Applying the Expert-Novice Paradigm in Tennis Coaching: Improving Coaches' Knowledge, Diagnostic Skills and Understanding of the Tennis Serve Technique

Yulia Fetisova

Thesis submitted in fulfilment of the requirement for the degree of

Doctor of Philosophy

Institute for Health and Sport

College of Exercise and Sport Science

Victoria University

April, 2021

Abstract

Tennis coaches' technical knowledge plays a critical part in performance analysis as it impacts their recommendations to athletes. To date, the research on tennis coaches' knowledge is limited, and no previous studies have attempted to examine expert tennis coaches' knowledge and diagnostic ability of the tennis serve technique. This research aimed to examine the knowledge and diagnostic ability of expert and novice tennis coaches, and to identify the key distinguishing characteristics between expert and novice tennis coaches. As a result, the key distinguishing characteristics between expert and novice tennis coaches were identified, and there was a recognised need to develop an online training course to improve coaches' knowledge and understanding of the tennis serve technique. An online coach education course was then developed, and the effectiveness of the course was evaluated.

This thesis comprised three studies employing a mixed-methods design. Data was collected and analysed by using both qualitative and quantitative methods to gain a deeper understanding of novice and expert tennis coaches' knowledge, diagnostic skills and learning. The main data collection methods were in-depth interview and an online questionnaire that was constructed specifically for this investigation. Pre- and post-intervention design was used to investigate the efficacy of a training intervention on coaches' knowledge and their diagnostic ability of the tennis serve technique. A video-based test was developed to measure the effectiveness of the online course.

As a result of the first two studies, models representing declarative and practical knowledge of expert and novice tennis coaches were developed. The key distinguishing characteristics between novice and expert coaches were that experts displayed a superior understating of the functionality of the tennis serve technique and an advanced diagnostic ability. Expert coaches were able to see the tennis serve as "a whole" in comparison with novices who focused more on separate technical elements. It was suggested that novice coaches need to develop the knowledge of tennis serve from two perspectives: technical and functional.

The findings of this thesis extend our current understanding of tennis coaches' knowledge and diagnostic skills. The development and evaluation of an online training course provides a unique contribution to coach education in order to understand the cause-and-effect relationships between technical elements withing the flat serve

should allow tennis coaches to prescribe more effective training interventions. By knowing how one element may affect another, coaches will be able to identify and rectify technical issues by addressing the cause of the problem instead of focusing on many separate elements. The design of this program can also be used with other technical elements in tennis and can be applied to other sports to improve coaches' knowledge and diagnostic ability of sport technique.

Student Declaration

"I, Yulia Fetisova, declare the PhD thesis entitled "Applying Expert-Novice Paradigm in Tennis Coach Development: Improving Coaches' Knowledge, Diagnostic Skills and Understanding of the Tennis Serve Technique" is no more than 80,000 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".

"I have conducted my research in alignment with the Australian Code for the Responsible Conduct of Research and Victoria University's Higher Degree by Research Policy and Procedures."

Signature Date 3/30/2021

Journal Publications and Conference Presentations

Fetisova, Y., Zois, J., Spittle, M., & Dawson, A. (2021). Coaches' internal model of the tennis serve technique: Knowing or understanding? *International Journal of Sports Science and Coaching, 0(0), 1-17.* https://journals.sagepub.com/doi/abs/10.1177/1747954120984879

Fetisova, Y., Zois, J., Spittle, M., & Dawson, A. (2016, June 21-23). Sport coaches' visual perception and diagnostic skill (Conference Presentation). National Coaching Conference, Seattle, Washington.

Fetisova, Y., Zois, J., Spittle, M., & Dawson, A. (2017, 31st July – 2nd August). Expert-novice paradigm in coaching: Evaluation of the tennis serve technique (Conference Presentation). ICCE Conference, Liverpool, UK.

Acknowledgments

I started this process being a former high-performance tennis player and a coach with many years of experience. I've been playing tennis since I was four years old and I never stopped. Through my playing and coaching career my focus was on the constant development as a player and as a coach. This journey was exiting, inspiring and educational as I had the opportunity to contribute to tennis coach development and grow as a coach and researcher. At the same time, it was a marathon with life-changing events on my way to finish. I feel extremely grateful to all who supported me though this journey and helped me to see the lights even in the darkest times.

To my supervisors Andrew Dawson, James Zois and Michael Spittle: you are such a wonderful team. Andrew – thank you for your wisdom and a great support. I can't imagine myself completing this journey without you being my principal supervisor. You believed in me even when I did not. James – thank you for your understanding and advice that you provided through this journey. Michael – thank you for your expertise, knowledge and questions that made me dig deeper and learn.

To my husband who I am eternally grateful to for supporting, understanding and comforting me infinite number of times when I thought I'd never reach this goal.

To my family and friends: thank you for helping me to withstand all the storms in my life and not to give up although I was close to this point hundreds of times. Thank you for loving me, nurturing me and being with me during this challenging journey.

To all tennis players and coaches who volunteered to participate in this research: thank you for your time, enthusiasm, willingness to share your expertise and knowledge. I could not complete this research without you.

To the Australian Tennis Professional Coaches Association: I feel deeply thankful for helping me to find participants via your network which was an extremely valuable contribution to my final study on online coach education.

To Tennis Australia: thank you for providing me with the opportunity to present my work and invite coach to participate.

