum, 1990). Initially researchers described this phenomenon through the practice variability hypothesis (Van Rossum, 1990) and contextual interference effect (Barreiros et al., 2007; Brady, 2004, 2008). Both approaches outline the same key message that practicing multiple variations of the same skill and/or changing between different skills in the same practice task will reduce in practice performance but enhance skill learning and transfer (Brady, 2004, 2008). Generally these recommendations have been supported via a range of studies across multiple skill levels, age groups and sports including golf putting and basketball shooting (Porter & Magill, 2010), tennis serving (Buszard, Reid, Krause, Kovalchik, & Farrow, 2017), tennis groundstrokes (Farrow & Maschette, 1997; Hebert, Landin, & Solmon, 1996) and baseball batting (Hall, Domingues, & Cavazos, 1994). These studies did however identify that the acquisition of each skill was not necessarily always greater when more skill variations were performed, rather a threshold exists whereby the number of skill variations can be too high and subsequently hinder learning. Further tests, however, revealed that learning could be optimised through programs individualised to the skill level of the performer and gradually increasing the number of variations as skill level increases (Hodges, Edwards, Luttin, & Bowcock, 2011; Saemi, Porter, Ghotbi Varzaneh, Zarghami, & Shafinia, 2012).

Recently, Buszard et al. (2017) adopted two new terms to better describe the types of variability an athlete experiences during actual performance: ‘between-skill variability’ was used to describe the switching between different skills during practice (e.g., switching between a serve and forehand in tennis) and ‘within-skill variability’ to describe switches between variations of the same skill (e.g., hitting a T serve followed by wide serve in tennis). Similar to the concepts of contextual interference and practice variability, it can then be assumed that learning will be enhanced when within- and/or between-skill variability are tailored appropriately to the learner’s ability. These new terms also align closely with the types of skill variations observed during competition contexts in most sports (i.e., athletes are constantly required to switch within and between skills). This is obviously common in tennis, where each skill can be manipulated in multiple ways while every point requires players to swap between a serve or return and groundstroke. Accordingly, the terms within-skill and between-skill variability will be adopted in this thesis.

It remains evident that another characteristic of drill-based practice in sport is for coaches and athletes to set specific goals for improving skills one at a time (Memmert, 2015). Arguably, this compromises opportunities to practice under high levels of between-skill, and to a lesser extent, within-skill variability. This is certainly evident in the sports of soccer and tennis whereby athletes have been reported to practice the same skill in large blocks at any given time (Buszard et al., 2017;

Williams & Hodges, 2005). Higher levels of within-skill variability, however, appear to occur more naturally during practice. As a case in point, Buszard et al. (2017) analysed the serving performances of nine elite junior tennis players and found that six of the players practiced the serve with no between-skill variability in over half their practices (i.e., they served without hitting any other shots). Conversely, 93% of drills featured moderate to high levels of within-skill variability (i.e., within-skill variability metric $\geq$ 0.50 – see Buszard et al., 2017) as players routinely varied the direction of their serves (i.e., wide, body or T). The variability of practice, or lack thereof, remains a major concern for tennis practice and as such will be assessed throughout this thesis.

2.5 Representative Learning Design as a tool for assessing and improving the design of practice

The term 'representative design' was first proposed by ecological psychologist Egon Brunswik (1955, 1956) as a means to advocate the study of psychological processes at the level of organism-environment relations and emphasised the need to design experimental tasks that sample stimuli from the environment to ensure the environmental properties (i.e., information) of such contexts are preserved. Brunswik's theory could then be closely aligned to Gibson's (1979) theory of direct perception, which emphasises that performers share a tight coupling of perception and action with their environment (i.e., information drives movement which further informs an athletes action). Consistent with the start of this review, these two frameworks were adopted by sport scientists and psychologists to study adaptive movement behaviours in sport and physical activity (Araujo & Davids, 2009; Beek, Jacobs, Daffertshofer, & Huys, 2003; Davids & Bennett, 2008). In an attempt to consolidate the application of these theories and provide a formalised framework for assessing and enhancing the design of practice and experimental tasks, Representative Learning Design (RLD) was proposed for use by coaches, researchers and sport scientists (Pinder, Davids, et al., 2011).

RLD provides a framework for assessing the extent to which practice and experimental tasks are representative of a situation of interest (e.g., an athlete's competition context). Under the ecological dynamics framework, tasks high in representativeness will ensure that the critical relationships that athletes share with their competition environment are maintained in practice. Worded in another way, task designs that do not represent the performance environment: (i) may not sample the critical information sources required for performance of the practiced skills in competition and (ii) may not support the development of functional training tasks which achieve these goals (Davids, Araújo, Vilar, et al., 2013). To assist in evaluating task representativeness, RLD proposes the adoption of two key terms: functionality and action fidelity (Pinder, Davids, et al., 2011).

Functionality provides a measure of the degree to which an athlete can use the same information sources (i.e., visual cues) present during competition to contextualise their decisions and movement to achieve a similar level of success in practice as to what is expected in competition (Pinder, Renshaw, et al., 2011). For instance, competing against a ball machine is as a task low in functionality given it decouples the information-movement couplings (e.g., pre-perceptual ball flight information) inherent to competition (Pinder, Headrick, & Oudejans, 2015; Pinder et al., 2009; Shim et al., 2005). While, in tennis, asking a coach to 'feed' a ball using their racquet (in replace of a machine) could improve the functionality of this task by providing pre-perceptual ball flight information, the specific context of the information presented to an athlete must also be considered when assessing the functionality of a task (Pinder, Davids, et al., 2011). That is, additional information such as the speed, spin and specific court position from which the ball is fed is integral to the functionality of a task (Loffing, Sölter, Hagemann, & Strauss, 2016). For example, a coach feed originating from 1m behind the baseline with lots of speed and spin that imitates an opponent's groundstroke is likely to be much higher in task functionality than a feed originating from outside the boundaries of the court, close to the net with low speed and/or spin, given the latter scenario is unlikely to occur in competition. To draw upon scenarios from team ball sports; functional context-specific performance settings are achieved through the implementation of game-based practice tasks and scrimmages requiring players to compete against each other (i.e., as opposed to completing a task controlled by a coach (Chow et al., 2007; Renshaw et al., 2010; Roth, 2012).

To compliment assessments of functionality, action fidelity refers directly to the movement and outcomes of performances. Action fidelity was first conceptualised by Stoffregen, Bardy, Smart, and Pagulayan (2003) in flight simulations to describe the similarity between behaviour in an experimental task with that of the related performance setting. Tasks high in fidelity require that there is a transfer of performance from the simulator to the simulated system (Stoffregen, 2007; Stoffregen et al., 2003). In a sporting sense, action fidelity refers to the degree to which an athlete's movement behaviour (e.g., spatiotemporal kinematics) during practice replicates those of competition (Araujo et al., 2007; Pinder, Davids, et al., 2011; Stoffregen et al., 2003). In tennis, a task low in action fidelity would be the prescription of overhand-throw practice to infer transfer benefits to the serve (Reid et al., 2015). The degree of action fidelity can be measured by analysing the specific performance of an athlete in detail via task outcomes such as the similarity between movement outcomes, time taken to complete a task, and/or observing the spatiotemporal coordination of an athlete's movement (Araujo et al., 2007; Travassos et al., 2012). Indeed, spatiotemporal coordination has been a major focus in sport science research evaluating the efficacy of drill-based practice tasks devoid of contextual information such the abovementioned ball machine hitting/batting practice in tennis and cricket (Pinder et al., 2009; Shim et al., 2005), diving into foam versus water (Barris et al., 2013) and decomposed versions of the tennis serve (Reid et al., 2015; Reid et al., 2010; Whiteside et al., 2014). A limitation of the current methods used to assess action fidelity however is that they remain time-consuming and/or invasive due to the requirement for the use of biomechanical markers for measurement precision. Moreover, these assessments have only focused on assessing movement outcomes in conditions considered to be 'more representative' of performance contexts rather than performances during actual simulated or real competition play.

In an attempt to operationalise the concepts of functionality and action fidelity Slade et al. (2015) developed a sport-specific assessment tool for assessing the design of goal-shooting tasks in field hockey. This tool established two main criteria (activity type and representativeness of play) for replicating opportunities for field goals in hockey matchplay. Furthermore, practice tasks were classified into 4 main activity types: fast break, general-team build-up, turnover of possession and break down of the penalty corner set play. Task representativeness was assessed in relation to pre-shot play, position in the shooting circle, number of players involved, types of shot, opportunities for decision-making and defensive role of attackers (Slade et al., 2015, p. 665). These criteria proved effective in assessing the representativeness of field shooting activities in relation to the perceptual, technical, tactical and contextual aspects of the performance context. A major limitation of this work is the tool lacked objective validation, and is only applicable to one type of sport-specific activity (i.e., field goal shooting in hockey). Validated tools would still need to be grounded in an appropriate evidence base and easily implemented in practice.

2.5.1 Empirical evidence supporting the design of more representative tasks

To date, the premise that more representative practice opportunities can result in increased skill learning and transfer are primarily based on findings from cross-sectional interventions. Three studies have been the main focus of such predictions: (i) Pinder et al. (2009) and their work in cricket, (ii) Barris et al. (2013) and their work on diving and (iii) Travassos et al. (2012) and their work in futsal. Specifically, Travasoss et al. (2012) provides a practical example of how the representativeness of basic futsal practice drills can be measured and then improved by manipulating the fidelity of possibilities for action (i.e., number of passing options). The study involved eight senior futsal players performing four different passing tasks (see Figure 2.2). Passing speed and accuracy within these tasks was compared against pre-recorded footage of the same athletes in competition. Importantly, the findings highlighted that players displayed behaviours more representative of those expected in competition as the number of passing opportunities in the practice drills were increased. That is, as the number of passing options increased from 1 to 3 per player (i.e., players progressed from conditions from drills 1 to 4, see Figure 2.2), the speed at which players passed the ball decreased from 4.3 to 3.8 m/s, while the number of passes successfully landing with a teammate also decreased from 80% to 37%. These were much closer to those observed during pre-recorded matchplay footage (i.e., ball speed = 3.6 m/s and accuracy = 42%).

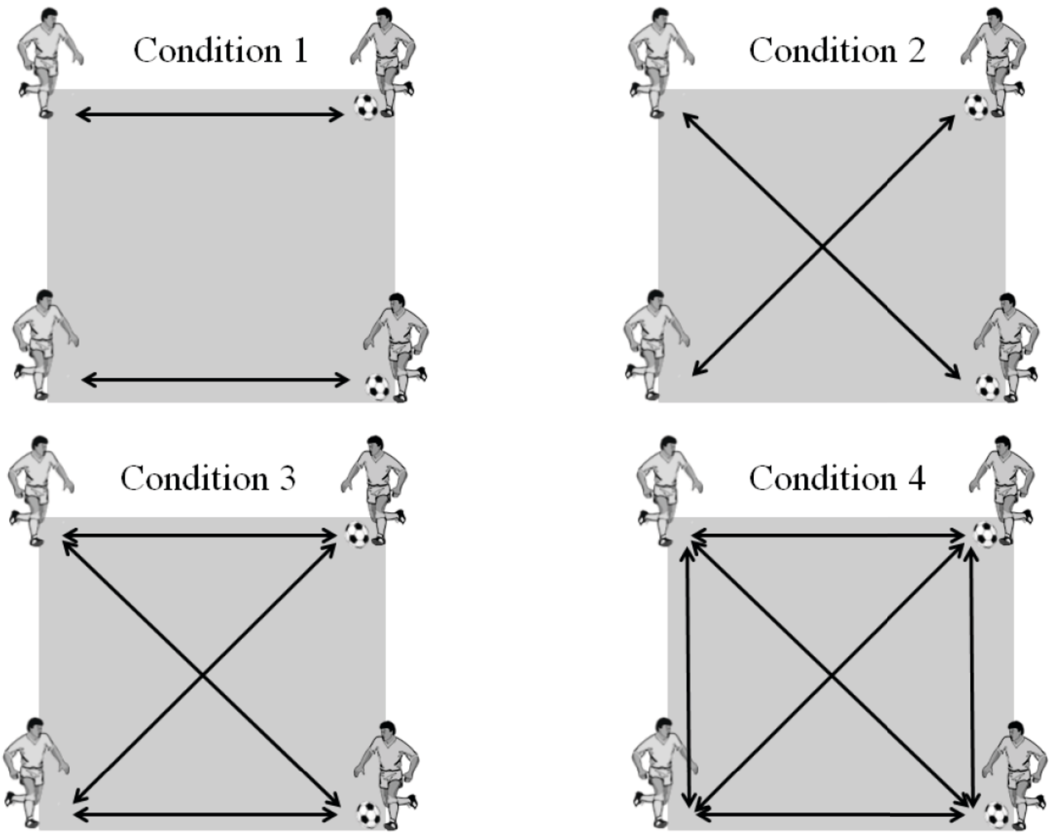

Figure 2.2 Research protocol used by Travassoss et al. (2012) to manipulate ball carriers passing possibilities.
Note, figure re-printed from Travassos et al. (2012); condition 1 - pass predetermined to the front teammate; condition 2 - pass predetermined to the diagonal teammate; condition 3 - emergent pass to one of the players who did not have possession of the ball, positioned in front or diagonally; condition 4 – emergent pass to one of the players who did not have possession of the ball, positioned in front, diagonally or laterally.

Complimenting this cross-sectional work is a more recent study by Oppici, Panchuk, Serpiello, and Farrow (2017), which explored the long-term impact of practicing under different task constraints. Unique to this study, a set of pre-determined criteria determined two experimental groups comprised of athletes with > 1000 hours of exposure to structured practice in (i) soccer-specific or (ii) futsal-specific task constraints. Athletes with practice across both team sports were excluded from the study. When the athletes from each group were exposed to experimental tasks with the same task constraints (i.e., a 6 vs. 6 small-sided game), differences in the players’ perceptual skills were identified (i.e., the futsal athletes alternated their attention up to 40% more frequently between the ball and their opponent when they had the ball in their possession). Alternatively, the soccer players attended to cues in the environment up to 25% more often than futsal players. Intuitively, this supports the notion that increased-exposure to context-specific performances (i.e., more representative practice) may promote the development of skills more efficient for their indented performance environment (Araujo et al., 2006; Araujo et al., 2007; Davids et al., 2012).

Despite the abovementioned cross-sectional observations providing initial evidence to suggest that practice in more representative tasks could be beneficial for enhanced learning and transfer, further experimental investigations are needed. To improve the understanding of the relationship between representative practice, learning and transfer, two key limitations must be overcome: (i) comparisons of athlete behaviour in practice are rarely drawn against performances during actual competition, and (ii) the actual learning benefits gained from prolonged exposure to more representative practice conditions as compared to less representative tasks remains un-quantified. As such, at this point in time, RLD proves to be a promising framework for enhancing the design of experimental and practice tasks, but further empirical research is required. The current lack of empirical evidence quantifying changes to the acquisition and transfer of skills across different timescales following practice in tasks considered to be more or less representative, therefore, limits the translation of the prediction that more representative practice is better (Pinder, Davids, et al., 2011). Understandably, however, academics continue to suggest that interventions of this nature remain ‘difficult’, ‘time consuming’ and/or ‘require significant funding’ to adequately resource a project that can maintain the required levels of experimental control necessary to quantify such predictions (Abernethy et al., 1993; Farrow & Baker, 2015; Pinder et al., 2015)

2.5.2 Developmental and gender considerations for the design of representative practice tasks

It is important to acknowledge that when implementing RLD into practice, practitioners need to ensure that the information presented to an athlete is developmentally appropriate and representative of the context in which *they* compete. For example, in the sport of tennis, the best junior athletes in the world hit the ball on average 7-21 kph slower on serves and 1-6 kph slower during general play compared to their adult counterparts (Kovalchik & Reid, 2017). Similarly, in team sports including rugby (Gabbett, 2002), soccer (Stølen, Chamari, Castagna, & Wisløff, 2005) and Australian Football (Veale, Pearce, Buttifant, & Carlson, 2010), it is known that the physical characteristics of adult and junior athletes differ significantly. Namely, adults are significantly stronger and have superior aerobic capacities (e.g., adult rugby union players can run up to 22% faster over 10, 20 and 40m, have up to 30% greater aerobic capacities (V02 max) and can jump up to 70% higher than juniors – see Gabbett, 2002). Accordingly, it seems logical that the representativeness of a task is based on an ecological framework (i.e., interacting constraints on action) and is scaled to the age and proficiency of the learner (Pinder, Renshaw, & Davids, 2013). A general recommendation for scaling tasks is therefore to increase task complexity as skill proficiency increases (Ford et al., 2010; Pinder, Davids, et al., 2011). Moreover, providing as many opportunities as possible for athletes to compete against athletes of a similar age and/or ability is also important to ensure that they remain adequately challenged (Guadagnoli & Lee, 2004).

Tennis Australia's Hotshots program for children 10 years and under provides the perfect example of how learning can be advocated via scaled down versions of the adult game (Tennis Australia, 2018). Specifically, Hotshots provides recommendations for the use of reduced net heights, court dimensions, racquet lengths and lower ball compressions. Importantly, through the use of scaled equipment athletes playing these games are able to explore functional solutions (e.g., how to maintain a rally) considered beneficial for future performances in the adult game. For example, it is known that the scaling of equipment enables players to strike the ball harder with better technique, have longer rally lengths and ultimately enjoy the sport more (Buszard et al., 2014; Timmerman et al., 2015). Despite Hot Shots having a specific focus for 10 and under athletes, its principles also have implications for enhancing the design of practice tasks in adult sport too. The premise of this program being to teach tennis through competing in tasks that are more representative of competition (Araujo & Davids, 2009; Davids et al., 2012).