To the Melbourne International Tennis School: thank you for sharing my invitation to participate with your coaches when every coach on board counted.

To Maribyrnong Sports Academy – it was a great pleasure to meet like-minded people who were passionate about tennis and their professional development. I'm very grateful for your quick response and help in inviting coaches to participate in my research.

To Professor Will Hopkins: I'm extremely grateful for helping me with quantitative analysis, for providing such as great support with all stages from analysing the data to writing up the results. Your patience and support were a great inspiration for me when I did not have any more stamina to deal with such a complex statistical analysis.

To Emma Doyle: thank you for your enthusiasm and support in finding the participants who were such an essential component for this research.

To Tim Buszard: thank you for your enthusiasm to help me to find participants at the start of the project, it gave me a great start.

To Sharon Lierse: thank you for proofreading this thesis.

Table of Contents

List of Tables

List of Figures

List of Abbreviations

MANOVA - Multivariate Analysis of Variance

M – Mean

ITF – International Tennis Federation

ITN – International Tennis Number

N – Number

SD – Standard Deviation

WPW – Whole-Part-Whole

ATPCA – Australian Tennis Professional Coaches Association

CL – Confidence Interval

SPSS – Statistical Package for Social Sciences

PBL - Problem Based Learning Approach

Chapter 1 Introduction

Coaches play a crucial role in the development of athletes by providing technical, tactical training, planning, mentoring and support (J. Cote, 2006; Ford, Coughlan, & Williams, 2009). To be effective, especially as a high performance or expert practitioner, coaches need to have a deep understanding of their sport which is usually a complex mix of sport performance elements including: pedagogical (learning and development); technical (specific sport motor skills); tactical (specific performance strategies); bio-physical systems (strength, speed, power, agility, and endurance); medical (health, welfare and rehabilitation); ethico-legal (sport integrity and anti-doping) and psycho-social (performance enhancing mental skills, leadership, personal development, team cohesion and interpersonal relationship development) (Gould & Mallett, 2021). Cushion and Nelson (2013) believe that coaches require different types of knowledge (such as technical and technical) and various skills (e.g., error identification, correction and planning) (C. Cushion & Nelson, 2013) and are required to perform their role well at any level of performance. Coaches can develop these skills during formal and informal education, self-education which integrate with their coaching and playing experience and development of learning skills such as reflection (Gilbert & Cote, 2013). Sporting associations around the world have introduced mandatory coaching certification to ensure the quality of coaching. The development of coaches' formal education programs and assessing the quality of the program is a critical process toward enhancing of coaching expertise and development as coaches' knowledge and skills have an impact on athletes' performance, motivation and health (Silva et al., 2020).

This thesis will focus on examining the technical development of novice and expert tennis coaches, specifically their knowledge development, diagnostic skills and learning of how to coach the flat serve in tennis. To better understand how tennis coaches learn to diagnose and correct skill errors in a complex skill such as the flat serve in tennis this thesis will provide an in-depth examination of tennis coaches technical knowledge and expertise, and how novice coaches can enhance their technical knowledge and coaching through completing a novel online learning program.

1.1. Understanding coaching expertise

The identification of expertise attributes and understanding the development mechanisms of expert performance is essential for athletes and coach development (Wharton & Rossi, 2015). A number of studies have identified distinguishing characteristics between expert and novice athletes where experts' anticipation ability and visual search behaviour were compared to non-experts in various sports such as badminton, basketball, soccer and amongst other sports (Abernethy, 1990, 1991; Abernethy, Gill, Parks, & Packer, 2000; Abernethy & Zawi, 2007; Arroyo, Dominguez, Arias, Garcia-Gonzalez, & Alvarez, 2016; Canal-Bruland, Van Der Kamp, & Van Kesteren, 2010; Farrow & Abernethy, 2003; P. Furley & Dörr, 2016; Goulet, Bard, & Fleury, 1989; Hohmann & Munzert, 2007; Isaacs & Finch, 1983; R. C. Jackson & Mogan, 2007; Kioumourtzoglou, Kourtessis, Michalopoulou, & Derri, 1998; Loffing & Hagemann, 2014; Memmert, Hagemann, Althoetmar, Geppert, & Seiler, 2009; D. Memmert, D. J. Simons, & T. Grimme, 2009; Mori, Ohtani, & Imanaka, 2002; Murray, Harris, & De La Pena, 2007; Paull & Giencross, 1997; Poulter, Jackson, Wann, & Berry, 2005; Rowe, Horswill, Kronvall-Parkinson, Poulter, & McKenna, 2009; G. J. P. Savelsbergh, Williams, Van Der Kamp, & Ward, 2002; Shim, Carlton, Chow, & Chae, 2005; Singer, Cauraugh, Chen, Steinberg, & Frehlich, 1996; N. J. Smeeton & Huys, 2011; Tenenbaum, Levy-Kolker, Sade, Liebermann, & Lidor, 1996; Ward, Williams, & Bennett, 2002; Wu et al., 2013). These studies found that expert athletes demonstrated fast-access recognition capability, problem categorisation, faster pattern recognition, a capability to accurately perceive stimuli in game situations and athletic performance compared to non-expert athletes. Importantly, extensive, specialized knowledge was recognised as a critical attribute of expertise (Berliner, 1994; De Marco & McCullick, 1997; R. Glaser, 1987; Nash, Martindale, Collins, & Martindale, 2012; Tan, 1997; Wharton & Rossi, 2015). Although much attention has been given to athletes, less in known about coaches' technical expertise.

Several studies have also investigated the expertise attributes of sporting officials and coaches on their decision-making, diagnostic skills and visual search behaviour (Armstrong & Hoffman, 1979; Bian, 2003; Boyd, 2004; DiCicco, 1990; Franks, 1993; Ghasemi, Momeni, Jafarzadehpur, Rezaee, & Taheri, 2011; Giblin, 2014; Grgantov, Jurko, & Milic, 2013; Grundel, Schorer, Strauss, & Baker, 2013; Imwold & Hoffman, 1983; C. M. Jones & Miles, 1978; Larkin, Berry, Dawson, & Lay, 2011; Leas & Chi,

1993; MacMahon & Ste-Marie, 2002; Moreno, Saavedra, Sabido, & Luis, 2006; Nazarudin et al., 2015; Paradis, Larkin, & O'Connor, 2016; Petrakis, 1986; V.E.D. Pinheiro, 1990; Sherman, Sparrow, Jolley, & Eldering, 2001; Skrinar & Hoffman, 1979; Souchon, Livingstone, & Maio, 2013; Spitz, Put, Wagemans, Williams, & Helsen, 2016, 2017, 2018; Wilson & Mock, 2013; Woorons, 2001; Yanofsky, 1998). However, much less is known about expert coaches' diagnostic ability and knowledge (Armstrong & Hoffman, 1979; Bian, 2003; Giblin, 2014; V.E.D. Pinheiro, 1990; Sherman et al., 2001; A. Smith, Roberts, Wallace, & Forrester, 2012; A. Smith, Roberts, Wallace, Kong, & Forrester, 2015; Woorons, 2001), although the role of coaches in an athlete's performance cannot be underestimated. To date, no study has been conducted to identify the key attributes of expert coaches' technical knowledge and diagnostic skills of the tennis serve technique which is the most important stroke in tennis (Antunez, Hernandez, Garcia, Vaillo, & Arroyo, 2012). This is essential for coach education providers to obtain and implement this knowledge in coach education programs.

Previous studies on coach expertise have examined coaches' performance by applying the expert-performance approach which is a guiding framework for research in sport expertise (K. A. Ericsson & Smith, 1991; Ford et al., 2009; McRobert, Ward, Eccles, & Williams, 2011; A. M. Williams & Abernethy, 2012; A. M. Williams & Ericsson, 2005; A. M. Williams, Fawver, & Hodges, 2017). This approach allows the researchers to compare experts to non-experts, to identify the key attributes of the expertise, and to examine how expertise is developed (Antunez et al., 2012). This thesis will apply this framework to capture the technical knowledge and diagnostic ability of expert and novice tennis coaches and develop a training intervention to improve novice coaches' knowledge and diagnostic abilities.

The understanding of expert performance is a fundamental step in the process of coach learning and development (Nash & Collins, 2006). The recognition of the key distinguishing characteristics between expert and novice coaches is essential as this knowledge can be applied to coach education (Lyle & Cushion, 2017).

1.2. Coaches' technical knowledge and diagnostic ability

There are two primary types of knowledge: declarative knowledge and practical knowledge (J. Cote & Gilbert, 2009; Dorgo, 2009). Declarative knowledge represents "what is known" by the coach about sport technique, tactics and rules (Dorgo, 2003).

For example, the knowledge that tennis serve can be flat, kick or slice. Practical knowledge refers to “knowing how” and is applied by coaches during practice. For instance, the knowledge about how to perform the flat tennis serve. During the training session, coaches apply declarative knowledge to assess the performance of athletes and provide recommendations for improvements. The knowledge of technically correct motion refers to the internal model that is very sport-specific (Lees, 2002; Sherman et al., 2001; Thompson, Bezodis, & Jones, 2009). When analysing sport technique, coaches compare their internal model with the performance of their athlete and the feedback is formulated and provided to the athlete (V.E.D. Pinheiro & Simon, 1992). It is crucial to understanding the internal model of coaches as it directly affects athletes’ performance. Only a few studies have examined coaches’ internal models of technique (J. Cote, Salmela, Trudel, & Baria, 1995; J. Cote & Salmela, 1995; R. Jones, Bezodis, & Thompson, 2009; Leas & Chi, 1993; A. Smith et al., 2012; A. Smith et al., 2015; Thompson et al., 2009) and no attempts have been made to study the internal model of tennis coaches. There is also no evidence that the internal model is being taught in any formal tennis coach education programs. This thesis will focus on coaches’ declarative and practical knowledge of the tennis serve technique.

1.3. Adult skill acquisition and adult learning

Skill acquisition in sport explains underlying mechanism of acquiring new motor skill (Moe, 2004). It is crucial to understand adult skill acquisition as it assists coach educators with optimising coach education programs design (Müller, Fitzgerald, & Brenton, 2020).