As with scaling the equipment and/or rules of the adult game to make it more suitable for junior athletes, coaches can also manipulate the constraints (i.e., task, environment and/or organismic constraints) of practice for more specific learning outcomes (Newell, 1986). For example, Timmerman et al., (2017) explored the effects of manipulating pitch sizes and player densities on physical demands (i.e., high intensity running and sprinting), skilled actions (i.e., total number of passes, success of these passes and number of dribbles) in junior field hockey. Specifically, players were exposed to two conditions whereby the density (228 m^2 or 158m^2 per player) and number of players (11 or 8 per side) were manipulated. Using GPS and notational analysis it was highlighted that decreasing the number of players on a same sized pitch leads to an increase in the number of successful passes and skilled actions by up to 50% per player. Alternatively, increasing player densities (i.e., increasing the number of players on a same sized pitch or decreasing pitch size but not player numbers) resulted in a 45% decrease in the total distance run at high intensity and a 66% decrease in total distance sprinted. While the manipulation of pitch sizes and player densities provides one example of changing task constraints to promote specific learning adaptations, coaches could also look to alter rules, scoring methodologies and/or even the instructions provided. Moreover, specific changes to environmental constraints (e.g., wetting the pitch or using speaker systems to project crowd noises) could be equally as effective in promoting new learning adaptations. The key is to ensure that players are still required to perceive and act on affordances that present themselves during these scaled tasks (Davids, Araújo, Vilar, et al., 2013).

One last consideration for designing representative practice tasks is the knowledge that male and female performances can differ significantly, even in the same sport. For example, potential considerations for males co-competing with females have been discussed with males typically found to be taller, heavier, stronger, faster and have larger aerobic capacities than females of the same age, particularly for developing athletes over the age of 13 years (Krause, Naughton, Benson, & Tibbert, 2018; Tissera et al., 2018). More specifically, in the sport of tennis, gender is known to change the game dramatically at the professional level, with males hitting the ball on average 5kph faster and traversing the court 0.30 m/s faster during general play (Reid, Morgan, & Whiteside, 2016) which leads to the use of different tactics (Hizan, Whipp, & Reid, 2015). Arguably gender, at least in the sport of tennis, therefore presents another constraint that may need to be considered when attempting to design representative tasks that maximise opportunities for context-specific skill learning and transfer. To date, however, no research has yet investigated the implications for designing tasks to be non-gender specific.

2.6 Assessments of learning and transfer

Traditionally the assessment of skill learning and transfer in most sports has been undertaken in laboratory conditions to ensure high levels of experimental control (Dhami, Hertwig, & Hoffrage, 2004; Williams & Kendall, 2007). This approach enables researchers to be confident that any learning outcomes are the result of the specific constraints imposed during an intervention. More recently however, researchers have begun to question the efficacy of laboratory test conditions through evidence from RLD in practical settings (Buszard et al., 2017; Farrow, Reid, Buszard, & Kovalchik, 2018; Robertson, Burnett, & Cochrane, 2014). In the same way that competing against a ball projection machine does not afford the same information as competing against a live opponent (Pinder et al., 2009; Shim et al., 2005), it is generally predicted that laboratory test conditions do not offer adequate informational constraints for the transfer of perception and action skill in to competition i.e., they are low in functionality and action fidelity (Pinder et al., 2015).

A review of the literature revealed 15 different tests used by researchers and practitioners to evaluate tennis skill (see Table 2.1). Approximately 70% reported measures of reliability and validity for assessing skill differences within and between different cohorts. Over time there has been clear attempts to better simulate the hitting and/or movement components of tennis through the inclusion of actual hitting skills (Miley, 2004; Theodoros, Antonios, & Kariotou, 2008) as opposed to hand-eye coordination tasks (Hewitt, 1966; Hewitt, 1968) and/or simulating common patterns of play (Vergauwen, Madou, & Behets, 2004; Vergauwen, Spaepen, Lefevre, & Hespel, 1998). Despite these initial improvements, athlete performances within each test remain decoupled from actual competition performances for one main reason – the relationship that the athlete shares with his/her opponent is not captured. Serve tests, for example, do not include a returner, the single most important piece of information used by the server to couple the speed and direction of their serve during a match (Gillet, Leroy, Thouvarecq, & Stein, 2009; Whiteside & Reid, 2016). Similarly, rally drills, mostly use ball machines which as previously discussed results in a task devoid of pre-perceptual ball flight information (Shim et al., 2005). The efficacy of such tests to provide an accurate estimate of skill transfer therefore remains questionable.

Table 2.1

Tests for tennis skill and physiological performance.

Test	Skills assessed	Outcome measures	Constraints
Dyer Backboard Test (Dyer, 1935; Dyer, 1938)	• Forehand • Backhand	• Frequency of shots	• Ball is self-fed via a drop and hit • Working with an opponent the players attempt to strike the ball as many times as possible in 30s • One point deducted whenever a new ball is needed
Forehand and Backhand Drive Test (Broer & Miller, 1950)	• Forehand • Backhand	• Landing depth	• Ball is self-fed via a drop and hit • Ball must pass over net but under a rope extending 4ft above net height • Target zone inclusive of 9 feet inside baseline • No opponent
Test for service accuracy Cobane (1962) as cited in (Hensley, 1989)	• Serve	• Serve in/out of service box	• Original manuscript not available
Tennis Achievement test (Hewitt, 1965, 1966)	• Serve • Forehand • Backhand	• Target zones • Distance post bounce	• Ball is fed underhand via a coach • Groundstrokes to pass over net but under 7ft restraining rope • No opponent
Forehand and Backhand Drive test (Timmer, 1965)	• Forehand • Backhand	• Ball velocity • Target zones	• Original manuscript not available
Kemp Vincent rally test (Kemp & Vincent, 1968)	• Forehand • Backhand	• Frequency of shots	• Working with an opponent the players attempt to hit as many shots as possible in 3 min • Only shots landing in the court are counted
Bounce Test (Hewitt, 1968)	• NA	• Frequency of ball bounces	• Bounce ball between ground and hips for 30 s
Shoulder Test (Hewitt, 1968)	• NA	• Frequency of ball taps	• Bounce ball between hips and shoulder for 30 s
Revised Broer-Miller tennis test Shepard (1972) as cited in (Hensley, 1989)	• Forehand • Backhand	• Target zones	• Original manuscript not available

Avery-Richardson Tennis Serve Test (Avery, Richardson, & Jackson, 1979)	• Serve	• Target zone • Distance post bounce	• Ball is self-fed via a drop and hit • Order of serves are scripted
Tennis forehand-backhand drive stroke firmness test (Purcell, 1981)	• Forehand • Backhand	• Target zones • Time factor • Coach rating	• Groundstroke shots fed by ball machine • Groundstrokes are fed in blocked manner (i.e., 10 forehands followed by 10 backhands)
Leuven Tennis Performance Test (Vergauwen et al., 1998)	• Serve • Forehand • Backhand	• Target zones • Ball velocity • Stroke precision • Distance to sideline • Distance to baseline • Velocity precision index • Global quality of play	• Groundstroke shots fed by ball machine • 3 types of pre-defined rallies administered at random • Each rally begins with a 1st and 2nd serve followed by 5 groundstrokes • Direction of shots indicated by a light above the ball machine • No opponent
Foreground test (Vergauwen et al., 2004)	• Forehand • Backhand	• Target zones • Ball velocity • Stroke precision • Distance to sideline • Distance to baseline • Velocity precision index • Velocity precision success	• Groundstroke shots fed by expert coach • 3 types of pre-defined rallies (neutral, attacking, defensive) administered at random • No opponent
ITF on court assessment (Miley, 2004)	• Serve • Forehand • Backhand • Volley	• Target zones • Distance post bounce	• Series of tests with one combined score • Groundstrokes and Volleys are coach fed • Serves are hit in allocated order
Unnamed test (Theodoros et al., 2008)	• Serve • Forehand • Backhand	• Target zones	• Groundstrokes fed by ball machine • Shots played from centre of court • No opponent

Recent advancements in technology have presented opportunities for researchers to explore new options for assessing skill learning and transfer (Perš, Bon, Kovačič, Šibila, & Dežman, 2002; Reid et al., 2016). Examples of more generic technologies include the use of eye-tracking to assess gaze behaviour in soccer (Oppici et al., 2017), local positioning systems in netball to identify frequently reoccurring movement sequences (Sweeting, Aughey, Cormack, & Morgan, 2017) and/or vision based solutions in a multitude of team and individual sports (for a review see Barris and Button, 2008).

The sport of tennis now uses Hawk-Eye™ (Hawk-Eye Innovations Ltd, Basingstoke, UK) at all four Grand Slam tournaments for adjudicating line calls. Comprised of eight to twelve 60 Hz cameras, Hawk-Eye tracks the three-dimensional coordinates of the ball and the two-dimensional coordinates of the players during a rally. Descriptive information of shots (e.g., shot types, ball landing locations, winners/errors) and player movement (e.g., movement speed, positioning and changes of direction) can then be computed either through propriety algorithms or more complex custom numerical differentiation to a mean error of 2.6mm (Hawk-Eye Innovations, 2015b). Importantly, this provides researchers and practitioners with a real-time non-invasive means of tracking both athlete movement characteristics (i.e., locomotion) and skill outcomes (e.g., ball speeds, spin rates and landing locations) in-situ (for examples in Grand Slam tennis see – Loffing, Hagemann & Strauss, 2009 and Reid et al., 2016). Hawk-Eye has great potential to support the assessment of a range of practice task designs to maximise skill learning and transfer in tennis, however, it is currently unclear if coaches are using this information to design on-court practice tasks.

Researchers have also begun to develop new performance metrics for tennis considered to better contextualise an athlete's performance/behaviour relative to their environment. For example, through estimating player positioning and ball contact coordinates, Carvalho et al. (2013) developed a metric called positional advantage to numerically represent which player was in a position of advantage or disadvantage in a rally. Similarly, Whiteside and Reid (2016) used a serve angle metric to infer whether a serve was more or less likely to result in an ace or unreturned serve. Importantly, such metrics provide a new way to visualise and identify specific changes in athlete behaviour that may have otherwise been overlooked using more traditional analysis (e.g., number of points won/lost, unforced/forced errors). For instance, the knowledge that a player is improving their positional advantage despite losing more matches provides context to the coach/athlete that they are still making positive changes to their game. Accordingly, the coach/athlete can more carefully plan their next practice phase.

It remains clear that current assessments of skill, particularly those in tennis, poorly represent in-competition performance. The addition of Hawk-Eye and other similar technologies however significantly improves the sport's ability to assess player performances in-situ. Equally, the addition and continual development of new metrics will further enhance insights into skill learning and transfer. This thesis will therefore move away from traditional approaches of skill assessment and provide in-situ assessments of functionality and action fidelity considered highly representative of tennis matchplay.

2.7 Summary

It has been highlighted that sporting expertise is achieved through numerous hours of sports practice across an athlete's lifetime (Ericsson et al., 1993), yet the quality, type and representativeness of this practice remains relatively unknown (Davids, 2000). Significantly, the available evidence points to youth coaches and athletes prioritizing low as opposed to high representative activities. This contrasts with the assertion that skill learning can be maximised through well-designed activities that promote learning in practice that is representative of competition. Correspondingly, there appears a need for coaches to be guided in improving the representativeness of activities being delivered. RLD provides a theoretical framework for assessing and manipulating current practice, which will be used in this thesis. Given the incongruence between the tenets of some contemporary skill acquisition theory and what is purported to epitomise the practice of many sports, this thesis will progress our knowledge of practice scheduling in the skill-intensive sport of tennis.

Tennis provides the perfect vehicle to support this research given the current practice approaches used by tennis coaches reflect those in many other sports. That is, there appears to be a preference to block (particularly the serve) rather than randomly distribute the practice of skills across a session (Buszard et al., 2017). Secondly, in an attempt to develop consistent movement patterns coaches typically decompose skills into their smaller constituent parts (Reid et al., 2010; Reid et al., 2013; Whiteside et al., 2014). Lastly, tasks fail to represent the critical sources of information (e.g., ball flights or opponents court positioning) required for competition performance (Loffing & Hagemann, 2014; Shim et al., 2005). This thesis will therefore profile the current design of tennis practice against the RLD framework and then based off these findings, provide recommendations for improving the current assessment and design of tennis practice for enhanced learning and transfer of practiced skills.

CHAPTER 3

ASSESSMENT OF ELITE JUNIOR TENNIS SERVE AND RETURN PRACTICE: A CROSS-SECTIONAL OBSERVATION

Assessment of elite junior tennis serve and return practice: a cross-sectional observation by L.M. Krause, T. Buszard, M. Reid, R. Pinder, D. Farrow was published in the peer review journal, Journal of Sports Science*, 37/24, 2818-2825, 2019*.

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CHAPTER 4

HELPING COACHES APPLY THE PRINCIPLES OF REPRESENTATIVE LEARNING DESIGN: VALIDATION OF A TENNIS SPECIFIC PRACTICE ASSESSMENT TOOL

4.1 Abstract

Representative Learning Design (RLD) is a framework for assessing the degree to which experimental or practice tasks simulate key aspects of specific performance environments (i.e., competition). The key premise being that when practice replicates the performance environment, skills are more likely to transfer. In applied situations, however, there is currently no simple or quick method for coaches to assess the key concepts of RLD (e.g., during on-court tasks). The aim of this study was to develop a tool for coaches to efficiently assess practice task design in tennis. A consensus-based tool was developed using a 4-round Delphi process with 10 academic and 13 tennis-coaching experts. Expert consensus was reached for the inclusion of seven items, each consisting of two sub-questions related to (i) the task goal and (ii) the relevance of the task to competition performance. The Representative Practice Assessment Tool (RPAT) is proposed for use in assessing and enhancing practice task designs in tennis to increase the functional coupling between information and movement, and to maximise the potential for skill transfer to competition contexts.

4.2 Introduction

Athletes regulate their movements based on information from other players and/or moving objects (Pinder, Renshaw, et al., 2011; Renshaw et al., 2007; Shim et al., 2005). It is therefore crucial for coaches to identify the emergent links between information (perceptions) and movement (decisions and resultant actions) that occur in specific performance contexts, such as competition (Davids et al., 2012; Pinder, Davids, et al., 2011), and then preserve them in their practice task designs. Preservation of these perception-action couplings is essential for athletes to develop and refine context-specific movement solutions that will more directly transfer to competition performances (Davids, Araújo, Vilar, et al., 2013; Pinder, Davids, et al., 2011; Pinder et al., 2015).

Traditionally, irrespective of skill level, the desire to develop consistency within complex motor skills has remained a priority for coaches (Farrow et al., 2013). Common methods to achieve this goal include; blocking practice repetitions so that repeated repetitions of the same skill are practiced with little interference (Barreiros et al., 2007; Brady, 2008; Farrow & Maschette, 1997), decomposing skills into their smaller constituent parts (Reid et al., 2010; Whiteside et al., 2014) and/or using practice tasks devoid of competition-specific information (Hoskins-Burney & Carrington, 2014; Professional Tennis Registry, 2013). Despite these methods being popular among coaches, research has shown that they can contribute to undesirable movement outcomes. For example, athletes have been shown to have significantly different spatiotemporal kinematic responses in interceptive skills in tennis and cricket batting when facing a real opponent compared to when using a ball machine (Pinder et al., 2009; Pinder, Renshaw, et al., 2011; Shim et al., 2005). Equally, tennis and volleyball athletes perform a ball toss significantly differently in isolation as compared to when actually striking a ball (Davids et al., 2001; Reid et al., 2010; Whiteside et al., 2014).

Contemporary research suggests a shift toward tasks that more closely resemble competition performance will encourage improved opportunities for skill transfer to competition (Rosalie & Müller, 2012). For example, the provision of opportunities for active decision-making (Araujo et al., 2006; Baker, Cote, & Abernethy, 2003) and challenging an athlete's emotional state through contextual changes, such as score and crowd noise (Hendricks, 2012; Runswick, Andre, et al., 2017), could assist enhancing movement consistency under pressure. So too can arranging skills in a variable practice order (Magill & Hall, 1990) and ensuring that movement solutions are coupled to sources of information present during competition (Loffing et al., 2016). Additionally, the importance of scaling tasks (i.e., the number and complexity of variables being manipulated) to the age and proficiency of a learner should not be overlooked (Partington & Cushion, 2013). However, based on current observations of practice (Ford et al., 2010; Low et al., 2013; Slade et al., 2015) it appears that coaches of all levels (novice to elite) still require assistance in ensuring these key elements are considered when designing individual practice tasks.

'Representative Learning Design' (RLD) has been proposed as a framework for coaches, researchers and sports scientists to assess the extent to which practice and experimental tasks are representative of the situation of interest, in this case the athlete's competition context (Pinder, Davids, et al., 2011). To guide researchers and practitioners in the assessment of task design, RLD proposes two key terms; functionality and action fidelity (Pinder, Davids, et al., 2011; Pinder, Renshaw, et al., 2011). Functionality refers to the degree to which an athlete is able to use the same information sources (i.e., visual cues) present during competition to contextualise their decisions and movements (Pinder, Renshaw, et al., 2011). For example, the use of a projection machine (Shim et al., 2005) or a coach 'feeding' balls from set court positions (Loffing et al., 2016) is likely to reduce the functionality of a task as information-movement couplings inherent to competition are removed. Action fidelity was proposed to assess the degree to which an athlete's movement behaviour (i.e., spatiotemporal kinematics) during practice replicates movement performance during competition (Araujo et al., 2007; Stoffregen et al., 2003). An example of low action fidelity would be the prescription of overhand-throw practice to infer transfer benefits to the tennis serve (Reid et al., 2015). In such situations, changes to practice task constraints lead to significant changes in the movement kinematics typical of competition.

Currently, a major limitation for coaches looking to enhance the representativeness of practice is an absence of readily available assessments to guide practice task design (see Slade et al., 2015 for an exception). While RLD provides a framework for enhancing the representativeness of task design (Pinder, Davids, et al., 2011) further work is required to enable coaches to better implement the concepts from within RLD in applied sport-specific settings.

To our knowledge, the current study is among the first to incorporate the concepts of RLD into an applied assessment tool to evaluate sport practice. Tennis was used as an exemplar sport as it has a tradition for prioritizing high volumes of repetitive hitting in practice with limited consideration of contextual information (Reid et al., 2007). The expertise of motor learning researchers and expert tennis coaches was sought to assist in developing, validating and assessing the reliability of the tool via a Delphi process. The final tool, known as the 'Representative Practice Assessment Tool' (RPAT), is expected to allow coaches to assess practice tasks based on key principles of RLD, so as to ultimately improve the quality of tennis skill development.

4.3 Methods

4.3.1 Study Design

This study used a Delphi methodology to achieve consensus on the information considered essential to evaluating the RLD of tennis practice tasks. This method involves having a panel of experts comment on the information they believe is pertinent to achieving the research outcome via anonymous questionnaire (Graham, Regehr, & Wright, 2003). Expert responses, are collated and analysed over a series of repeated rounds until an acceptable level of ‘group’ consensus is reached (Lynn, 1986; Mullen, 2003). Approval to conduct the research was granted by the University Ethics Committee.

4.3.2 Selection of experts

Considering dropout rates from previous Delphi research (Evers, Goossens, De Vet, Van Tulder, & Ament, 2005; Mokkink et al., 2010; Palter, MacRae, & Grantcharov, 2011) a total of 32 experts were approached from two populations: academia (N = 16) and tennis coaching (N = 16). The academic experts consisted of motor learning researchers that had published a minimum of three peer-reviewed journal articles on the development of expertise or improvement of practice design within the past five years. Coaching experts were required to hold the highest level (or equivalent) of coaching accreditation in Australia as well as possessing at least five years of international high performance coaching experience. Experts fitting the abovementioned requirements were recruited using an electronic platform (Qualtrics, Provo, Utah). Written consent (Appendix E) was obtained from each expert prior to the commencing the assessments of content validity (rounds 1-3) and inter-rater consistency (round 4) described below.

4.3.3 Stage 1: Conceptualization of the RPAT

Prior to commencing the first validation round, all five co-authors worked together to formulate a 10-question version of the RPAT (Figure 4.1). The lead author (LK) proposed 36 potential questions to be included referencing existing RLD research in sport and key coaching resources in Tennis. Each question assessed whether a tennis practice task effectively simulated aspects from competition tennis contexts. To finalise the tool, the lead author led a group discussion with all four co-authors whereby their knowledge in RLD, skill transfer and tennis coaching was used to refine these questions further.

PRACTICE ASSESSMENT TOOL

Player: ____________ **Coach:** ____________ **Date:** ________ **Name of task:** ____________

Goal of task: ____________

Type of Activity: ☐ Hand-fed ☐ Racquet-fed ☐ Groundstroke rally ☐ Net approach/volley ☐ Serving ☐ Returning ☐ Point Simulation ☐ Other

		Not at all		Could be better		Certainly	NA	If a score of 1-3 is given, specify how the task could be improved
1	Does the goal detail a specific purpose?	1	2	3	4	5	NA	
2	Does the task require the player to make tactical decisions relative to their level of skill?	1	2	3	4	5	NA	
3	Is the ball being fed in a manner that is relevant to the task goal?	1	2	3	4	5	NA	
4	Does the task allow the players to be adaptable in shot selection?	1	2	3	4	5	NA	
5	Does the task allow the players to be adaptable in shot execution?	1	2	3	4	5	NA	
6	If used, have training aids (cones, nets, poles, markers etc) assisted in reaching the learning outcome i.e. guiding skill development without overly constraining behaviour?	1	2	3	4	5	NA	
7	Is the player striking the ball with intent relevant to the task goal?	1	2	3	4	5	NA	
8	Is the player moving with intent relevant to the task goal?	1	2	3	4	5	NA	
9	Does the task provide an appropriate level of challenge for the performer?	1	2	3	4	5	NA	
10	Are there sufficient opportunities for positive skill transfer to performance?	1	2	3	4	5	NA	

SCORE = (Total from 1-5) / (50- NA scores) = ________

Figure 4.1 Pre-conceptualised 10-question RPAT.

4.3.4 Stage 2: Content validity assessment of the RPAT

Upon finalizing the initial 10-point RPAT each expert was sent an email by the lead researcher. This email contained a link and password to the first round of the questionnaire, an up-to-date copy of the assessment tool and a pre-recorded tennis practice task. Consistent across each round of questionnaire the experts were asked to (i) pilot the tool against the supplied pre-recorded practice task, (ii) rate each of the proposed RPAT questions and accompanying definitions on a 4-point likert scale (Lynn, 1986) and (iii) propose additional questions, general comments, and make changes to the RPAT where they felt necessary. The experts were given one month to complete each questionnaire after which the next round commenced approximately one-month later.

At the completion of each round the experts' responses (i.e., likert scores and written comments) was collated by the lead researcher into an anonymous feedback report. This report included assessments of content validity for each specific question and definition within the RPAT. Content validity was assessed using Lynn's (1986) content validity index which involved evaluating the proportion of experts who rated each proposed RPAT question as "relevant" or "extremely relevant" (3 or 4 on a 4-point Likert) to maintaining a RLD. A CVI $\geq$ 80% was required for both the academic and coaching groups to sufficiently support the content validation of a question or definition (Lynn, 1986). Items not meeting the minimum group consensus (CVI $\geq$ 80%) were either re-worded or dropped completely based on a case-by-case review. Additional written comments provided by the experts were used to support each case-by-case review prior to the five co-authors accepting, declining or referring changes back to the expert panel in the next round of questionnaire. A summarised version of the feedback report was also supplemented to each expert prior to the next round of questionnaire. Where questions were removed it was made clear in the summarised report allowing them to consider the impact this would have for the new iteration of the assessment tool. Comments and feedback from each round of Delphi remained anonymous to retort any potential bias. The Delphi process was terminated at the conclusion of round three given expert consensus comfortably satisfied the inclusion of a total of 7 RPAT questions (CVI $>$ 80%; Lynn, 1986). Figure 4.2 provides a summary of the three round validation process.

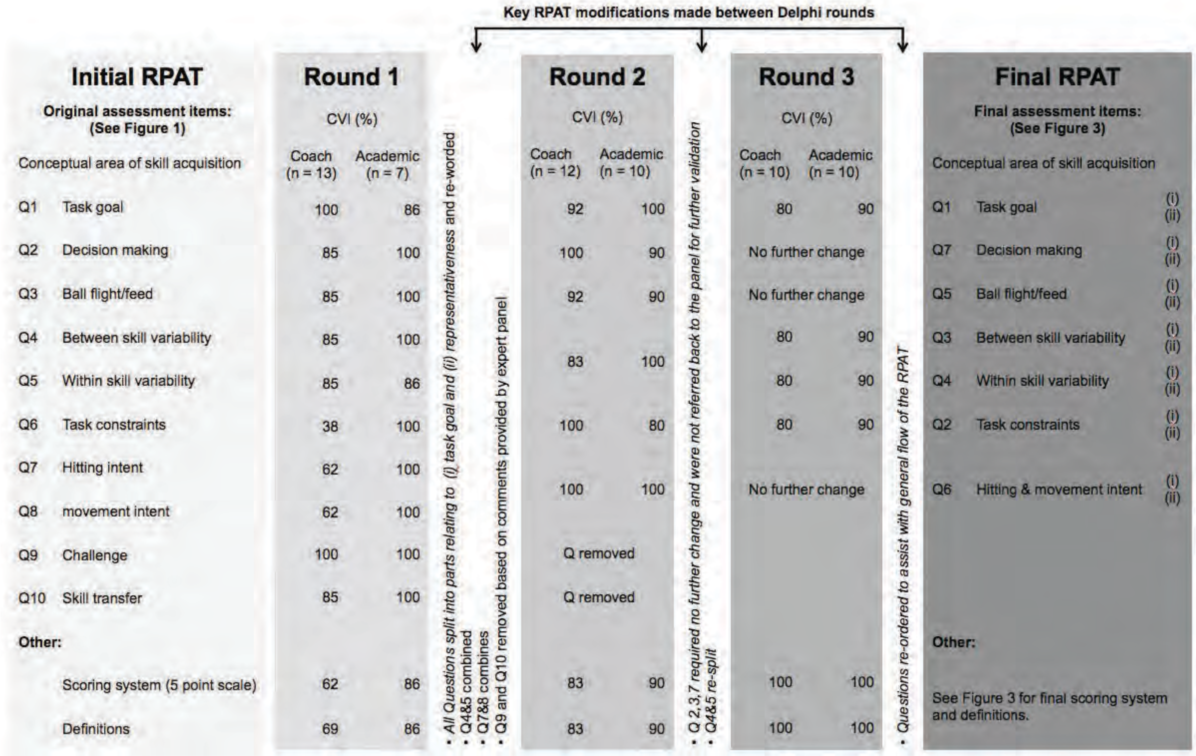


Figure 4.2 Overview of the Delphi process.

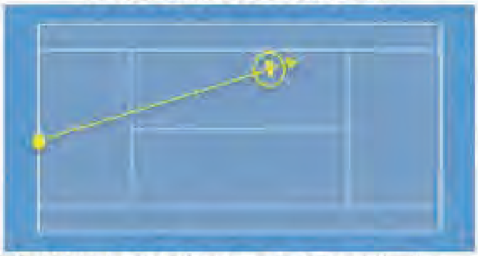
4.3.5 Stage 3: Inter-rater consistency of the RPAT

This stage aimed to assess the inter-rater consistency of the final RPAT. This involved having each expert rate five pre-recorded tennis tasks using the final validated RPAT. All five videos were different from those presented during the validation phase. The tasks were representative of common high performance practice tasks (National Academy Victoria, 2008) delivered across two key domains of tennis play: serve and return (n = 2), and groundstroke/rally (n = 3) (Crespo & Miley, 1998). Footage was captured from practice sessions undertaken by athletes within Tennis Australia's National Academy. Accompanying each video was a description of the 'task goal' and the 'constraints' placed on the task to assist expert evaluation (Figure 4.3). At the completion of this round, expert responses were collated and the consistency of RPAT scores assessed on each specific two-part question for all five videos.

4.3.6 Data analysis

Statistical analysis was undertaken using R Studio (R Core Team, 2016). CVI for each question and definition was assessed using Lynn's (1986) frequency table method. For single RPAT questions, the consistency among raters was evaluated by measuring the standard deviation of the questions ratings. As standard deviation is a measure of variance, higher and lower standard deviation was representative of questions with less and more inter-rater consistency, respectively. Based on the properties of normal distribution (De Winter & Cahusac, 2014; P. M. Lee, 2012), an item with a standard deviation of less than 1 was considered to have "good" consistency. Correspondingly, resulting RPAT scores of ± 1 to 2 standard deviations represented "average consistency" and scores greater than ± 2 standard deviations equated to "poor consistency" between raters. 'Mode' scores (i.e., the most frequently registered RPAT scores per question) were also reported to provide a description of the scoring consistency between the academic and coaching groups.

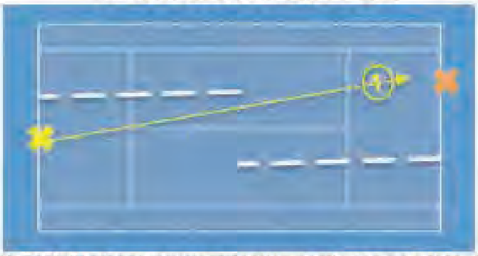
Task 1: Basket Serve Drill



Task Goal: Improve ability to serve wide on deuce court by establishing good serving technique, rhythm and/or consistency.
Task Constraints:
- Players instructed to direct serves 'wide' to deuce court.
- Player hits 20-30 shots consecutively before having a rest.

Extra notes: Some technical instruction/correction made throughout by a coach.

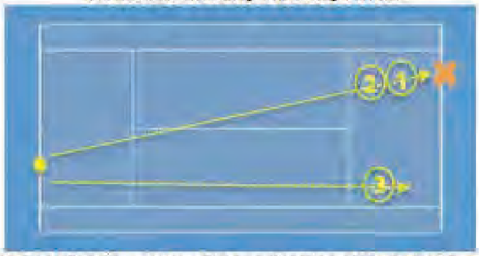
Task 2: Cross Court Plus



Task Goal: Challenge players to construct and win points through forehand placement, pace and/or consistency.
Task Constraints:
- Restricted playing area (deuce singles to marked white lines).
- Feed underhand crosscourt to deuce court.
- Forcing opponent to hit a backhand results in winning the point.
- Hitting the ball outside the playing area results in the loss of the point.
- First to 7 points wins.

Extra notes: Players encouraged to manipulate ball spin and speed.

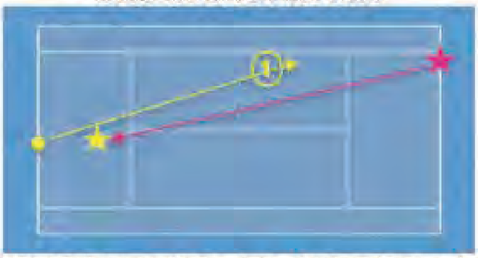
Task 3: Cross, Cross, Line



Task Goal: Feeding player = Change direction of the ball with precision, pace and/or depth to win point either directly (hitting a winner) or indirectly (forcing error). Returning player = Hit crosscourt with consistency, pace and placement to counterattack, neutralize or seize control of the point.
Task Constraints:
- Feed crosscourt to deuce court (feed counts as first shot in pattern).
- Feeding player maintains pattern of cross, cross, line.
- Returner hits every ball crosscourt.
- Hitting the ball out or failing to maintain the pattern results in a loss of point.
- First to 7 points wins.

Extra notes: Players encouraged to manipulate ball spin and speed.

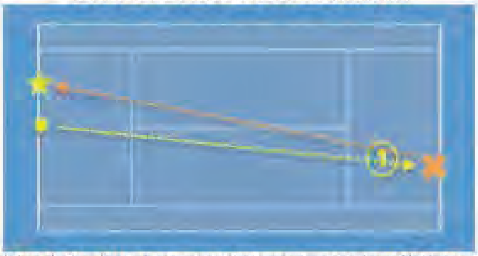
Drill 4: Serve Plus One



Task Goal: Refine serve plus first shot tactics through rehearsal of the following combination: wide serve to deuce court and then use the forehand to set up or win the point.
Task Constraints:
- Player serves wide to deuce court.
- Player to only use forehand on next shot.
- First shot after serve is played off a coach feed not an actual return.

Extra notes: Players encouraged to hit an aggressive forehand to win or set up a point based on the location of return (feed from coach).

Drill 5: Cross Court Animal



Task Goal: Feeding player = create opportunities to with the point through effective decision-making aimed at creating space by changing direction of the ball. Returning player = Defend or counter attack effectively crosscourt.
Task Constraints:
- Feed underhand crosscourt to ad court.
- Player feeding can hit anywhere.
- Player returning can only hit crosscourt.
- Hitting the ball out (both players) or failing to hit crosscourt (returner) results in loss of point.
- First player to 7 points wins.

Extra notes: Returner encouraged to focus on playing high percentage tennis with depth and patience.

Legend:

Colour codes:
Yellow = Feeding play
Orange = 'Live' opponent play
Pink = Coach 'feeding'

Symbols:
- Player who can only direct shots crosscourt
- Shots hereafter, can be played by this player in any direction
- Direction of constrained feed/shot
- (1) Feeding players shot number

Figure 4.3 Practice tasks 1-5 used for the assessment of inter-rater reliability.

4.4 Results

4.4.1 Panel members

A total of 32 experts were invited of whom 23 agreed to participate. While the majority of participants were from within Australia (80%), the experts represented a diverse range of Universities (N = 10) and high performance coaching environments (N = 6). Of the participating experts, 88% (Academics = 10, Coaches = 13) participated in at least one round and 77% (Academics = 10, Coaches = 10) in all four Delphi rounds. Over the previous five year period, participating academics averaged 15.0 ± 11.2 publications (Research Gate, 2017; SCOPUS, 2017) and all coaches maintained a minimum level 3 coaching accreditation (Tennis Australia, 2015).

4.4.2 Stage 1 Content Validation (Delphi rounds 1-3)

Round 1: Following the first Delphi round, consensus was reached (CVI > 80%) for eight questions. Additional comments (N = 71) related to all aspects of the tool suggested further changes were required. In summary, the experts proposed the following changes that were accepted (n = number of comments related to change):

- Separating each question into two sub-parts to create a more direct link between the 'goal' and the 'representativeness' of a task (n = 8).
- Re-wording the question related to 'task constraints' to more holistically capture the effectiveness of imposed constraints in the context of a task (n = 5).
- Reword and combine questions related to skill variability (Q 4 & 5) (n = 4) and intentionality (Q 7 & 8) (n = 5) as they did not warrant separation.
- Removing questions related to task difficulty (Q9) (n = 3) and skill transfer (Q10) (n = 3), as they were too difficult to objectively rate and/or already implied by scores given to alternate questions.

- Re-defining and/or separating task initiation and activity type classifications under two new headings (n = 8).
- Rewording remaining questions (n = 6) and definitions (n = 16) to make them easier to interpret for a range of practitioners.

Alternatively, the following changes were proposed but rejected:

- Changing from a 5 to a 3-point likert scoring scale (n = 3). A smaller scale would not provide raters enough flexibility to differentiate ratings between tasks (Dawes, 2012).
- The inclusion of questions related to developmental readiness (n = 1), longitudinal practice repetition (n = 1), technical/tactical aspects of practice (n = 3), and coach instruction/feedback (n = 5). These were considered to already be captured indirectly or deemed to be outside the scope of this study.

Based on the above changes, this round narrowed the tool to a total of 6 questions.