The five-stage model of adult skill acquisition includes 5 stages: novice, advanced beginner, competence, proficiency and expertise (Dreyfus, 2004). During the novice stage the learner is provided with facts and instructions that can be followed without specific skills. It is important that the learner understands the context to effectively apply new information (Dreyfus, 2004). The advanced beginner stage is characterised by gaining the experience, developing deeper understanding of the context and recognising of new situational aspects. Competence stage refers to decision-making process, when a student learns to choose what is important information during situation and what should be ignored. Proficiency is further skill advancement and incudes situational discrimination when the learner can choose successful situation

over unsuccessful. However, there is not enough experience with outcomes: the learner knows what to do but does not have variety of potential outcomes. The expertise stage includes the knowledge not only what needs to be achieved but also how to achieve specific results as an expert gains the experience for effective decision-making. During the first four stages the decision is analytical in nature. Expertise is characterised by intuitive decisions (Dreyfus, 2004).

There are four main adult learning theory: behaviorism, cognitivism, humanism, and constructivism. These theories allow to improve performance and apply the right instructions, technique and design when developing online education programs (Arghode, Brieger, & McLean, 2017; Yilmaz, 2011).

The key assumption of behaviorism is conditioning, and it focuses on knowledge acquisition and observable behavior (Arghode et al., 2017). According to this theory learning conditions are put in place to achieve controlled learning environment and response cycle in learners (Boghossian, 2006). When applying this theory, the online educators should design activities where students learn through knowledge of results. The desired responses are reinforced, and corrective feedback is provided for non-desirable responses. This theory is applied in online adult learning when learning a repetitive skill is required. Behaviorism can be applied in distance learning students are presented with a question and if the answer is incorrect, they are given the explanation why the answer is incorrect followed by another attempt (Arghode et al., 2017).

Cognitivism emphasises the processing, storing and retrieving the information (Biniecki & Conceigao, 2016). The learning occurs via structured, appealing presentations which motivate students (Arghode et al., 2017). Learners should be provided with opportunity to actively participate in the process and develop their own goals (Allen, 2007). When applying this theory in online learning it is important to engage learner via structured and interesting learning content along with positive feedback and critical reflection (Arghode et al., 2017).

The central premise of humanism is self-actualisation, personal growth, human development, feelings and lifelong learning where decision-making, self-awareness, independence and motivation are emphasised (Arghode et al., 2017; Merriam & Ca,

2007; Weber, 2014). Humanists believe that the leaner is responsible for their learning process (Weber, 2014). Humanism can be applied in online learning when learners can relate to the concepts, and when online activities include relevant examples (Arghode et al., 2017).

Constructivism theory reflects the view that mental effort and social interactions are essential components of knowledge development (Altman, 2009; Arghode et al., 2017). The combination of learners' motivation, understanding and effective instruction is a key for successful learning (Arghode et al., 2017). Constructivism approach is applied in adult online education with collaborative, situational, experiential and self-directed learning (Arghode et al., 2017).

These adult learning theories should be carefully considered when designing online education programs for adults. For example, instructional designers should include engaging online discussion activities that empower adult earning (Arghode et al., 2017; McDougall, 2015). The instructions should be engaging and effective and effective feedback is provided (Arghode et al., 2017).

1.4. Coach education

The understanding and optimization of coach education has been under considerable attention for the last few years (Stoszkowski, MacNamara, Collins, & Hodgkinson, 2021). There are three main forms of coach learning: formal, non-formal and informal where coaches gain knowledge via peer interaction, professional training, mentoring, coaching experience, athletic experience, observation, personal reflection, self-learning through books or technological resources (Erickson, Bruner, MacDonald, & Cote, 2008; Gonzalez-Rivera, Campos-Izquierdo, Villalba, & Hall, 2017; Koh, Lee, & Lim, 2017; Stoszkowski & Collins, 2016).

Online coach education has become a recognised form of learning in different sports (C. Cushion & Townsend, 2019). Some sport organizations have included online learning as a key part of their formal coach education such as Swimming Australia online learning program (Swimming Australia, 2020). Other programs implement online learning as part of informal coach education where coaches are provided a range of learning resources such as Tennis Australia's online learning platform *Bounce* (Tennis Australia, 2020a). Although online coach education has become an

integral part of the modern world, only a few studies have evaluated the effectiveness of online coach training programs (Driska, 2018; Glang, Koester, Beaver, & McLaughlin, 2010; Kerr et al., 2015; Petrov, 2018; Schweizer, Plessner, Kahlert, & Brand, 2011). To date, no studies focused on online coach education have been conducted in tennis, despite tennis being one of the most popular sports in the world at all levels of participation from community and recreational sport to high-profile professional competitions (Over & Sharp, 2008).

1.5. Problem statement

The focus of research on sport expertise has begun to include coaches and there is a recognised need to extend the current knowledge of coach expertise (Ford et al., 2009). To date, there have been no investigations focusing on coaches' internal model of technique in tennis, although declarative knowledge has been recognised as an essential part of coaching expertise (Gilbert & Cote, 2013). The expert-novice paradigm has been used extensively to examine athlete expertise, however, there has been a paucity of research examining coach expertise from this perspective. Few studies have used this approach with sport referees (Ghasemi et al., 2011; Nazarudin et al., 2015; Paradis et al., 2016; Wilson & Mock, 2013). However, no studies have examined the main distinguishing characteristics between novice and expert coaches on their internal model. A knowledge gap exists when attempting to understand the coaches' internal model of sport technique, and there have been no attempts to educate coaches on how to recognise key technical cues in any sports, even though the recognition of the key cues is essential to coaching (Mitchell et al., 2020). The understanding of distinguishing characteristics in declarative and practical knowledge of expert and novice coaches may be applied in coach education to facilitate knowledge transfer from expert to novice coaches and enrich coach development.