Round 2: Consensus (CVI > 80%) was reached for all scoring systems and definitions at the end of round 2. However, again, specific comments (N = 23) proposed four further iterations to the RPAT which were accepted:

- Rewording the 'task goal' question to better capture how practice goals may translate to competition (n = 3).
- Rewording the question and definitions related to task constraints to be more inclusive of task design (n = 4).
- Rewording other questions (n = 6) and definitions (n = 2) to improve interpretation for a range of practitioners.
- Re-splitting and re-defining the practice variability question to address within- and between-skill variability (n = 4).

Comparatively, the following changes were proposed but rejected:

- Making the NA scoring option question specific (n = 2).

- Adding a question on coach instruction (n = 1) and reducing the scoring system to a 3-point likert scale (n = 1).

At the completion of this round, the RPAT contained the same core content as at the conclusion of the first round. The re-splitting of the question related to within- and between-skill variability increased the total number of RPAT questions to 7.

Round 3: Following round 3, CVI scores for both the coaching and academic groups remained > 80%. There was a significant reduction in the number (N = 9) of expert comments. These comments only required trivial changes to the rewording of questions, all of which accepted. These changes concluded the validation of the proposed RPAT (Figure 4.4).

4.4.3 Stage 2: Inter-rater consistency (Delphi round 4)

For all tasks, the academic and coaches provided the same initiation and activity type classifications (CVI > 90%). Combined or arranged by group (i.e., coach or academic), average inter-rater consistency for scores assigned to tasks 2, 3, 4 and 5 was "good" (Table 4.1). This is supported by combined expert standard deviation scores of < 1 for the majority of items on tasks 2-5 (11/14 for task 2, 14/14 for task 3, 14/14 for task 4, and 13/14 for task 5). Similarly, combined expert mode scores for each task (Table 4.2) demonstrates RPAT scores assigned to the pre-recorded videos were consistent between all but task 1. That is, task 1 was scored 19 points lower than task 2 and 18 points lower than tasks 3-5. Similarly, task 1 also produced the worst agreement between the academic and coaching groups, particularly when totaled mode scores were compared between the two groups. Specifically, the difference between the academic and coaching groups' mode scores in task 1 was 8 points, over double that sighted in the other four tasks (≤ 3 points difference).

PRACTICE ASSESSMENT TOOL

Task goal/s: ____________________

Constraints placed on task: ____________________

How is the task initiated? □ Hand-fed □ Racquet-fed □ Serve □ Other

Type of Activity: □ Groundstroke □ Net approach/volley □ Serve □ Return □ 'Constrained' point simulation/match play □ Match play □ Other

	Not at all		Could be better		Certainly		If a score of 1-3 is given, specify how the task could be improved.
1. Is the task goal:							
i) Specific enough for its intended outcome to be measured?	1	2	3	4	5	NA	
ii) Similar to the type of goal required to be executed by players in competition?	1	2	3	4	5	NA	
2. Do the task constraints (i.e. task design and equipment) placed on the task assist in:							
i) Achieving the task goal?	1	2	3	4	5	NA	
ii) Transferring skills to competition?	1	2	3	4	5	NA	
3. Does the task encourage variation between shots (e.g. FH, BH, Volley, Serve)?							
i) Appropriate to the task goal?	1	2	3	4	5	NA	
ii) Similar to what is expected during competition?	1	2	3	4	5	NA	
4. Does the task encourage variation within the same shots (e.g. FH topspin, FH flat, FH slice)?							
i) Appropriate to the task goal?	1	2	3	4	5	NA	
ii) Similar to what is expected during competition?	1	2	3	4	5	NA	
5. Is the ball being fed (first ball & subsequent shots) in a manner:							
i) Appropriate to the task goal?	1	2	3	4	5	NA	
ii) Similar to what is expected during competition?	1	2	3	4	5	NA	
6. Is the athlete striking the ball and moving:							
i) Appropriate to the task goal?	1	2	3	4	5	NA	
ii) Similar to what is expected during competition?	1	2	3	4	5	NA	
7. Does the task encourage decision making:							
i) Appropriate to the task goal?	1	2	3	4	5	NA	
ii) Similar to what is expected during competition?	1	2	3	4	5	NA	

Task Goal Score: ____/35 = ____% Match play Score: ____/35 = ____% TOTAL SCORE: ____/70 = ____%

LIST OF DEFINITIONS

Skill:*
A stable coordination pattern that can be adapted to changes in the performance environment as quickly as possible to achieve functional and consistent outcomes.

Constraint:*
A limitation or restriction placed on the task. A task can be constrained in three separate or integrated ways including (Figure 1):

Figure 1: Model of constraints

Individual:	Factors related to the learners, physical, physiological, cognitive and emotional makeup. i.e. Affecting player motivation/emotion, performing under fatigue
Task:	Factors related to the tasks design, including the task goal, rules and equipment including all verbal instructions. i.e. Using line/court/net restrictions, pre-determining patterns, training aids, restricting shot selection/type.
Environment:	Physical factors such as the surroundings of learner and information available in learning contexts. i.e. Court surface, ball type/brand, weather conditions (indoor/outdoor), lighting, spectators.

How task was initiated:

Hand-fed:	Ball is fed to player by hand (without a racquet)
Racquet-fed:	Ball is fed to player by coach or opponent racquet underhand.
Serve:	Ball is fed to player by opponent or coach overhead using a serve.
Other:	Ball fed in a manner that does not fit under any of the above classifications e.g. ball machine

Type of activity:

Groundstroke:	Activity consists predominately of shots played on or behind the baseline.
Net approach/volley:	Activity consists of shots played inside the court and/or from close proximity to the net.
Serve:	Activity consists predominately of service practice.
Return:	Activity includes a large proportion of return practice.
'Constrained' point simulation/match play:	Activity aims to replicate match play, yet is constrained in some way or form (serve may or may not be inclusive).
Match play:	Activity aims to replicate match play without constraint (serve included).
Other:	Activities that do not fit under any of the above classifications.

Athletes' ability to perform the skill(s) in this activity:*

Novice:	Athlete is beginning to assemble a functional coordination pattern. Pre-determined outcomes are rarely achieved and performance diminishes quickly during open tasks.
Intermediate:	Athlete has developed a functional movement pattern. Pre-determined outcomes are now achieved to a moderate level of certainty and performance diminishes less-quickly during open tasks.
Skilled:	Athlete has assembled a functional coordination pattern for use in changing environments. Pre-determined outcomes are achieved consistently to a high level of certainty and remain relatively stable even during open tasks.

*Definitions derived from Newell's (1985) stages of learning and/or Newell's (1986) model of constraints.
*Definitions derived from Schmidt's (1975) Schema theory.

Figure 4.4 Final validated RPAT including classification and definitions.

Table 4.1

Inter-rater consistency standard deviation (SD) scores among the expert panel for five tennis practice drills.

	Task 1: Basket Serve Drill			**Task 2: Cross Court Plus**			**Task 3: Cross, Cross, Line**			**Task 4: Serve Plus One**			**Task 5: Cross Court Animal**		
Drill initiation[a]	Serve			Racket-Fed			Racket-Fed			Serve			Racket-Fed		
Activity type[a]	Serve drill			Constrained point			Constrained point			Serve, Groundstroke			Constrained point		
	Academic	Coach	Combined	Academic	Coach	Combined	Academic	Coach	Combined	Academic	Coach	Combined	Academic	Coach	Combined
Q1A	1.14	0.83	1.25	0.61	0.35	0.70	0.58	0.57	0.60	0.56	0.53	0.60	0.71	0.93	0.71
Q1B	1.08	0.83	1.29	0.87	1.07	0.48	0.85	1.03	0.60	0.66	0.35	0.83	0.49	0.53	0.49
Q2A	0.88	0.64	1.06	0.59	0.71	0.52	0.50	0.57	0.44	0.56	0.00	0.78	0.49	0.46	0.49
Q2B	0.90	0.92	0.88	0.62	0.76	0.48	0.57	0.67	0.44	0.77	0.35	0.56	0.56	0.52	0.56
Q3A	1.25	1.41	1.17	1.43	1.51	1.17	0.74	0.57	0.93	0.69	0.83	0.57	0.66	0.46	0.66
Q3B	1.20	1.41	1.06	1.20	1.28	1.08	0.74	0.67	0.83	0.79	0.35	0.93	0.53	0.46	0.53
Q4A	1.14	1.25	1.10	0.81	0.53	0.94	0.46	0.42	0.50	0.71	0.74	0.71	0.50	0.53	0.50
Q4B	1.13	1.20	1.14	0.86	1.19	0.47	0.46	0.32	0.60	0.64	0.35	0.79	0.43	0.53	0.43
Q5A	1.18	0.99	1.34	0.86	0.92	0.63	0.76	0.70	0.50	0.78	0.89	0.71	0.66	0.74	0.66
Q5B	1.13	1.16	1.16	1.39	1.19	1.35	1.01	1.20	0.33	0.86	0.89	0.88	1.11	1.49	1.11
Q6A	1.30	1.28	1.38	0.59	0.35	0.48	0.48	0.48	0.50	0.70	0.46	0.87	0.49	0.52	0.49
Q6B	1.26	1.20	1.36	0.87	0.93	0.53	0.62	0.67	0.44	0.73	0.64	0.73	0.49	0.53	0.49
Q7A	1.24	1.28	1.26	0.46	0.00	0.53	1.17	1.29	0.87	0.66	0.00	0.88	0.64	0.46	0.64
Q7B	1.03	1.13	0.99	0.42	0.46	0.32	1.15	1.25	1.00	0.62	0.35	0.67	0.71	0.83	0.71
Average	**1.13**	**1.11**	**1.17**	**0.83**	**0.80**	**0.69**	**0.72**	**0.74**	**0.61**	**0.70**	**0.48**	**0.75**	**0.61**	**0.64**	**0.61**

[a]Classifications based off most common response among experts (> 90% agreement among experts); SD ≤ 1 = “good consistency” SD of 1-2 = “average consistency” and SD ≥ 2 = “poor consistency” between raters.

Table 4.2

Most frequent (mode) scores RPAT scores among the expert panel for five tennis practice drills.

	Task 1: Basket Serve Drill			**Task 2: Cross Court Plus**			**Task 3: Cross, Cross, Line**			**Task 4: Serve Plus One**			**Task 5: Cross Court Animal**		
Drill initiation[a]	Serve			Racket-Fed			Racket-Fed			Serve			Racket-Fed		
Activity type[a]	Serve drill			Constrained point			Constrained point			Serve, Groundstroke			Constrained point		
	Academic	Coach	Combined	Academic	Coach	Combined	Academic	Coach	Combined	Academic	Coach	Combined	Academic	Coach	Combined
Q1A	4	3	4	5	4	5	4	4	4	4	4	4	4	4	4
Q1B	2	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Q2A	3	3	3	4	4	4	4	4	4	4	4	4	4	4	4
Q2B	3	3	3	4	4	4	4	4	4	3	4	4	4	4	4
Q3A	2	1	1	4	4	4	4	4	4	4	4	4	4	4	4
Q3B	2	1	2	4	4	4	4	4	4	4	4	4	4	4	4
Q4A	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Q4B	2	4	2	4	4	4	4	4	4	4	4	4	4	4	4
Q5A	5	4	5	4	4	4	4	4	4	4	4	4	4	4	4
Q5B	4	4	4	4	3	4	4	4	4	4	4	4	4	4	4
Q6A	4	1	4	5	4	5	4	4	4	3	4	4	4	4	4
Q6B	4	1	1	4	4	4	4	4	4	4	4	4	4	4	4
Q7A	2	1	1	4	4	4	3	4	4	4	4	4	4	4	4
Q7B	2	1	1	4	4	4	3	4	4	3	4	4	4	4	4
RPAT score	**43**	**35**	**39**	**58**	**55**	**58**	**54**	**56**	**56**	**53**	**56**	**56**	**56**	**56**	**56**

[a]Classifications based off most common response among experts (> 90% agreement among experts); mode scores represent the most common score reported by experts using the RPAT's five point rating scale.

4.5 Discussion

This study set out to validate a tool to assess tennis practice task design based on key concepts from RLD (Pinder, Davids, et al., 2011). A Delphi methodology, which combined the opinions of motor learning experts and high performance tennis coaches, helped to validate the instrument (the RPAT). The assessment of inter-rater consistency was encouraging and highlights the potential application of the RPAT for multiple raters. More pertinently, its development narrows the gap between the theory and application of RLD (Farrow et al., 2013), which in turn, should help to improve the efficacy of practice task design in tennis.

The first-round response rate of 72% and an attrition rate of 11% (3 coaches, no academics) across all four rounds were regarded as positive (Choi, Cho, & Kim, 2005; Haines, Baker, & Donaldson, 2013; Paterson, Bryant, Bates, & Bennell, 2017). Similarly, the CVI consensus was higher than other reports (Mokkink et al., 2010). Accordingly, the majority of the changes to the RPAT were based on expert comment, which to the knowledge of the authors is atypical of other Delphi processes. This comment was particularly informative in round 1, where coaches deemed Q6, Q7 and Q8 less relevant (CVI $\leq$ 62%) than the academics (CVI = 100%). Specifically, concerns were raised with the wording as compared to the content of these questions, meaning that the removal of these questions based on the CVI alone would have been erroneous. All questions, including those reworded, returned CVI > 80% for both academics and coaches in the final two Delphi rounds, confirming that each iteration of the RPAT was an improvement on the last.

The major rationale for the development of the RPAT was to operationalise the assessment of functionality and action fidelity in the sport of tennis. The final RPAT achieved this through the validation of 7 two-part questions considered pertinent to enhancing skill learning and transfer. Intuitively, Q1 captures the importance of designing practice tasks to meet specific learning outcomes and presenting these outcomes relative to competition performance (see Farrow & Robertson, 2016 for a review). More instinctively, the remaining 6 questions predominately focused on the functionality of information provided within a task's design (Pinder et al., 2015). For instance, Q2 assessed the impact that constraints have on the nature and learner-specific difficulty of a task (Newell, 1986) while the importance of providing more variable as opposed to constant movement solutions (Barreiros et al., 2007; Magill & Hall, 1990; Van Rossum, 1990) is captured in questions 3 and 4. Questions 5 and 6 assessed the relationship between ball delivery and flight information (Q5), shown to be important for the early anticipation of an opponent's shot and subsequent movement coordination (Q6 - subjective assessment of action fidelity) (Loffing et al., 2016; Shim et al., 2005). Lastly, Q7 assessed whether sufficient affordances were presented to encourage context specific decision-making (Araujo et al., 2006; Baker et al., 2003). The RPAT provides a significant step in summarizing the motor learning literature and RLD into an applied assessment.

The final stage of this project assessed the consistency of RPAT ratings between multiple users on five pre-recorded tennis practice tasks. Inter-rater consistency remained relatively ‘good’ and total RPAT scores were consistent both within and between the academic and coaching experts for all tasks except task 1. We suspect that the nature (i.e., degree of representativeness) of task 1 as well as the provided description of the task goal could account for some of the discrepancy in the overall RPAT score and inconsistency between expert ratings. For example, both task 1 and 4 were initiated by a serve, yet task 1 retained a specific technical focus, was highly structured and included isolated blocked repetition of the serve in the absence of a returner. This led to low combined expert mode scores being returned for questions related to between-skill variability (Q3A = 1, Q3B = 2) and decision-making (Q7A = 1, Q7B = 1), and a notable difference in coach and academic scores (Table 4.2). Equally, given task 1 isolated the performance of the serve, unlike the coaches, the academics may have struggled to interpret the athletes movement intentions post serve which may explain their higher score for this task. This may also explain the large difference in the mode ratings between the two expert groups on Q6. Task 4, on the other hand, involved a competitive focus that required the server to play subsequent shots based on returns hit by a coach. Resultantly, this increased the experts combined mode scores on questions related to within- and between-skill variability (Q3A = 4, Q3B = 4) and decision-making (Q7A = 4, Q7B = 4), which generally corresponds to a task being higher in RLD (Baker & Farrow, 2015; Davids et al., 2012; Pinder, Davids, et al., 2011). Similar to task 4, the combined experts mode scores for tasks 2, 3 and 5 was $\geq$ 4 for all seven questions, which reflects the competitive nature, increased movement variability and decision-making that characterised these tasks. Constructively, this provides initial evidence that the RPAT is sensitive to changes in task design and able to separate tasks higher and lower in RLD.

Despite the tasks analysed in this study representing five common tasks performed by high performance tennis coaches (National Academy Victoria, 2008), more tasks with varying degrees of RLD should be investigated to fully ascertain the utility of the tool's rating system particularly given the differences between coach and academic scoring in task 1. Also, assessing changes in the sensitivity of RPAT ratings following systematic familiarization such as that proposed by Brewer and Jones (2002) would be helpful. Alternative iterations of the RPAT could also be investigated to support the RLD of practice in sports that share similar performance affordances to tennis such as baseball or cricket. In this context, we propose Q1, Q2 and Q7 could remain unchanged given their generic nature, while the remaining questions could be re-worded to be sport-specific. Alternatively, highly transferable sports like table tennis may require no changes at all. Next, given that coach instruction (Hendry, Ford, Williams, & Hodges, 2015; Jackson & Farrow, 2005) and feedback (Sigrist, Rauter, Riener, & Wolf, 2013) influence learning and transfer, they warrant further investigation. This could be pursued in the form of a separate assessment to compliment the RPAT or alternatively, modifying an existing tool such as the CAIS developed by Cushion et al., (2012). Equally, evaluating the RPAT for use among differing levels of expertise would be valuable given the requirement for RLD to be relevant to the learner's capabilities (Davids, Araújo, Vilar, et al., 2013). Notably, if the RPAT is used as intended and the rater evaluates a task with specific reference to the appropriate level of competition of the learner, then we predict that a task scoring high on the RPAT should be both high in RLD and be appropriately challenging (Davids, Araújo, Vilar, et al., 2013).

4.6 Conclusion

The Delphi method allowed for the determination of expert consensus regarding the integration of RLD and the overarching concepts of functionality and action fidelity into an applied assessment tool in tennis. To our knowledge this is the first assessment tool for coaches and researchers to quantitatively assess multiple practice tasks to ensure that opportunities for skill learning and transfer to competition are maximised. Preliminary inter-rater tests showed practitioners should remain confident that RPAT scores between two raters are likely to be similar for most tasks. Additionally, the RPAT appears to be sensitive enough to separate tasks higher or lower in RLD as well as distinguish changes to a tasks design.

CHAPTER 5

APPLICATION OF REPRESENTATIVE LEARNING DESIGN FOR ASSESSMENT OF COMMON PRACTICE TASKS IN TENNIS

Application of representative learning design for assessment of common practice tasks in tennis by L. Krause, D. Farrow, T. Buszard, R. Pinder, M. Reid, was published in the peer review journal, Psychology of Sport and Exercise*, 41, 36-45, 2019*.

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CHAPTER 6

REPRESENTATIVE LEARNING DESIGN AS A TOOL FOR ENHANCING SKILL TRANSFER: A TENNIS EXAMPLE

Representative learning design as a tool for enhancing skill transfer: a tennis example was published as Enhancing skill transfer in tennis using representative learning design

Enhancing skill transfer in tennis using representative learning design by L. Krause, D. Farrow, R. Pinder, T. Buszard, S. Kovalchik, M. Reid, , was published in the peer review journal, Journal of Sports Science*, 37/22, 2560-2568, 2019*.

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CHAPTER 7

GENERAL DISCUSSION

7.1 General Discussion

The overarching aim of this thesis was to assess the efficacy of contemporary practice methods for maximizing skill learning and the transfer of skills to competition performance. Additionally, this thesis aimed to consolidate current theoretical literature to enable coaches to better understand key principles for enhancing learning transfer via improved practice design in sport. Using tennis as the experimental vehicle, four specific experiments were conducted which attempted to:

1. Align the current practice approaches for developing tennis talent against the representative learning design (RLD) framework.
2. Conceptualise and validate a practical coaching tool.
3. With support from objective motion capture ball and player movement (i.e., Hawk-Eye) data, implement the validated assessment tool to assess the representativeness of common practice tasks considered useful for enhancing skill learning and transfer.
4. Assess benefits for learning and transfer of the tennis serve following increased exposure to one of three representative practice tasks; low, moderate or high - as classified by ratings from the assessment tool (i.e., RPAT).

This final chapter will consolidate the key findings from each experiment and discuss the theoretical, methodological and practical implications from the program of work. The methodologies used will be critically evaluated and suggestions for future research provided. Conclusions will be drawn in response to the aims outlined above and at the beginning of the thesis.

7.2 Main findings

Chapter 3 provided a descriptive analysis of the current approaches used by elite junior tennis players to develop the two most important tennis skills, the serve and return. This was an important starting point for this thesis to contextualise the types of practice

This was an important starting point for this thesis to contextualise the types of practice currently being employed by tennis coaches to teach key skills. Detailed analysis of the tasks being used to teach these skills identified three main types of serving task (serve only (SO), serve return (SR) and serve +3rd (S3)) and two types of return task (return only (RO) and return +4th (R4)) used by coaches to teach these skills. General observations were consistent with research in other sports highlighting that practice of the serve and return was prioritised in drill-based tasks considered to be less representative of competition. Namely, it was highlighted that the majority of current serve and return practice is poor at preserving the functional links between perception and action relevant to competition performance. For example, only 55% of all serve practice included a returner and less than 20% of all practice provided players with the opportunity to continue the rally past the return. A preference for isolating the practice of serve and return skills, without rehearsing the 3rd and/or 4th shots of a point, was also a key trait of the observed tasks (Tables 3.3 and 3.4). When the practice observations were compared with the competition behaviours of a matched cohort of elite junior tennis players it was found that players typically displayed lower levels of task success and implemented less desirable serving tactics in practice (i.e., serving toward centre of service box as opposed to extremities - see Tables 3.2, 3.3 and 3.4). It is therefore suggested that current approaches for teaching the serve and return are sub-optimal for maximizing skill learning and transfer. In turn, it was confirmed that tennis practice shares many qualities with other sports (Ford et al., 2010; Low et al., 2013; Williams & Hodges, 2005), suggesting that these learnings in tennis can be transferred to other sports.

Given this backdrop, Chapter 4 harnessed experiential and theoretical knowledge to develop and validate the RPAT. This work applied the concepts from RLD to provide a practical coaching tool to support coaches in optimizing opportunities for skill learning and transfer. The combined opinions of motor learning experts and international tennis coaches led the RPAT to consist of 7 questions, each split into a part (a) focused on the ‘goal’ and a part (b) focused on the 'representativeness' of a task (Figure 4.4) to better assess (i) practice outcomes and (ii) likelihood of skill transfer to competition. The validity of the RPAT in applied settings was reinforced through findings that inter-rater consistency remained high across a variety of tasks with, raters being able to distinguish between tasks considered to be higher or lower in 'representativeness'.

In addition to applying the RPAT, Chapter 5 compared Hawk-Eye ball and movement characteristics of elite junior tennis players competing in matchplay to four common groundstroke rally tasks used in high performance tennis programs to transfer skills to competition (National Academy Victoria, 2008). Ultimately it was concluded that the four practice tasks failed to replicate the same ball and movement characteristics of matchplay. That is, generally the tasks promoted 'cooperative' (longer rallies and less winners) as opposed to the 'combative' behaviours (e.g., shorter rallies and more winners) expected during matchplay. As such, it was recommended that practitioners need to better consider the consequences for skill learning and transfer when making changes to a practice tasks design.

By using the RPAT to design a series of serving tasks considered less and more representative (similar to those identified in Chapter 3), Chapter 6 empirically tested the effectiveness of increasing task representativeness for enhancing skill learning and transfer. The results (presented in Tables 6.3, 6.4 and 6.5) highlighted that changes to task representativeness resulted in changes in serving behaviour from pre- to post-test. The apparent changes in behaviour did not, however, result in players winning more points or hitting more aces/unreturned serves. Rather, players found new solutions to winning points. For specific example, in matchplay, players who practiced the serve in tasks considered to be less representative of tennis matchplay (i.e., practicing the serve without an opponent (SO) or served to an opponent but did not play any extra shots (SR)) appeared to prioritise speed over placement on 2nd serves. Alternatively, when players were required to couple the serve with a second shot in practice (S3), players appeared to strategically slow the speed of their 2nd

serves to focus on placement in matchplay (i.e., a speed-accuracy trade-off in competitive performance contexts). The current findings suggest that practice and/or experimental task design needs to better reflect the intended learning outcomes and task goal (i.e., higher task representativeness is not necessarily more effective). For example, a tennis player wanting to improve serving accuracy, particularly on 2nd serve, may be best prioritising more representative practice while a player looking to improve ball speed could achieve this through (what we may consider to be) a less representative tasks.

7.3 Theoretical implications

The findings of this thesis expanded the current RLD framework using the sport of tennis as a task vehicle. To date, RLD and its application for improved learning and transfer have been based on cross-sectional studies (Barris et al., 2013; Pinder et al., 2009; Travassos et al., 2012) and coach testimonials (Slade et al., 2015). Importantly, the observations across Chapters 3, 5 and 6 confirmed the main tenets of RLD; manipulations to task representativeness will alter the emergent behaviours of an athlete (Pinder, Davids, et al., 2011). Equally, for the most part, it was confirmed that athlete behaviours observed in matchplay are best simulated in tasks that more closely represent matchplay contexts. Chapter 6, however, provided the first empirical evidence from a learning intervention that the application of RLD principles for enhanced skill learning and transfer require further consideration. That is, increasing the representativeness of a task does not simply imply enhanced skill learning. Instead, it is more reasonable to suggest that changes to task representativeness promote (i) different learning outcomes/adaptations and (ii) outcomes that are very specific to how practice was conducted (e.g., a player who serves less variably in practice, serves less variably in competition). As such, it appears that researchers should place a greater emphasis on aligning the degree to which a task is representative to the intended learning outcomes wishing to be transferred to competition.

Prior to this thesis, RLD focused on the two key principles of functionality and action fidelity for assessing the degree to which information and movements are represented in practice tasks. The RPAT developed in Chapter 4 provides a novel example of how these principles can be simplified to assist in the assessment and improvement of task designs (e.g., asking raters to compare athlete movement behaviours they see emerging in practice against what they would expect during competition). This approach enables a repeatable, time-efficient and comprehensive means for assessing the representativeness of practice and experimental tasks – as highlighted through the application of the RPAT in Chapters 5 & 6. Collectively, this promotes a more seamless transfer of the functionality and action fidelity principles from research into applied settings.

7.4 Methodological implications

In addition to validating and implementing the RPAT, this thesis promotes ball and player tracking technologies such as Hawk-Eye as novel solutions for challenging traditional coaching and/or experimental methods used to teach skills and infer transfer. The application of Hawk-Eye in this thesis has allowed the in-situ assessment of athlete behaviour, which has previously been a major limitation of most skill acquisition research. The use of ball and player tracking allowed us to more comprehensively explore the emergent behaviours of athletes in-situ across a range of representative tasks including matchplay. That is, previous examples have mostly only undertaken movement analyses of a single skill in tasks considered to be more or less representative of competition performances (e.g., forward defensive drives against a live opponent versus a machine (Pinder et al., 2009; Shim et al., 2005) or diving into a foam pit versus water (Barris et al., 2013).

This thesis reaffirmed existing concerns that traditional assessments of skill learning are poor predictors of actual matchplay performances (Buszard et al., 2017; Farrow et al., 2018; Robertson et al., 2014). Chapter 6 identified that when players' performances were assessed in matchplay their behaviours were vastly different to those observed in a skills test where they served to no opponent. For example, athletes who decreased serve speed during the matchplay test were found to increase serve speed during the skills test. As such, the results from previous experimental studies that have attempted to infer skill transfer through tasks low in representativeness may be misleading. In tennis this is certainly a concern given only one study has used matchplay as a transfer test (Buszard et al., 2017). A second limitation of previous methods for assessing skill is the variables being used often provide little to no context of key moments within a match and/or neglect the relationship a player shares with their opponent (e.g., inferring skill from the number of successful passes in soccer without contextualizing these relative to their difficulty – Ali, 2011). The adoption of contemporary statistics such as positional advantage (Carvalho et al., 2013), serve angle (Whiteside & Reid, 2016) and practice variability (Buszard et al., 2017) throughout this thesis provide examples of how researchers could use similar statistics to provide more meaningful insights into player behaviour. Utilising these statistics during in-situ matchplay assessments and/or skill tests that maintain the perception and action processes the player shares with their environment (i.e., opposition and other contextual factors) is also recommended.

7.5 Practical implications

The findings from this thesis confirm previous suggestions that tennis practice prioritises volume of shots over quality of practice (Reid et al., 2007). Namely a large portion of the practice tasks observed in Chapters 3 and 5 could be considered low in representativeness. That is the observed tasks: (i) de-coupled key perception-action processes required during a tennis match (e.g., serving to no opponent), (ii) promoted the execution of tactics that may be considered less desirable for competition transfer (e.g., making ball contact further behind the baseline) and/or (iii) scheduled the practice of skills in a blocked as opposed to variable manner.

To counter the above observations, three simple recommendations can be advanced from this thesis. First, coaches should attempt to maintain rather than decouple key perception and action processes. For example including a returner and/or requirement for a 3rd shot when practicing the tennis serve (see Chapter 6) ensures the server can maintain the critical coupling they share with the returner during a match (Whiteside & Reid, 2016). Second, coaches should closely evaluate a player's movement and actions during practice (e.g., via the RPAT, Hawk-Eye or visual/video inspection) to ensure they are self-regulating responses most relevant to the athlete's priorities and task goals. For instance, in Chapter 5 it was recommended that a court marker be placed at a key distance (e.g., 0.5m behind the baseline) as a reference for players of where they should be trying to position themselves to maximise opportunities to stay aggressive in a point. Third, coaches should look to include greater variability (e.g, between-skill variability) into the design of their practice tasks to encourage athletes to search and discover the laws that organise information and action (Barreiros et al., 2007; Brady, 2008; Van Rossum, 1990).

The findings from Chapter 6 provide an applied example of how task design can be manipulated to impact learning and transfer. It was observed that consistent exposure to practice conditions considered more or less representative of competition results in the emergence of different behaviours when the practiced skills (i.e., the serve) are performed in matchplay. Ultimately, no specific serving was shown to be more successful than another yet the specific behaviours that emerged with changing task constraints provide evidence that coaches need to tailor the design of practice tasks to the intended learning outcomes and skill level of their athlete. Moreover, the scheduling of the intervention (i.e., 2-3 session per week for 6 weeks and 50 serves per session) was similar to those delivered in elite tennis environments. Resultantly, the findings from this thesis remain relevant to applied tennis environments.

Consistent with previous observations (Pinder et al., 2013; Renshaw et al., 2016), the abovementioned implications suggest that coaches may not have previously comprehended how the RLD framework could be applied to assess the design of practice tasks. Validation of the RPAT, however, provides coaches with a simple checklist for assessing the representativeness of tennis practice tasks. Practical examples of how Hawk-Eye can be used to provide feedback on task representativeness and/or assessments of player behaviour will further assist in closing this gap. The non-invasive, time efficient and in-situ nature of such methods also provides significant advantages over previous methods (e.g., joint segment analysis – Barris and Button, 2008 and Whiteside et al., 2014), which may make coaches less apprehensive about undertaking such assessments.

For sporting organisations such as Tennis Australia, the findings from this thesis provide important information that challenges the various coaching material currently provided to coaches (Tennis Australia, 2007, 2010, 2015). As such, examples provided for improving task design in this thesis, along with those published elsewhere (Reid et al., 2015; Reid et al., 2010; Reid et al., 2013; Whiteside et al., 2014), the validation of the RPAT, and application of Hawk-Eye, could be used as a cornerstone to develop better-rounded coaching frameworks that highlight the importance of both practice volume *and* quality (i.e., representativeness).

7.6 Strengths of this thesis

This thesis had a number of key strengths, none more important however than this research being the first to (i) assess the specific constraints used to teach sport-specific tennis skills as they relate to the constraints observed in competition matchplay (Chapter 3), (ii) provide a validated quantitative assessment for task design in tennis (Chapters 4 and 5) and

(iii) test the effect of practicing in more versus less representative contexts (Chapter 6). These novel contributions resonate given that academics have historically suggested that such research is ‘difficult’, ‘time consuming’ and/or ‘requires significant sources of funding’ (Abernethy et al., 1993; Farrow & Baker, 2015; Pinder et al., 2015).

This thesis is further strengthened by it being among the first to provide representative assessments of practice performances relative to actual in-situ matchplay rather than matchplay simulations (e.g., net batting against a bowling machine versus live bowler – see Pinder et al., 2009 and Pinder, Renshaw, et al., 2011). The nature of the Hawk-Eye ball and player tracking data used also provides unique insights into player behaviour and performance outcomes which is vastly different to previous assessments of spatiotemporal movement kinematics (Barris et al., 2013; Pinder et al., 2009), and emergent opportunities for decision-making (Correia et al., 2012; Travassos et al., 2012). A major limitation of the Hawk-Eye system is its cost but other high fidelity and more cost effective optical tracking solutions are entering the market (e.g., local positioning systems in netball – Sweeting et al., 2017).

7.7 Limitations of this thesis

This thesis has some limitations that need to be acknowledged. In Chapters 3 and 6 the practice schedules of each player were only assessed comprehensively (i.e., shot level data of every ball hit) during sessions within their allocated National Academy and School squads respectively. The sporadic nature and travel required to film additional practice sessions outside of the observed squad environments meant attempts to reconcile the total volume or type of any additional serve or return practice could only be achieved through player-recall. The retrospective nature of Chapter 3, meant the additional practice outside of those filmed could not be recalled which may have resulted in the total volumes of serve or return practice being underrepresented. Chapter 6, however, required players to estimate the total number of extra serves hit since their last squad session through the use of a simple questionnaire (see Appendix O).

A common critique of most skill acquisition research, especially experiments using elite performers, is that sample sizes are often small (Baker & Farrow, 2015). Unfortunately, this issue remained a major challenge in this thesis for Chapters 3, 5 and 6 given (i) the talent pool of elite junior tennis players in Australia is very small and (ii) in the case of the learning intervention, athletes and their coaches were reluctant to alter training programs to encompass the requirements of the experiment conducted in Chapter 6. Nonetheless, the practice assessment in Chapter 3 is debatably more comprehensive than those undertaken previously given the practice habits of 12 different players, coached by 4 different coaches, were assessed individually before their data was combined. This is arguably more rigorous than generalizing the practice of an entire squad coached by the same coach (Low et al., 2013; Slade et al., 2015; Williams, Ward, Bell‐Walker, & Ford, 2012). Moreover, the sample size of approximately 10 athletes per group in Chapters 5 and 6, are comparable to those used by similar studies (i.e., cross sectional evaluations and learning interventions) which used 8 participants or less (Barris et al., 2013; Buszard et al., 2017; Hall et al., 1994).

The validation of the RPAT in Chapter 4 also encountered some challenges, which as a consequence were also carried over into Chapters 5 and 6. Despite thousands of possible training tasks being available to teach tennis skills, the initial assessment of the RPAT's construct validity (Chapter 4) was only based off the scores from five common practice tasks thought to differ considerably in task representativeness. While Chapter 6 provided further evidence to suggest the RPAT has moderate-high levels of validity for evaluating the representativeness of specific practice tasks, in time, practitioners may need to explore the validity over a more diverse range of tasks. Additionally, the RPAT does not include any assessments of coach instruction or feedback which are equally critical to enhancing skill learning and transfer (Hendry et al., 2015; Jackson & Farrow, 2005; Sigrist et al., 2013). Nonetheless, there are tools already published for capturing coach instruction and/or feedback (e.g., the CAIS developed by Cushion et al., 2012) that could be applied in parallel with the RPAT to provide a more holistic assessment of a practice task.