Research has also revealed that video-based approaches have been widely used in research in sport to improve perceptual-cognitive skills of athletes and umpires. However, no previous work has used video-based learning methods to improve coaches' knowledge and diagnostic ability on technique in sport. The current investigation makes the first attempt to apply video-based learning methods to examine coaches' diagnostic ability of the tennis serve technique and to develop an online education tool.

Online educational tools have previously been developed and validated in many fields (Gayed et al., 2018; S. L. Smith & Kelloway, 2016; Wang & Zhi, 2009). However, research in sport is limited and no studies have attempted to develop an online training tool in tennis that focuses on developing an online training course. This brings an original contribution to coach education and provides novice tennis coaches around the world with the opportunity to improve their knowledge, understanding and diagnostic ability of the tennis serve technique. This thesis will address these problems and provide the unique practical application for coach education and development.

1.6. Thesis aims

This thesis aims to:

1. Examine the internal model of expert and novice tennis coaches of the flat tennis serve technique, and to identify the key distinguishing characteristics between the expert and novice coaches.
2. Examine the practical knowledge and diagnostic ability of expert and novice tennis coaches of the flat tennis serve technique, and to identify the key distinguishing characteristics between the expert and novice coaches.
3. Develop and evaluate the effectiveness of an online training course that aims to improve coaches' practical knowledge, diagnostic ability and understanding of the flat tennis serve technique.

1.7. Thesis structure

This thesis consists of eight chapters (Figure 1). Chapter one introduces the topic, provides a brief overview of coaching expertise, technical knowledge and coach education. It then states the research problems and aims of this thesis. Chapter two is the literature review providing critical examination of the empirical research on coach technical expertise and online education in tennis and other sports. This thesis has employed the pragmatism research paradigm to guide the methods used herein as discussed in detail in Chapter 3 (Liamputtong, 2017). The mixed methods approach used in this thesis have been determined by what would best address the broad research problem and the specific aims outlined above (Liamputtong, 2017). The end result is a multi-layered, mixed methods approach, whereby both quantitative and qualitative data has been collected and analysed. The next three chapters represent three integrated investigations. Chapter 4 focuses on the coaches' internal model of the tennis serve technique, where key distinguishing characteristics between experts and novices were identified. The second study which is discussed in Chapter 5 aims to examine the coaches' practical knowledge, diagnostic ability, and attributes of coach expertise. This study consists of two phases where coaches' practical knowledge and diagnostic ability are examined during an interview and then by completing an online questionnaire. The results of study one and two revealed the need to develop an online training course to improve coaches' knowledge, diagnostic ability and understanding of the tennis serve technique. Thus, study three in Chapter

6 examines the development and evaluation of an online training course that helps novice tennis coaches improve their diagnostic ability of the flat tennis serve technique. Chapter 7 provides an integrated discussion of the qualitative and quantitative findings from all three studies, and finally, Chapter 8 draws together the general conclusion from this thesis, discusses the limitations of the research, proposes several practical applications in tennis coach education and discusses the implications for coach education and development in the wider sport community.

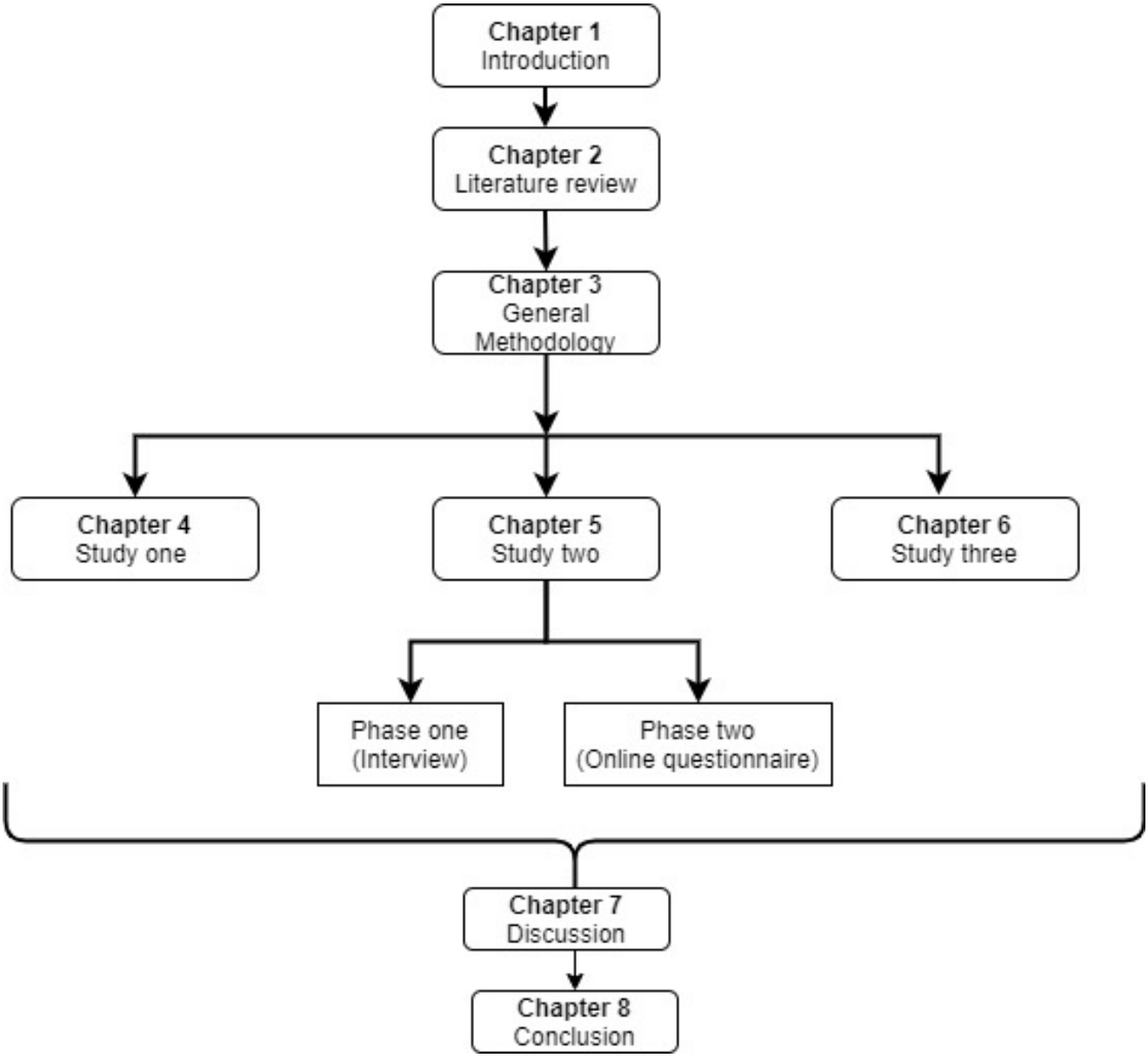


Figure 1 Thesis structure

Chapter 2 Review of the Literature

2.1. Introduction

What we know and understand about coaching has transformed since the early 1970's when coaching was first examined in detail by researchers who explored what successful coaching looked like (Day, 1980). Normative literature on the role of the coach has established that coaches perform a complex array of tasks to help individual athletes and teams achieve their sport performance goals at all levels of sport participation (Gould & Mallett, 2021). The coaching process is defined as a "process of guided (athlete and/or team) improvement and development in a single sport at identifiable stages of development" (International Council for Coaching Excellence, Association for Summer Olympic International Federations, & Leeds Becket University, 2013, p. 14). Gould and Mallet (2021) describe the process of coaching as an ever-evolving interaction of three perspectives: 1) Coaches knowledge; 2) Athlete outcomes; and 3) Specific coaching contexts.

Coaches' knowledge is one of the key attributes of coaching expertise. The structure of knowledge encompasses procedural and declarative knowledge which includes sport-specific knowledge, professional knowledge, content knowledge, interpersonal and intrapersonal knowledge. The integration of all types of knowledge is considered to be a critical process for coaches' effectiveness (J. Cote & Gilbert, 2009). Athlete outcome is another component of coaches' effectiveness (J. Cote & Gilbert, 2009) and includes six characteristics that play a significant role in athlete development: competition, training, organisation, coach's personal characteristics, athletes' characteristics and contextual factors (Côté, Bruner, Erickson, Strachan, & Fraser-Thomas, 2010). Effective coaching should generate positive athletes outcomes such as healthy training habits, integrity and internal sense (J. Cote & Gilbert, 2009).

Specific coaching contexts refer to the settings in which coaches work on athletes outcomes: recreational sport, developmental sport and elite sport (Trudel & Gilbert, 2006). It is important to match individual coaches to coaching contexts and the need of the athletes as it affects the coaching effectiveness (J. Cote & Gilbert, 2009).

The purpose of this literature review is to focus on the development of coaches' technical knowledge, in particular, to provide an in-depth discussion about expertise in sport as it applies to coaching and thereby provide a conceptual framework for

exploring the development of tennis coaches' technical knowledge, their diagnostic ability and critically examine online coach education. This review will start with an examination of the empirical literature on coaching expertise and coaches' knowledge, where the term "internal model" will be explained in the light of the diagnostic process of athlete performance. Previous work in this field will be evaluated, knowledge gaps identified, and significance of this study demonstrated. Secondly, the expert performance approach will be introduced to better understand coaching expertise. This will include a critical review of the literature on the expert-novice paradigm applied to athletes, referees and coaches in sport. Knowledge gaps in the existing literature will be identified and the need for training interventions highlighted. Thirdly, a critical review of the literature on perceptual-cognitive skills training, video-based and online coach education will be reviewed. And finally, an examination of current literature of the tennis serve technique will be provided.