7.8 Future directions

The findings from this thesis propose a number of interesting directions for future research. Importantly, this thesis highlights that the RLD framework is a useful framework for assessing and designing practice tasks in sport in both experimental and applied settings. Ideally practice should elicit similar emotional responses to those experienced in competition and so future research should look to incorporate the affective learning design (Headrick et al., 2015) or cognitive load (Runswick, Andre, et al., 2017; Runswick, Roca, et al., 2017) frameworks to address this aspect of performance more comprehensively. This could include updating the RPAT with additional questions to assess the emotional response athletes exhibit during specific tasks. Alternatively, the use of existing assessments including the competitive state anxiety inventory-2 (Cox, Martens, & Russell, 2003) and/or rating scale of mental effort (Zijlstra, 1993) could be complementary (for an example of their application see Maloney et al., 2018). Furthermore, the RPAT is currently only validated for use in tennis, yet with some fine-tuning it could be adapted to assess task representativeness across a wider range of sports (see discussion in Chapter 4) to continue to evaluate how changes to task representativeness affect learning and transfer.

Based on the findings of this thesis, three general research directions can be provided: (i) assess the implications for learning and transfer over different time scales, (ii) assess this relationship across different age and skill groupings and, (iii) investigate better assessments for identifying emergent changes in movement behaviour and/or skill outcomes. Each of these points is discussed in detail below.

Chapter 6 showed how increased exposure to tasks of differing representativeness resulted in different emergent behaviours. It would therefore be interesting to identify how immediate these behavioural tendencies are transferred to competition performances. For example, if emergent behaviours can be transferred from practice to competition following 6-weeks of consistent exposure (i.e., 2-3 practice sessions per week) to the same practice task, could less practice time achieve the same. Current observations from Chapter 4 and previous examples in the RLD literature (Barris et al., 2013; Pinder et al., 2009; Travassos et al., 2012), which highlight the immediacy of behavioural change in response to more representative tasks, provides a foundation for such work. As a case in point, during a tennis tournament player's play every second day providing one day for practice before their next match, it would be interesting to simulate this schedule to identify if meaningful transfer from a single practice session can be implemented into the next day's match. While it may be argued that these changes may not be permanent given a lack of time for retention they still may provide the 1-2% edge required to beat a similarly matched opponent. The premise of such a short intervention (i.e., 1-2 sessions), however, remains left-of-field considering researchers often attempt to mimic out-of-tournament training blocks by using 6-8 week designs when investigating skill learning and transfer (Baker & Farrow, 2015). Nonetheless, assessments across different time-scales would provide researchers and coaches with specific recommendations for the frequency and volume of practice required for transfer (permanent or not) to take effect. Furthermore, the inclusion of a retention test in any future investigations would be beneficial to validate behavioural change.

This thesis focused on skilled and elite level junior tennis players. The generalizability of these results to other populations therefore remains unknown. As such, an interesting question is whether there are optimal ranges for task representativeness across certain age and/or skill groupings. For example, it is commonly acknowledged among other skill acquisition models, such as the practice variability hypothesis (Van Rossum, 1990) and the challenge point hypothesis (Guadagnoli & Lee, 2004), that the acquisition of skills are improved when the amount of variability and task difficulty are increased systematically with age and/or skill level. Based on this knowledge, one hypothesis is that higher levels of task representativeness (i.e., which includes higher variability and task difficulty) may provide more optimal skill learning and transfer among older and/or more highly skilled athletes. An alternative hypothesis is that tasks higher in representativeness will provide more desirable behaviours regardless of age and/or skill proficiency. The latter prognostication however is based off the assumptions that: (i) the task closely represents the age and skill based competition in which the athlete competes and (ii) this level of competition provides an adequate amount of challenge for that individual.

Lastly, as highlighted in Chapters 5 and 6, despite being a strength of this thesis, researchers need to continue to explore new innovative ways to assess player performances in-situ (e.g., through tools such as Hawk-Eye). As already discussed, common statistics such as those used by broadcasters (e.g., points won) provide very little context to the outcome of a certain action, play, or point. As such, it is critical that contextual factors that have a significant bearing on an athlete's decision-making and subsequent behaviour such as the relative positioning of opponents, field position of the ball (e.g., attacking or defensive half of the field) and/or specific time-point in a match (e.g., final 30s vs. first 30s) are considered through statistical approaches. The examples of using the Buszard et al. (2017) metric of practice variability and the Carvalho et al. (2013) measure of positional advantage, already discussed in this thesis, along with the Kovalchik and Reid (2018) approach to classifying shot trajectories, sets a precedence for such work.

7.9 Concluding remark

This thesis examined the efficacy of RLD as a tool for assessing and improving the design of sport-specific practice. It is known that experimental and practice tasks representative of competition contexts result in emergent behaviours closer to those that occur during competition performance contexts (Barris et al., 2013; Pinder et al., 2009; Travassos et al., 2012). However, previous research provided no empirical evidence for supporting increased learning and transfer benefits of practicing in more representative tasks over longer time-scales. This thesis tested the theoretical recommendations that practice needs to better represent competition via applying the RLD framework to the sport of tennis. Through application of the RLD framework it was identified that tennis practice prioritised more time in tasks considered to be less versus more representative of competition contexts (Chapter 3), which confirms previous concerns that tennis practice may be sub-optimal and/or inefficient (Reid et al., 2007). In an attempt to overcome this issue and support coaches and researchers in the design of more representative practice tasks, Chapter 4 consolidated the theory of RLD (Pinder, Davids, et al., 2011) and validated the first assessment tool for evaluating multiple types of practice drills in tennis – the RPAT. The RPAT was then applied to showcase how it could be used to: (i) assist in the assessment of task design (Chapter 5) and (ii) enhance the design of practice tasks for enhanced learning and transfer (Chapter 6). These applications confirmed predictions that changes to a task design (and the degree of 'representativeness') results in the development of alternate emergent behaviours, which are directly transferred to matchplay performances (Davids, Araújo, Vilar, et al., 2013; Pinder et al., 2009).

In conclusion, this thesis extends the current theoretical framework (RLD) and has offered new actionable insight to improve the design of practice and experimental sporting tasks. The findings from this thesis can be used to inform the manipulation of the design of practice and experimental tasks that, when aligned to an athlete's priorities, provide an effective framework for developing more desirable behaviours that transfer directly to competition performances. Despite the focus being on tennis, the results presented, have application to other interceptive sports with similar spatiotemporal demands.

CHAPTER 8

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CHAPTER 9

APPENDICES

VICTORIA UNIVERSITY
MELBOURNE AUSTRALIA

CONSENT FORM FOR PARTICIPANTS INVOLVED IN RESEARCH

INFORMATION TO PARTICIPANTS:

We would like to invite your child to be a part of the study title "A descriptive analysis of the practice profiles of skilled junior tennis players". The project will aim to help us understand how junior tennis players practice. The project requires your child to (i) allow the research team access to the training information you record through Tennis Australia's training monitoring app and (ii) agree to having a member of the research team attend and film your on-court tennis practice for 6 weeks. The video footage will be used by the research team to look at the types of drills being undertaken in practice as well as record the type (e.g., forehands and backhands) and total number of shots that your child hits. Whilst there is a small risk of injury in this project it would be no more than expected during a normal practice session. Similarly, while the research team will watch the videos of your child playing, the focus will not be on the players technical skill just the drills being undertaken and the volume/types of shots being hit.

CERTIFICATION BY PARTICIPANT:

I, ____ (parent/guardians name)
of ____ (parent/guardians suburb)
certify that I am at least 18 years old and that I am voluntarily giving my consent for
my child______________________________________ (participant/child's name)
to participate in the study titled: "A descriptive analysis of the practice profiles of skilled junior tennis" being conducted by Victoria University and Tennis Australia.

I, ___________________________________(participant/child) give assent to participate in the study.
□ Yes □ No (please tick)

I certify that the objectives of the study, together with any risks and safeguards associated with the procedures listed hereunder to be carried out in the research, have been fully explained to me and that I freely consent to my child's participation involving the below mentioned procedures:

- Providing access to my child's training monitoring data for the 6 specific weeks of observation required.
- Allowing a member of the research team to attend and film every practice session (unless specified otherwise by my child, myself or my child's coach) during the allocated 6-week period.
    - This includes allowing the research team to use this footage to:
        - Count the total number and type of shots (e.g., forehands, backhands) that your child hits during practice
        - Profile the practice drills being performed

I agree to be filmed for research.
□ Yes □ No (please tick)

I agree for this film to be used in presentations for teaching purposes and for scientific presentations.
□ Yes □ No (please tick)

I certify that I have had the opportunity to have any questions answered and that I understand that I can withdraw from this study at any time and that this withdrawal will not jeopardise me in any way.

I have been informed that the information I provide will be kept confidential.

Signed: ______________________________ Date: ______________________

Any queries about your participation in this project may be directed to the researcher team below:

Prof Damian Farrow
Professor of Skill Acquisition
Victoria University – Institute of Sport, Exercise and Active Living
E: Damian.Farrow@vu.edu.au, Ph: +61 408 445 701

Lyndon Krause, BExSc (Hons)
PhD student at the Institute of Sport Exercise and Active Living
E: Lkrause@tennis.com.au Ph: +61 423 308 074

If you have any queries or complaints about the way you have been treated, you may contact the Ethics Secretary, Victoria University Human Research Ethics Committee, Office for Research, Victoria University, PO Box 14428, Melbourne, VIC, 8001, email Researchethics@vu.edu.au or phone (03) 9919 4781 or 4461.

VICTORIA UNIVERSITY
MELBOURNE AUSTRALIA

INFORMATION TO PARTICIPANTS INVOLVED IN RESEARCH

You are invited to participate

Your child is invited to participate in a research project entitled "A descriptive analysis of the practice profiles of skilled junior tennis". This project is being conducted by student researcher Lyndon Krause as part of his PhD study at Victoria University under the supervision of Prof. Damian Farrow from the Institute of Sport, Exercise and Active Living.

Project explanation

The main reason athletes practice is to get better. While we know that practice helps to make athletes better, what we don't really know is exactly what practice and how much practice the best junior athletes are undertaking. Therefore in order to inform up and coming coaches of what is currently being undertaken and potential how current opportunities for practice could be improved we need to profile what is happening both inside Tennis Australia's academies as well as outside of these academies. This project therefore aims to identify the types of drills and activities being practiced along with the type (e.g., forehand, backhands) and total volumes of balls being hit. This will assist the development of better coaching programs benefiting the entire tennis community. Therefore, the purpose of this project is to describe the practice profiles of a small number of skilled Australian junior tennis players.

What will you be asked to do?

We are recruiting a small number of skilled junior tennis players from across Melbourne to participate. To participate your child will be need to:

- Provide the research team 6 weeks worth of their training monitoring data collected through Tennis Australia's app.
- Allow a member of the research team to attend and film their on-court tennis practice sessions (unless specified otherwise by yourself or your coach/s) over a continuous 6-week period.
    - This includes allowing the research team to use this footage to:
        - Count the total number and type of shots (e.g., forehands, backhands) that your child hits during this practice.
        - Profile the practice drills being performed

If your child agrees to participate, the research team will contact your child's tennis coach/s and to confirm that they are also happy to have their practice sessions filmed. Set up and pack down of the cameras will be done by a researcher so that we do not disturb your child's practice.

What you gain from participating?

As a participating player your child will receive a feedback report providing an overview of the practice sessions that they undertook across the 6-week observation period along with a description on the total number of shots and type of shots (i.e., forehands/backhands) they hit during practice. They will then have the option of further discussing this report with leaders in the field of skill acquisition and tennis coaching.

How will the information I provide be used?

The findings from this study will benefit the greater tennis and coaching community by providing a detailed description of the practice being completed by skilled junior tennis players. The data may also be used by Tennis Australia in the development of better coaching programs benefiting the entire tennis community. The most important findings will be presented in a research journal and may influence international sport science and coaching practice. Your child's data will be stored safely at

Victoria University on a password-protected computer and will not be able to be identifiable by anyone at all during the whole process.

What are the potential risks of participating in this project?

Given the nature of this study is purely to observe tennis players in the normal tennis environment, risks will be minimal. Risks of injury will be the same as during any normal coach-led practice session. We also acknowledge that being filmed during practice can be daunting, however we must remind you and your child that only members of the research team will be able to view this footage. If at any time you feel uncomfortable during this project you and/or your child can remove their participation without question or consequence.

How will this project be conducted?

Initially, a member of the research team will visit your child at one of your national tennis centre practice sessions to discuss the project and confirm a start date (either the first 6 or last 6 weeks of term per Tennis Australia's junior development scheduling). During this 6-week block, the research team will ask your child for access to the data that they submit daily through Tennis Australia's training monitoring app. In addition you as the parent and/or your child's coach may be contacted to make sure that we know the location and duration of your practice session's so that a researcher can be onsite to film. Set up of the camera will happen five minutes before practice. This camera will then be removed at the end of your child's session. The camera will be mounted on top of the tennis fence behind the baseline so that it will not be in the way of practice. This camera will be positioned so that it can only film your child's court, not those playing around them. After each session the camera will be taken back to Tennis Australia and download the video footage downloaded to a password protected laptop. This footage will then be used profile the drills being performed and to count the total number of shots your child hit during the recorded session We must remind you that your child's participation is completely voluntary and they will not be advantaged or disadvantaged in any way or form if they chose not to participate.

Who is conducting the study?

Research from Victoria University and Tennis Australia are jointly conducting this project. Any queries about your participation in this project may be directed to the Chief Investigator listed below.

Prof Damian Farrow
Professor of Skill Acquisition
Victoria University – Institute of Sport,
Exercise and Active Living
+61 408 445 701

Lyndon Krause, BExSc(Hons)
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Institute of Sport, Exercise & Active Living (ISEAL)
Victoria University & Tennis Australia
Melbourne, VIC 8001
Phone: +613 9919 4512

If you have any queries or complaints about the way you have been treated, you may contact the Ethics Secretary, Victoria University Human Research s Committee, Office for Research, Victoria University, PO Box 14428, Melbourne, VIC, 8001, email researchethics@vu.edu.au or phone (03) 9919 4781 or 4461.

VICTORIA UNIVERSITY
MELBOURNE AUSTRALIA

Date, Year
Name
Club Name
Club Address

This letter is to confirm that as the coach of ______________________________ tennis club I hereby grant Victoria University and Tennis Australia researchers access to the club's facilities to undertake the required video filming for the project titled: "A descriptive analysis of the practice profiles of skilled junior tennis players". Strictly, filming will however only be permitted for the allocated times and sessions that I provide the research team. This extends to me being able to have filming ceased at any time without consequence to my player, the player's parent and/or the tennis club and myself.

Permission to access the required courts for the purpose of this study will be provided up until the completion of the research project or unless stated otherwise by myself.

Kind regards,

____ (Insert signature)

____ (Full name)

CONSENT FORM FOR PARTICIPANTS INVOLVED IN RESEARCH

INFORMATION TO PARTICIPANTS:

We would like to invite your child to be a part of the study titled: "Determination of the stroke and movement performance characteristics of 12 and under tennis". The project will aim to (i) improve our understanding of how junior tennis compares to professional level tennis and (ii) whether common practice drills actually represent matchplay performance. This project requires your child to attend one, one-off 2 hour session located at the National Tennis Centre in Melbourne. This session will be undertaken in two parts. Part 1 will involve your child performing four 4-minute practice drills designed to replicate activities your child would typically undertake during practice. Part 2 will involve your child playing a regulation three set tennis match against a player of the same gender, skill level and handedness. The entire session will be filmed using standard video and Tennis Australia's state of the art Hawk-Eye ball and player tracking system (the same system that is used for line challenges at the Australian Open). There are risks involved with participation in this study, however they will be no greater than the risks your child is exposed to during typical practice or competition play.

CERTIFICATION BY SUBJECT:

I, ____ (parent/guardians name)
of ____ (parent/guardians suburb)
certify that I am at least 18 years old and that I am voluntarily giving my consent for
my child_______________________________________ (participant/child's name)
to participate in the study titled: "Determination of the stroke and movement performance characteristics of 12 and under tennis" being conducted by Victoria University and Tennis Australia.

I, ____ (participant/child's name) give assent to be involved in the study.

□ Yes □ No (please tick)

I certify that the objectives of the study, together with any risks and safeguards associated with the procedures listed hereunder to be carried out in the research, have been fully explained to me by Lyndon Krause and that I freely consent to my child's participation involving the below mentioned procedures:

- Attending one one-off sessions at Tennis Australia National Tennis Centre:
    - Participation in 4 x 4 minute practice drills.
    - Participation in a regulation 3-set tennis match.
- Video and Hawk-Eye (ball and player tracking) recordings of each session.

I agree with the filming of my child performing these activities as well as the presentation of this video footage for teaching purposes and scientific presentations.

□ Yes □ No (please tick)

I certify that I have had the opportunity to have any questions answered and that I understand that I can withdraw my child from this study at any time and that this withdrawal will not jeopardise me or my child in any way.

I have been informed that the information I and/or my child provide will be kept confidential.

Signed: _____________________________________ Date: ________________

Any queries about your child's participation in this project may be directed to the lead researcher (see over).

Prof Damian Farrow
Professor of Skill Acquisition
Victoria University – Institute of Sport, Exercise and Active Living
+61 408 445 701

Lyndon Krause, BExSc(Hons)
PhD student at the Institute of Sport Exercise and Active Living
+61423 308 074

If you have any queries or complaints about the way you or your child has been treated, you may contact the Ethics Secretary, Victoria University Human Research Ethics Committee, Office for Research, Victoria University, PO Box 14428, Melbourne, VIC, 8001, email Researchethics@vu.edu.au or phone (03) 9919 4781 or 4461.