2.2. Coaches' knowledge and reasoning chains

Different types of knowledge have previously been recognised such as sport specific knowledge, practical knowledge, pedagogical knowledge, and strategic knowledge (Abraham, Collins, & Martindale, 2006; Dorgo, 2009; Thomas & Thomas, 1994). Cote and Gilbert (2009) believe that the conceptual foundation for coaches' knowledge is declarative and procedural knowledge (Gilbert & Cote, 2013). Declarative knowledge is the information about the subject, facts that are memorised and can be recalled. It answers the question "what is known". In sport it refers to knowledge about the sport such as rules, tactics and techniques (Thomas & Thomas, 1994). For instance, coaches' knowledge on technical attributes of sprint running technique refers to declarative knowledge. The methods to measure declarative knowledge are interviews and paper and pencil tests. Procedural knowledge is knowing how to perform a certain action can be examined with paper and pencils test, games or interviews (Thomas & Thomas, 1994). For example, the description of the tennis serve is available in the literature and provides coaches with a guide on "how to" perform the sequence of the serve: when to toss the ball, contact, how and when to jump (Ivancevic et al., 2011; Tennis Australia, 2013). Practical knowledge refers to the knowledge that is applied by a coach during practise and acquired through experience (Dorgo, 2009). This type of knowledge represents "knowing how" to do certain activity from practical perspective and is different from theoretical knowledge of "how to" and has been

examined previously in teaching (Dorgo, 2003). However, there is no current research on coaches' practical knowledge on the tennis serve although practical "knowing how" plays a significant role in effective coaching (Dorgo, 2003, 2009).

Previous studies have attempted to examine coaches' declarative and procedural knowledge in various sports such as swimming (Leas & Chi, 1993), sprint running (R. Jones, Bezodis, et al., 2009; Whelan, Kenny, & Harrison, 2016), track and field (Whelan et al., 2016), volleyball (Arroyo et al., 2016), sailing (Saury & Durand, 1998), gymnastics (J. Cote et al., 1995; J. Cote & Salmela, 1995) and basketball (D. F. Jones, Housner, & Kornspan, 1995). The studies applied in-depth interviews, protocol analysis, and questionnaires (Nash & Collins, 2006) and reported that experts demonstrated a greater amount of knowledge, depth and connectedness compared to novices. However, no investigations have been conducted to examine coaches' declarative and practical knowledge of the tennis serve technique.

One of the approaches to get a deeper understanding of coaches' knowledge and to examine knowledge depth and connectedness is the identification of causal relationships in coaches' knowledge. This approach has been successfully applied previously in the field of medicine where the diagnostic expertise of radiologists interpreting X-rays was examined (Lesgold et al., 1998). Expert radiologists were asked to analyse X-ray images. During the data analysis, the specific properties in the interview script were identified and called "findings" such as "pneumonia", "an abnormally small heart". The relationships between findings were also examined. For example, the participant suggested that "blood pooling" could be the result of "heart failure". A causal connection between findings was called a "reasoning chain". This concept has also been implemented in sport science in swimming to investigate the diagnostic expertise of competitive swimming coaches, and to assess the connectedness and coherence of coaches' knowledge on freestyle stroke technique (Leas & Chi, 1993). In this study the "findings" referred to the specific attributes of the freestyle swimming technique. For instance, "turbulence" was caused by "hip and leg swing". It was reported that expert swimming coaches significantly outperformed novices in the number of reasoning chains ($p=.026$). The number of reasoning chains reflected the coherence and connectedness of the coaches' knowledge base (Leas & Chi, 1993).

2.3. Coaches' diagnostic ability and their internal model

One of the key responsibilities of a coach is technique analysis and providing feedback in a timely and accurate manner (Giblin, 2013, 2014; Nash & Collins, 2006). Diagnostic ability can be defined as "the ability to recognise variations from a schema in visually presented examples of a motor skill" (V.E.D. Pinheiro & Simon, 1992, p. 292). Schema refers to an internal model of the ideal technique, which is compared to the actual techniques of the performer during the diagnostic process (V.E.D. Pinheiro & Simon, 1992). Qualitative analysis of technique in sport is the observation of the movement and its quality, interpretation and understanding of the skills performed, and providing the base for improvement (Giblin, 2014; Knudson, 2007; Lees, 2002).

In coaching, where diagnosis of sport movement is required, visual perception is critical as the relevance of the information that coaches impart on athletes is directly related to what they see and perceive (Giblin, 2014; Moreno et al., 2006). In fast ball-sports such as tennis, coaches are required to process large amounts of visual information in a short timeframe (Shukala, Paul, & Jaspar, 2011). The ability to accurately determine the key movement characteristics, interpret the biomechanical information, and provide a quick response is the key ability in coaching expertise (Sherman et al., 2001). Coaches feedback to the players is directly affected by what coaches can or cannot "see" in a player's technique (Giblin, 2014). Therefore, it is important to understand how coaches from varying levels of expertise observe technical skill.

Visual perception expertise and diagnostic ability in sport can be studied by comparing experts' performance with non-experts within the same domain (Vicente & Wang, 1998). Previous studies in tennis focused on visual observational pattern (Giblin, 2014; Mitchell et al., 2020; Petrakis, 1986), the influences of playing and teaching experience on the diagnostic ability (DiCicco, 1990), coaches' visual perception (Giblin, 2014), prediction accuracy (C. M. Jones & Miles, 1978) and perceptual capacity (Woorons, 2001). Limited research has been performed to investigate the diagnostic ability of coaches (Armstrong & Hoffman, 1979). To date, no investigation has been conducted to explore coaches' internal model and their practical knowledge on the tennis serve technique.

The term "mental model" refers to the internal representation of external events (J. Lyle & Cushion, 2017). Three types of mental model have been recognised in sport:

goal model, simulation model and performance model. The goal model is a coaches' perception of the goal, the process of movement towards the goal and continuous assessment of the goal. The simulation model explains coaches' expectations about future events such as training session. The performance model refers to what is needed to achieve the goal such as previous achievements and current performance. The "technical" model is a component of the performance model and refers to the knowledge about technique, tactics, and physical conditioning. Coaches' "technical" knowledge is the "internal model" of a technically correct motion against which coaches compare the actual performance (Lees, 2002; Sherman et al., 2001; Thompson et al., 2009).