VICTORIA UNIVERSITY
MELBOURNE AUSTRALIA

CONSENT FORM FOR PARTICIPANTS INVOLVED IN RESEARCH

INFORMATION TO PARTICIPANTS:
We would like to invite you to be a part of the study titled: "A descriptive analysis of the practice profiles of elite junior tennis". The project will aim to holistically describe the practice schedules of elite tennis players whilst delving more systematically into the specific types of practice drills and hitting volumes being undertaken. This will be achieved b
This will be achieved through a Delphi study, which will require you to complete a succession of internet-based questionnaires related to the validation of this assessment tool. Furthermore, you will be asked to assess the tool using real world pre-recoded video footage. There are no apparent risks involved with participation in this study.

CERTIFICATION BY SUBJECT:

I, ____ (full name)
Certify that I am at least 18 years old and I am voluntarily giving my consent to participate in the study titled: "The validation of a tennis-specific practice assessment tool" being conducted by Victoria University and Tennis Australia.

I certify that the objectives of the study, together with any risks and safeguards associated with the procedures listed hereunder to be carried out in the research, have been fully explained to me by Lyndon Krause and that I freely consent to my participation involving the below mentioned procedures:

- Completing 2-3 Delphi rounds consisting of 30 minute questionnaires related to validating the tool including;
  - Outline whether you consider the listed properties and items to be important to the design of practice activities.
  - Express your level of agreement or disagreement to related terminology and definitions on this tool.
  - Briefly comment on your attitudes towards the importance of these properties when assessing the overall quality of a practice activity.
- Implementing the tool against a number of pre-recorded tennis practice activities (approximately one hour).

I understand that I will be supplied video recordings of both match and drill activities and that I will be required to keep their content and the identities of the participants within these videos completely confidential. I agree to NOT distributing these videos or any other material supplied by the research team to me, in any way or form (please tick below).

□ Yes □ No
I certify that I have had the opportunity to have any questions answered and that I understand that I can withdraw from this study at any time and that this withdrawal will not jeopardise me in any way.

I have been informed that the information I provide will be kept confidential.

Signed: ______________________________________ Date: ________________

Any queries about your participation in this project may be directed to the lead researcher (see over);

Prof Damian Farrow
Professor of Skill Acquisition
Victoria University – Institute of Sport, Exercise and Active Living
+61 408 445 701

Lyndon Krause, BExSc(Hons)
PhD student at the Institute of Sport Exercise and Active Living
+61423 308 074

If you have any queries or complaints about the way you or your child has been treated, you may contact the Ethics Secretary, Victoria University Human Research Ethics Committee, Office for Research, Victoria University, PO Box 14428, Melbourne, VIC, 8001, email Researchethics@vu.edu.au or phone (03) 9919 4781 or 4461.

INFORMATION TO PARTICIPANTS INVOLVED IN RESEARCH

Your child is invited to participate

Your child is invited to participate in a research project entitled "The validation of a tennis-specific practice assessment tool". This project is being conducted by student researcher Lyndon Krause as part of his PhD study at Victoria University under the supervision of Prof.Damian Farrow from the Institute of Sport, Exercise and Active Living.

Project explanation

For a long time it has been suggested that athletes across many sports, including tennis, prioritise 'quantity' over 'quality' practice. This is concerning given that it has been shown that some of the most common activities used by coaches and athletes to prioritise quantity into their schedules (i.e., the use of ball projection machines) can lead to athletes practicing very different movement solutions (skills) to what they would perform during competition. Accordingly it has been proposed that spending too much time prioritising quantity over quality practice may result in reduced skill learning and transfer of skills towards competition. Therefore, it is important that coaches design activities that prioritise 'quality' over 'quantity'. One way in which the quality of an activity can be improved is by attempting to replicate competition performance as closely as possible. Nevertheless, despite the best efforts of coaches given the vast range of factors (i.e., perceptual, contextual, tech/tactical factors) that must be considered, upholding the design quality of practice activities is difficult. Accordingly, it is proposed that a tool assisting coaches to assess and improve practice activities based on such factors would be immensely valuable. Therefore, this study aims to validate the use of a practice assessment tool into the real world tennis setting, which could be used by coaches and trainers to improve the quality of practice, therefore enhancing the skill development of tennis athletes in Australia.

In this project, your child will perform one, one-off video and Hawk-Eye* recorded session involving you child participating in a coach-led practice session consisting of 6 x 20 minute practice activities.

3 x 20 minute Coach led practice session (1.5 hours).

In no particular order your child will be asked to participate in; 1 x 20 minute service activity, 1 x 20 minute Baseline/groundstroke activity and 1 x 20 minute Midcourt/rally activity. Between each activity a 10-minute drinks and recovery break will be provided. Each activity has been carefully designed to replicate activities typically undertaken in the tennis practice setting; therefore, it is likely your child has experienced these activities before. The session will be conducted by one of Tennis Australia's high performance tennis coaches.

Validation of the assessment tool:

Video and Hawk-Eye* vision obtained from this session will be outsourced to a panel of 30 tennis and academic experts for validation of the proposed practice assessment tool. The panel will be required to provide current working with children's checks and must not have any formal relation to your child, including being in no position to influence any future selections that your child may be involved in.

**Hawk-Eye system:*

The Hawk-Eye system used in this project is the same technology used globally at many tennis tournaments for the review of line calls. In this project the Hawk-Eye will be used to provide accurate game play dynamics including ball speeds and players movements. This data will later be used for validation of the assessment tool by comparing 'subjective' responses from the panel of experts to the 'actual' Hawk-Eye match and practice dynamics.

What will my child be asked to do?

Your child will be asked to attend a one off 1.5 hour testing session at the National Tennis Centre in Melbourne. The session will consist of your child being matched with a player of similar ability and participating in three 20 minute coach-led practice activities, designed to replicate activities your child would typically undertake in the

practice setting. During this session your child will be filmed using standard hand-held video cameras and also Tennis Australia's player and ball tracking system (Hawk-Eye).

What will my child gain from participating?

Your child will be provided an overview of his/her performance during the recorded practice session as analysed from the Hawk-Eye system. This information can then be reviewed by your child their coach and yourself to highlight key areas and skills in which they excel or need to emphasise practice time toward.

How will the information my child provides be used?

First, the video footage of the recorded practice activities in which your child is helping to create will be presented to a panel of tennis and academic experts external to the research team. Accordingly the experts will use these videos to assess the ability of the pre-conceptualised tool to evaluate the design 'quality' of the activities presented before them. Additionally, the practice activity dynamics (Hawk-Eye data) in which your child is helping to create will be later correlated with expert responses to further assess the applicability of the assessment tool. The tool will provide practitioners (i.e., coaches) a valid measure for evaluating the design of practice activities being delivered to ensure opportunities for learning are maximised.

Second, the findings of this study will be presented in the form of a journal publication and thesis. This means other scientists and coaches will be able to benefit from the knowledge gained from this project. Some of the video recordings may also be used at presentations for Tennis Australia and/or academic conferences to highlight how the proposed assessment tool could be used. Please note that whilst your child will not be named within any reports or presentations, there is still a chance that someone outside of the research team may identify your child visually in the scenario that video footage of the practice tasks used as an exemplar.

What are the potential risks of participating in this project?

While participating in this study your child risks getting injured (e.g., soft tissue injuries or getting hit by a ball as they would during normal tennis practice or competition). All the necessary precautions to minimise the likelihood of this occurring will be taken. The video footage from both sessions of your child will be outsourced to a panel of 30 tennis and academic experts for assessment, therefore there is a small chance they may recognise your child. However, to protect your child's anonymity, all experts will be required to provide current working with children checks and have no formal association with your child. Furthermore, it must be emphasises that the experts focus will remain on nature and design of the activities being performed as opposed to your child's performance during these tasks.

How will this project be conducted?

The project will be conducted at the National Tennis Centre, Olympic boulevard, Melbourne, whereby each child will participate in 2 practice session over a 1 week period. Both sessions will be filmed and subsequently analysed by a panel of 30 experts. Furthermore, player dynamics will be analysed using the Hawk-Eye system with participants receiving their individual results after testing via email.

Who is conducting the study?

Researchers from Victoria University and Tennis Australia will jointly conduct the project. Any queries about your participation in this project may be directed to the Chief Investigator listed below.

Prof Damian Farrow
Professor of Skill Acquisition
Victoria University – Institute of Sport,
Exercise and Active Living
+61 408 445 701

Lyndon Krause, BExSc(Hons)
PhD student at the Institute of Sport
Exercise and Active Living
+61 423 308 074

Dr Machar Reid
Head of Innovations
Tennis Australia
+61 401 077 441

Dr Ross Pinder
Skill Acquisition Specialist
Australian Paralympic Committee
+61 410 857 897

Dr Tim Buszard
Industry Post-Doctoral Research Fellow
Institute of Sport, Exercise & Active Living (ISEAL)
Victoria University & Tennis Australia
Melbourne, VIC 8001
Phone: +613 9919 4512

If you have any queries or complaints about the way you have been treated, you may contact the Ethics Secretary, Victoria University Human Research Ethics Committee, Office for Research, Victoria University, PO Box 14428, Melbourne, VIC, 8001, email researchethics@vu.edu.au or phone (03) 9919 4781 or 4461.

VICTORIA UNIVERSITY
MELBOURNE AUSTRALIA

INFORMATION TO PARTICIPANTS INVOLVED IN RESEARCH

You are invited to participate

You are invited to participate in a research project entitled "The validation of a tennis-specific practice assessment tool". This project is being conducted by student researcher Lyndon Krause as part of his PhD study at Victoria University under the supervision of Prof. Damian Farrow from the Institute of Sport, Exercise and Active Living.

Project explanation

For a long time it has been suggested that athletes across many sports including tennis prioritise practice in relation to 'quantity' over 'quality'. This becomes concerning given that it has been shown that some of the most common activities used by coaches and athletes to prioritise quantity into their schedules (i.e., the use of projection machines) can lead to athletes practicing very different movement solutions to what they would perform during competition. Accordingly it has been proposed that spending too much time prioritising quantity over quality may result in reduced skill learning and transfer of skills towards competition. Therefore, it is important that coaches and athletes design activities that prioritise 'quality' over 'quantity'. Given the range of factors that must be considered, the assessment of practice design should be informed by how effectively an activity can replicate the performance environment in order to maximise skill learning and transfer towards competition. However, no such framework currently exists for use in the applied setting. Therefore, the purposes of this project are to:

1. Reach consensus on which key properties of practice activities should be evaluated, as well as how these properties should be defined.
2. Develop, validate, publish and disseminate a tool for the use of assessing tennis-specific practice activities based on these findings.

What will you be asked to do?

We are recruiting two types of experts from around Australia to participate in this Delphi project: i) academics and ii) high performance tennis coaches. As an expert in your respective field you are invited to participate in a series of internet-based questionnaires that will identify a number of properties and specific items asking you to:

- Outline whether you consider these properties and items to be important to the design of tennis practice activities;
- Express your level of agreement or disagreement to related terminology and definitions;
- Briefly comment on your attitudes towards the importance of these properties when assessing the overall quality of a practice activity.

We expect that each questionnaire will take approximately 30 minutes to complete. Multiple rounds (possibly 2-3) may be required to reach consensus on specific questionnaire items, and we appreciate your efforts in completing follow-up questionnaires to facilitate this process.

Following the conceptualisation and validation of this tool, you will also be invited back for one last round, which will include assessing the tools performance by rating a number of pre-recorded tennis practice activities using the newly developed tool. This will require approximately one hour of your time.

What you gain from participating?

This project will benefit the broader tennis, sport science and coaching community through the development of a validated tool for evaluating the design of tennis practice activities. This tool will provide practitioners and athletes a way to self-evaluate the 'quality' of practice activities being undertaken and provide a means for improving the overall design of low scoring activities. The findings from this study will also be reported in scientific manuscripts, and may influence international sport science and coaching practice.

How will the information I provide be used?

The findings from this study will be used to create a validated tool for evaluating the design of tennis-specific practice activities. In addition, the tool along with key findings will be presented in the form of a journal publication. Nevertheless, all data will remain anonymous with no information included that would allow any individual to be identified. Similarly, throughout the research process all information provided to the research team will be de-identified and coded prior to be analyses. Any identifying information including your name and assigned code, will be kept separately from the de-identified copy of the data and stored at Victoria University on a password protected computer.

What are the potential risks of participating in this project?

There are no anticipated risks associated with participating in this project.

How will this project be conducted?

This project will be conducted online using internet-based questionnaires. Prior to commencement you will be sent an email detailing the specific project requirements and will be provided opportunities to seek further information either via email or phone correspondence with a member of the research team. If this is all clear, you will be asked to participate in a series of successive online questionnaires containing generic questions related to the validation of the proposed tennis-specific practice assessment tool. Information retrieved from the questionnaire will be collated into a feedback report, de-identified and distributed among the panel of experts. This information will be used by the research team to inform changes to the assessment tool prior to re-sending a revised version to the panel of experts for further evaluation. This process will continue until consensus is reached between each panel member for the key properties and items identified on the tool. For each round you will be given one month to respond, and failure to do so in this time will result in termination from the project.

Who is conducting the study?

Research from Victoria University and Tennis Australia are jointly conduct this project. Any queries about your participation in this project may be directed to the Chief Investigator listed below.

Prof Damian Farrow
Professor of Skill Acquisition
Victoria University – Institute of Sport,
Exercise and Active Living
+61 408 445 701

Lyndon Krause, BExSc(Hons)
PhD student at the Institute of Sport
Exercise and Active Living
+61 423 308 074

Dr Machar Reid
Innovation Catalyst
Tennis Australia
+61 401 077 441

Dr Ross Pinder
Skill Acquisition Specialist
Australian Paralympic Committee
+61 410 857 897

Dr Tim Buszard
Industry Post-Doctoral Research Fellow
Institute of Sport, Exercise & Active Living (ISEAL)
Victoria University & Tennis Australia
Melbourne, VIC 8001
Phone: +613 9919 4512

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VICTORIA UNIVERSITY
MELBOURNE AUSTRALIA

Dear [name],

As an expert in [one of; Motor learning or Tennis Coaching], I am contacting you to gauge your interest in participating in a research project titled, "The validation of a tennis specific practice assessment tool".

Purpose:
For a long time it has been hypothesised that athletes across many sports including tennis prioritise practice 'quantity' over 'quality', which may result in reduced opportunities for skill learning and transfer towards competition. However, no guidelines currently exist for evaluating of the design of practice tasks being delivered in any sporting context. To address this issue, we wish to draw from the perspectives of professionals in motor learning and tennis coaching to reach consensus on what range of factors are most important to constructing 'high quality' tennis practice tasks. As a direct outcome of this project, we will develop a validated, practical evidence-based tool for guiding practitioners in assessing the design of practice tasks, effectively ensuring that opportunities for learning are enhanced.

What will I be required to do?
In short, participation in the current study will require you to comment on and validate the proposed practice assessment tool (see attached). This process will involve you (1) completing 2-3 questionnaires (30-40mins each) spaced approximately one-month apart and (2) finalizing the tools validity by implementing the tool against pre-recorded tennis practice activities (one-off assessment taking approximately 2 hours). More, specific details related to this project can be found in the 'Plain Language Statement' attached.

How do I participate?
If you wish to participate, please complete the attached consent form and return it to Lyndon Krause via the email provided below before xx/xx/xx. Following, your acceptance you will be sent a further email containing a login password and link to the first online questionnaire.

Please feel free to contact me via email (Lyndon.krause@live.vu.edu.au) or phone (0423 308 074) if you have any further questions.

Regards,

[redacted]

Lyndon Krause

PART 1: Practice Drills

Day: ____________________ Date: ____________ Player 1: ____________________ Player 2: ____________________

Who do you model your game on? ____________________ ____________________

Instructions for HawkEye set-up throughout Part 1:

BEFORE

1. Scoring – "tie-break numbers"
2. "New set" & players change ends
3. Allocate ends (+ve = Aami Park, -ve = MCG)
4. Scoring type = 'tie-break numbers'
5. **Start 4 min timer**

DURING

1. **New balls** (2 new balls every two drills)
2. 'Check server' (note 1st server in below table)
3. 'Change server' after every point
4. 'Code' the last shot of every rally
5. Assign score.

AFTER

1. "New set"
2. "Change ends"
3. Write final score in table below

Instructions for players during Part 1:

Prior to commencing first drill:

1. Provide 5min warm up (be strict).

Prior to commencing each drill:

1. Reinforce that the aim is to 'WIN' each rally.
2. Explain the rules.
3. Explain how points can be won.
4. Remind players to call their own lines.

*Drill #		Player 1	Player 2
	1st feed of game		
	Drill score		
	1st feed of game		
	Drill score		
	1st feed of game		
	Drill score		
	1st feed of game		
	Drill score		

*Refer to page 3 (Table 1) for proposed drill order

Part 2 – Matchplay:

Instructions for HawkEye throughout Part 2:

BEFORE

1. Close HawkEye used in Part 1
2. Re-open HawkEye - Create New match
(See HawkEye setup & Shutdown)
4. Scoring type = regulation (unselect tie-break)
5. Flip coin, winner selects 'serve or return'
6. Allocate ends (+ve = Aami Park, -ve = MCG)

DURING

1. **New balls** (2 new balls per set)
2. 'Check server' (Note 1st server in below table)
3. 'Change server' after each game.
4. 'Code' every serve & return.
5. 'Code' the last shot of every rally.
6. Assign Score

AFTER

1. 'Next game' at completion of each game
2. 'Change ends' every odd # games
3. At completion of set - select 'new set'
4. Write score at end of set below

Instructions for players during Part 2:

Prior to commencing match play:

2. Provide 5min for warm up (be strict).
3. Match will be player using regulation singles rules.
4. Remind players to call their own lines.
5. Explain that if 1-set-all deciding third set will be a super tie-break first to 11 (must win by two points).

MACTHPLAY		Player 1	Player 2
Set 1	1st Serve of set		
	Set Score		
Set 2	1st Serve of set		
	Set Score		
Set 3 (tiebreaker)	1st Serve of set		
	Set Score		

-

VICTORIA UNIVERSITY
MELBOURNE AUSTRALIA

CONSENT FORM FOR PARTICIPANTS INVOLVED IN RESEARCH

INFORMATION TO PARTICIPANTS:

We would like to invite you to be a part of a study that is examining the efficacy of three practice approaches to improve the serve in junior tennis players.

CERTIFICATION BY SUBJECT

I, *(parent/guardian's name)*..

certify that my child, *(child's name)*... can participate in the study: "Enhancing tennis skills during matchplay by manipulating the scheduling of serve practice" being conducted at Victoria University by Dr Tim Buszard (Chief Investigator).

I certify that the objectives of the study, together with any risks and safeguards associated with the procedures listed hereunder to be carried out in the research, have been fully explained to me by Tim Buszard, and that I freely consent to my child's participation which may involve the below mentioned procedures:

- Participate in skills testing and Hawk-Eye matchplay at the start and end of the term. Note, pre and post matchplay sessions will be undertaken on Tennis Australia's Hawk-Eye enabled court located at the National Tennis Centre, Melbourne at a time convenient to your child.

I certify that I have had the opportunity to have any questions answered and that I understand that I can withdraw my child from this study at any time and that this withdrawal will not jeopardise my child in any way.

I have been informed that the information my child provides will be kept confidential.

Parent/Guardian's signature:..

Date: ....

Child's signature:...

Date:.......................................

PLEASE RETURN THIS TO TIM BUSZARD VIA EMAIL tim.buszard@vu.edu.au OR IN PERSON AT TRAINING.

Any queries about your participation in this project may be directed to the chief investigator:

Tim Buszard (chief investigator)
9919-4512

If you have any queries or complaints about the way you have been treated, you may contact the Research Ethics and Biosafety Manager, Victoria University Human Research Ethics Committee, Victoria University, PO Box 14428, Melbourne, VIC, 8001 or phone (03) 9919 4148.

VICTORIA UNIVERSITY
MELBOURNE AUSTRALIA

CONSENT FORM FOR SCHOOL PRINCIPAL

INFORMATION TO SCHOOL PRINCIPAL:

Your school is invited to participate in a research project examining the influence of three practice approaches on the acquisition of serving skill in talented junior tennis players.

CERTIFICATION BY SUBJECT

I, *(school principal's name)* ……...

certify that .... Secondary School can participate in the study: "Enhancing tennis skills during matchplay by manipulating the scheduling of serve practice" being conducted by Dr Tim Buszard (Chief Investigator).

I certify that the objectives of the study, together with any risks and safeguards associated with the procedures listed hereunder to be carried out in the research, have been fully explained to me by Dr Buszard, and that I freely consent the following procedures to be conducted on school grounds for children in years 7 to 12 that return consent forms:

- *Enable the research team to oversee 3 X 30minuite tennis practice serving sessions per week for 8 weeks. Note CI Buszard will liaise directly with your schools Head Tennis Coach to gain their consent and assistance in the implementation of the required practice sessions.*
- *The research team to conduct one 10min skills test per player both pre and post the 8 week intervention. Timing for this testing will be liased with your schools head tennis coach for convenience.*
- *Additionally, one pre and one post matchplay session will be organised for each child at a time convenient to player and parent during out of school hours. Note, this testing will take place at the National Tennis Centre, Melbourne.*
- *The research team to film each of the 30min serving sessions for the 8-week period. Note, there is a risk that children outside the study may be captured. However, the research team will immediately delete any footage including a child not enrolled in the study.*

I certify that I have had the opportunity to have any questions answered and that I understand that I can withdraw the school from this study at any time and that this withdrawal will not jeopardise the school in any way.

I have been informed that the information about the children participating in the study will be kept confidential.

Principal's signature:...

Date: ....

Any queries about your participation in this project may be directed to the Chief Investigator: Dr Buszard (9919 4512 or tim.buszard@vu.edu.au).

If you have any queries or complaints about the way you have been treated, you may contact the Research Ethics and Biosafety Manager, Victoria University Human Research Ethics Committee, Victoria University, PO Box 14428, Melbourne, VIC, 8001 or phone (03) 9919 4148.

VICTORIA UNIVERSITY
MELBOURNE AUSTRALIA

INFORMATION TO PARTICIPANTS INVOLVED IN RESEARCH

Your child is invited to participate

Your child is invited to participate in a research project entitled "Enhancing tennis skills during matchplay by manipulating the scheduling of serve practice". Your child's participation is voluntary and is not related to selection / deselection within the [insert schools/Tennis Academy name here] program. The main aim of the project is to examine the efficacy of three commonly used practice approaches with regards to acquisition of serving skill.

This project will be conducted by Tim Buszard from the College of Sport and Exercise Science and ISEAL at Victoria University. The research team also includes Damian Farrow (Victoria University), Lyndon Krause (Victoria University) and Machar Reid (Tennis Australia).

Project explanation

This project will examine the influence of three practice approaches on the acquisition of serving skill in talented junior tennis players aged 18 years and under. Approach 1, will most closely replicate the demands of a match with the server required to hit both serves and groundstrokes against an opponent. Approach 2, will involve hitting only serves against an opponent (i.e., no other shots). Approach 3 (least like matchplay), will involve hitting only serves against no opponent.

Evidence from the laboratory suggests that practice that is more aligned to the demands of matchplay will lead to greater skill acquisition. Whilst this might seem like common sense, research in the applied setting does not provide such clear results. The purpose of this study is therefore to explore this issue in typical tennis training sessions with talented junior athletes.

What will your child be asked to do?

Your child will not be asked to do anything additional to the training sessions that they will participate in as part of the [insert schools/Tennis Academy name here] program. Indeed, the study will be conducted during normal training hours. Moreover, all [insert schools/Tennis Academy name here] program will participate in the serving protocol, which will take place during the first 30 minutes of every training session for the duration of one term. The exact protocol is as follows:

- Start of term – Skills testing* & matchplay (matchplay at National Tennis Centre, Melbourne)
- Throughout term – Serving practice
- End of term – Skills testing* & matchplay (matchplay at National Tennis Centre, Melbourne)

All children in the [insert schools/Tennis Academy name here] program will be randomly allocated to one of three groups. Specifically, Group 1 will be the 'most match-like' requiring the server to serve against an opponent and also play a groundstroke following the serve. Group 2 will still be match-like but only require the server to serve against an opponent. Group 3, will be the least match-like' requiring the server to serve to no opponent.

*** Only players who return the consent form will be asked to complete the skills testing and matchplay. For skills testing players will be removed individually from normal training to a**

nearby court for 10 minutes to complete this test while matchplay will require players to attend a schedule Hawk-Eye session at the National Tennis Centre, Melbourne. Co-researcher Lyndon Krause will be in touch to organise a matchplay session at your child's convenience once they are accepted into the study. Data will only be collected on the players who return consent forms.

The serving protocol involves approximately 40 serves per session, which the coaches have determined is the appropriate number of serves to elicit skill improvements. To place this number into perspective, a typical practice session that focuses predominately on serving includes approximately 90 serves, so it is believed that approximately 40 serves will not place undue stress on the children.

Please be aware that your child will be filmed throughout the study (pre-test, practice and post-test) to allow for analysis of serving performance. Indeed, this is very similar to normal training procedures within the [insert schools/Tennis Academy name here] program whereby training can often be filmed. However, for the purpose of our study, the footage of any child who does not return a consent form will be deleted from the researcher's possession immediately after each session. The remaining video footage will be stored on the Chief Investigators' hard drive and only the research team will have access to this footage. All training ad skills testing will be conducted within the [insert schools/Tennis Academy name here] precinct, while your child will be required to perform two matches at Tennis Australia's National Tennis Centre, on their Hawk-Eye** Enabled tennis court. Moreover, the data will be de-identified (i.e., your child's name will be replaced with a code) prior to any analysis undertaken. Your child is free to withdraw from participating in the study at any time.

***Hawk-Eye system:*

> The Hawk-Eye system used in this project is the same technology used globally at many tennis tournaments for the review of line calls. In this project the Hawk-Eye will be used to provide accurate game play dynamics including ball speeds and players movements, which can be used to evaluate serving performance.

What will your child gain from participating?

There are two important outcomes for the children participating:

1. Players who return consent forms will receive feedback regarding skill improvement, based on skill testing and Hawk-Eye matchplay data.

2. The findings will provide guidance on how to most effectively practice the serve. For instance, if our hypothesis is found to be true, we will recommend that children should practice the serve in conjunction with other skills, rather than the serve alone.

How will the information I give be used?

It is our intention to present the findings of the group data in the form of a journal publication. Please note that your child will not be named within this report and no one outside the team of researchers will be able to identify your child's results at any time during or following the study. An assigned identification number known only by the researchers will identify your child's results.

What are the potential risks of participating in this project?

1. The physical risks associated with this study are no more than the risks associated with typical training sessions in junior tennis. As with every training session in the [insert schools/Tennis Academy name here] program, the coaches will ask players to provide honest feedback about how their body is feeling. Any player that reports feelings of soreness will be encouraged to rest. The coaches will emphasise that children should not complete the serving protocol if they are feeling sore or injured.

2. Children may feel concerned that their performance during the pre- and post-tests may highlight any real or perceived physical and/or skill deficiencies, thus leading to potential embarrassment. The researchers will reinforce that all data will remain strictly confidential with their names de-identified through the use of codes and/or pseudonyms.

3. Situation could arise where children feel embarrassed to perform in front of their peers or where children watching may make fun of the participant. Consequently, all children will be told by the Chief Investigator at the beginning of the matches that they must show good sportsmanship by adhering to the rules of tennis and showing support for other children.

How will this project be conducted?

The project will involve players (males and females) from the [insert schools/Tennis Academy name here] program in Victoria practicing serving over the course of one term at Melbourne Park. The serving practice will be incorporated into the regular training sessions and data will only be collected on the children the provide consent to do so.

Who is conducting the study?

Should you have any questions regarding this project, please contact the chief investigator:

Chief Investigator
Tim Buszard
Telephone 9919-4512
Victoria University

Any queries about your participation in this project may be directed to the Chief Investigator or student researcher listed above. If you have any queries or complaints about the way you have been treated, you may contact the Research Ethics and Biosafety Manager, Victoria University Human Research Ethics Committee, Victoria University, PO Box 14428, Melbourne, VIC, 8001 or phone (03) 9919 4148.

Regards,

Tim Buszard
(Chief Investigator.

VICTORIA UNIVERSITY
MELBOURNE AUSTRALIA

Tim Buszard
Victoria University
School of Sport and Exercise Science
PO Box 14428
Melbourne VIC 8001

To [School Principal],

[School Name] is invited to participate in a research project entitled '"Enhancing tennis skills during matchplay
by manipulating the scheduling of serve practice"

The Chief Investigator of the project is Dr Tim Buszard from the Institute of Sport, Exercise and Active Living (ISEAL) at Victoria University. Dr Buszard is collaborating with fellow experts in skill acquisition in this study: Professor Damian Farrow (Victoria University), Dr Machar Reid (Tennis Australia) and PhD Candidate Lyndon Krause (Victoria University).

If you would like your school to be a part of this study, please sign the consent form attached to this letter. Specific details about the project are explained below. Our aim is to run this study in one school containing a 'high performance' tennis program. Your school is the only one that we are approaching initially.

Project explanation

This project will examine the influence of three practice approaches on the acquisition of serving skill in talented junior tennis players aged 18 years and under. Approach 1, will most closely replicate the demands of a match with the server required to hit both serves and groundstrokes against an opponent. Approach 2, will involve hitting only serves against an opponent (i.e., no other shots). Approach 3 (least like matchplay), will involve hitting only serves against no opponent.

Evidence from the laboratory suggests that practice that is more aligned to the demands of matchplay will lead to greater skill acquisition. Whilst this might seem like common sense, research in the applied setting does not provide such clear results. The purpose of this study is therefore to explore this issue in typical tennis training sessions with talented junior players.

What are participating children required to do?

Participating children will not be asked to do anything additional to the training sessions that they already undertake participate in as part of the [insert schools/Tennis Academy name here] program. Indeed, the study will be conducted during normal training hours. Moreover the preference will be for all children in the [insert schools/Tennis Academy name here] program to participate in the serving protocol, which will take place during the first 30 minutes of every training session for the duration of one term. Note, children not providing consent will not having any data collected by the research team and are more than welcome to seek alternative drills/sessions at the head coaches discretion.
The exact protocol is as follows:

- Start of term – Skills testing* & matchplay (matchplay at National Tennis Centre, Melbourne)
- Throughout term – Serving practice
- End of term – Skills testing* & matchplay (matchplay at National Tennis Centre, Melbourne)

All children in the [insert schools/Tennis Academy name here] program will be randomly allocated to one of three groups. Specifically, Group 1 will be the 'most match-like' requiring the server to serve against an opponent and also play a groundstroke following the serve. Group 2 will still be match-like but only require the server to serve against an opponent (i.e., no further shots). Group 3, will be the least match-like' requiring the server to serve to no opponent.

* Only children who return the consent form will be asked to complete the skills testing and matchplay. For skills testing children will be removed individually from normal training to a nearby court for 10 minutes to complete this test while matchplay will require each child to attend a schedule Hawk-Eye session at the National Tennis Centre, Melbourne. One accepted into the study co-researcher Lyndon Krause will organise a matchplay session outside of school hours at each child's convenience. Data will only be collected on the children who return consent forms.

The serving protocol involves approximately 40 serves per session, which has been determined as an appropriate number of serves to elicit skill improvements. To place this number into perspective, a typical practice session that focuses predominately on serving includes approximately 90 serves, so it is believed that approximately 40 serves will not place undue stress on the children.

Please be aware that each child will be filmed throughout the study (pre-test, practice and post-test) to allow for analysis of serving performance. Indeed, this is very similar to normal training procedures within the [insert schools/Tennis Academy name here] program whereby training can often be filmed. However, for the purpose of our study, the footage of any child who does not return a consent form will be deleted from the researcher's possession immediately after each session. The remaining video footage will be stored on the Chief Investigators' hard drive and only the research team will have access to this footage. All training ad skills testing will be conducted within the [insert schools/Tennis Academy name here] precinct, while each child will be required to perform two matches at Tennis Australia's National Tennis Centre, on their Hawk-Eye** Enabled tennis court. Moreover, the data will be de-identified (i.e., each child's name will be replaced with a code) prior to any analysis undertaken. Each child is free to withdraw from participating in the study at any time.

***Hawk-Eye system:*

The Hawk-Eye system used in this project is the same technology used globally at many tennis tournaments for the review of line calls. In this project the Hawk-Eye will be used to provide accurate game play dynamics including ball speeds and players movements, which can be used to evaluate serving performance.

What will the school gain from participating?

Specific to the school:
A report of the findings will be provided to you (the principal) and the schools head Tennis Coach. The outcomes of this project will be most beneficial for coaches interested in improving tennis players' skills. Please note that children will not be named within this report. The report will only

detail the results of groups of the children. Indeed, only the researcher assessing each child will be aware of each child's results.

Specific to the children participating:
Players who return consent forms will receive feedback regarding skill improvement, based on skill testing and Hawk-Eye matchplay data.

The findings will provide guidance on how to most effectively practice the serve. For instance, if our hypothesis is found to be true, we will recommend that tennis player should practice the serve in conjunction with other skills, rather than the serve alone.

How will the information that the children give be used?

It is our intention to present the findings of the group data in the form of a journal publication. Please note that the schools children will not be named within this report and no one outside the team of researchers will be able to identify any child's results at any time during or following the study. An assigned identification number known only by the researchers will identify your child's results.

What are the potential risks of participating in this project?

1. The physical risks associated with this study are no more than the risks associated with typical training sessions in junior tennis. As with every training session in the [insert schools/Tennis Academy name here] program, the head coach will ask players to provide honest feedback about how their body is feeling. Any player that reports feelings of soreness will be encouraged to rest. The coaches will emphasise that children should not complete the serving protocol if they are feeling sore or injured.

Children may feel concerned that their performance during the pre- and post-tests may highlight any real or perceived physical and/or skill deficiencies, thus leading to potential embarrassment. The researchers will reinforce that all data will remain strictly confidential with their names de-identified through the use of codes and/or pseudonyms.

A situation could arise where children feel embarrassed to perform in front of their peers or where children watching may make fun of the participant. Consequently, all children will be told by the Chief Investigator at the beginning of the matches that they must show good sportsmanship by adhering to the rules of tennis and showing support for other children.

How will this project be conducted?

The project will involve players (males and females) from the [insert schools/Tennis Academy name here] program in Victoria practicing serving over the course of one term (8 weeks) at your school. The serving practice will be incorporated into the regular training sessions conducted by your schools head tennis coach and data will only be collected on the children the provide consent to do so. Note, outside of this 8 week period participants will also be required to undertake one matchplay session pre and one matchplay session post the intervention at the National Tennis Centre, Melbourne. To reiterate, these sessions will take place outside school hours.

Who is conducting the study?

This study is being conducted by the Institute of Sport, Exercise and Active Living (ISEAL) at Victoria University.

Dr Buszard is in charge of this project. He does a lot of work with children, with a particular focus on understanding how children learn movement skills.

You can contact Dr Buszard (03 9919 4512 or tim.buszad@vu.edu.au) if you have any questions about this project.

If you have any queries or complaints about the way you have been treated, you may contact the Research Ethics and Biosafety Manager, Victoria University Human Research Ethics Committee, Victoria University, PO Box 14428, Melbourne, VIC, 8001 or phone (03) 9919 4148.

*Note, this questionnaire was used daily, with player serve counts entered directly into an excel spread sheet.

SINCE YOUR LAST SCHOOL BASED PRACTICE SESSION:					
Name	**Other practice (not including match practice)**			**Matchplay**	
	# Sessions	**Total time (min)**	**Serve count (n)***	**# Matches**	**Scores**
Player 1					
Player 2					
Player 3					
Player 4					
Player 5					
Player 6					
Player 7					
Player 8					
Player 9					
Player 10					