The internal model of a sport technique is very specific (J. Lyle & Cushion, 2017). For example, the internal model of the freestyle stroke in swimming would include knowledge about components that make up a particular stroke such as body position, arm stroke, and breathing in freestyle (Leas & Chi, 1993). In golf, it would include different components such as club motion or body position. Thus, the internal model consists of "chunks" of knowledge about sport technique that are linked and learnt from experience (J. S. B. T. Evans, 1989; J. Lyle & Cushion, 2017). During the technique analysis coaches compare their internal model with the actual technique of the athlete they are coaching. The differences between their internal model and observed performance are then recognised and feedback to the player is formulated (V.E.D. Pinheiro & Simon, 1992). Coaches use the internal model to assess the quality of the skills and, if needed, to plan an intervention (J. Lyle & Cushion, 2017). Therefore, it is crucial to understand the internal model of coaches as their knowledge directly affects the feedback provided to the athletes, and as a result, has an impact on athletes' performance.

A limited number of studies have attempted to investigate the internal model of coaches (J. Cote et al., 1995; J. Cote & Salmela, 1995; R. Jones, Bezodis, et al., 2009; Leas & Chi, 1993; A. Smith et al., 2012; A. Smith et al., 2015; Thompson et al., 2009). In these studies, two different approaches to understand coaches' internal models were applied.

The first approach was to identify key technical parameters that coaches associated with certain technique: ideal swimming freestyle stroke (Leas & Chi, 1993), top level golf swing (A. Smith et al., 2012; A. Smith et al., 2015) and top level sprint technique

(R. Jones, Bezodis, et al., 2009; Thompson et al., 2009). The main data collection methods were one-on-one semi-structured interviews. Data was analysed using the Grounded Theory Approach (B. G. Glaser & Strauss, 1967). As a result, the technical cues and the characteristics of technique were successfully identified. For example, four critical sprint technique components were identified: “posture”, “hip position”, “ground contact” and “arm action” (Thompson et al., 2009). Another study in sprint running revealed that coaches divided sprint technique into three distinct phases: “start”, “pick-up/drive” and “maintenance” (R. Jones, Bezodis, et al., 2009). The components of the internal model of the golf swing were identified by expert coaches as “posture”, “body rotation”, “arm and wrist action”, “sequential movement and body segments” and “club motion” (A. Smith et al., 2012; A. Smith et al., 2015). In swimming four major components of a swimming coaches’ internal model were identified: “body position”, “arm stroke”, “kick” and “breathing”.

An alternative approach to understanding a coaches’ internal model was used in a previous study in gymnastics that aimed to conceptualise gymnastics coaches’ internal model from a pedagogical and psychological perspective rather than identify technical parameters (J. Cote et al., 1995; J. Cote & Salmela, 1995). During in-depth interviews coaches were asked open-ended questions relating to the training and competition experience. For example: “could you describe the tasks you performed in the last competition you attended?” (J. Cote et al., 1995, p. 5) or “what are the differences between training an eight-year-old gymnast and 15-year-old gymnast?” (J. Cote et al., 1995, p. 6). Using the Grounded Theory Approach (B. G. Glaser & Strauss, 1967) the following components of expert coaches’ internal model were identified: “competition”, “training”, “organisation”, “coach’s personal characteristics”, “gymnast’s personal characteristics and level of development” and “contextual factors” (J. Cote et al., 1995).

Finally, mental model plays a critical role in the development of decision-making skills in sport (Richards, Collins, & Mascarenhas, 2017). Two models were presented to develop individual and team decision making. Model 1 included psychomotor processes where cognitive structures, mental models and shared mental models are developed. Model 1 consists of five layers: developing a performance vision, perceptual drive and technical execution, tactical and environmental satiations development, strategic development, and beta vision of performance (Richards et al.,

2017). Mental model is key aspect of performance, and it is formed based on alpha version which is coaches' "ideal" version of performance, and beta version which is coaches' reshaped vision of performance (Richards, Collins, & Mascarenhas, 2012).

Despite the studies mentioned above, no research has identified the key technical parameters that coaches associate with the tennis serve technique. The current investigation aimed to examine the key distinguishing characteristics between expert and novice tennis coaches' declarative and practical knowledge and their diagnostic ability. One of the approaches to understand coaching expertise is the expert performance approach (K. A. Ericsson & Smith, 1991).

2.4. The Expert Performance Approach

The expert performance approach was introduced by Ericsson and Smith in 1991 and since then has been adopted as a guiding framework for research in sport expertise (K. A. Ericsson & Smith, 1991; Ford et al., 2009; McRobert et al., 2011; A. M. Williams & Abernethy, 2012; A. M. Williams & Ericsson, 2005; A. M. Williams et al., 2017). This approach provides the opportunity to assess and enhance coaches' performance, by identifying experts' skills in comparison to non-experts (Ford et al., 2009).

The expert-performance approach includes three stages: capture the component skills of expertise, identify mechanisms underlying the experts' performance and examine how the expertise is developed (A. M. Williams & Ericsson, 2005). Figure 2 demonstrates these three stages and provides examples of testings and measures.

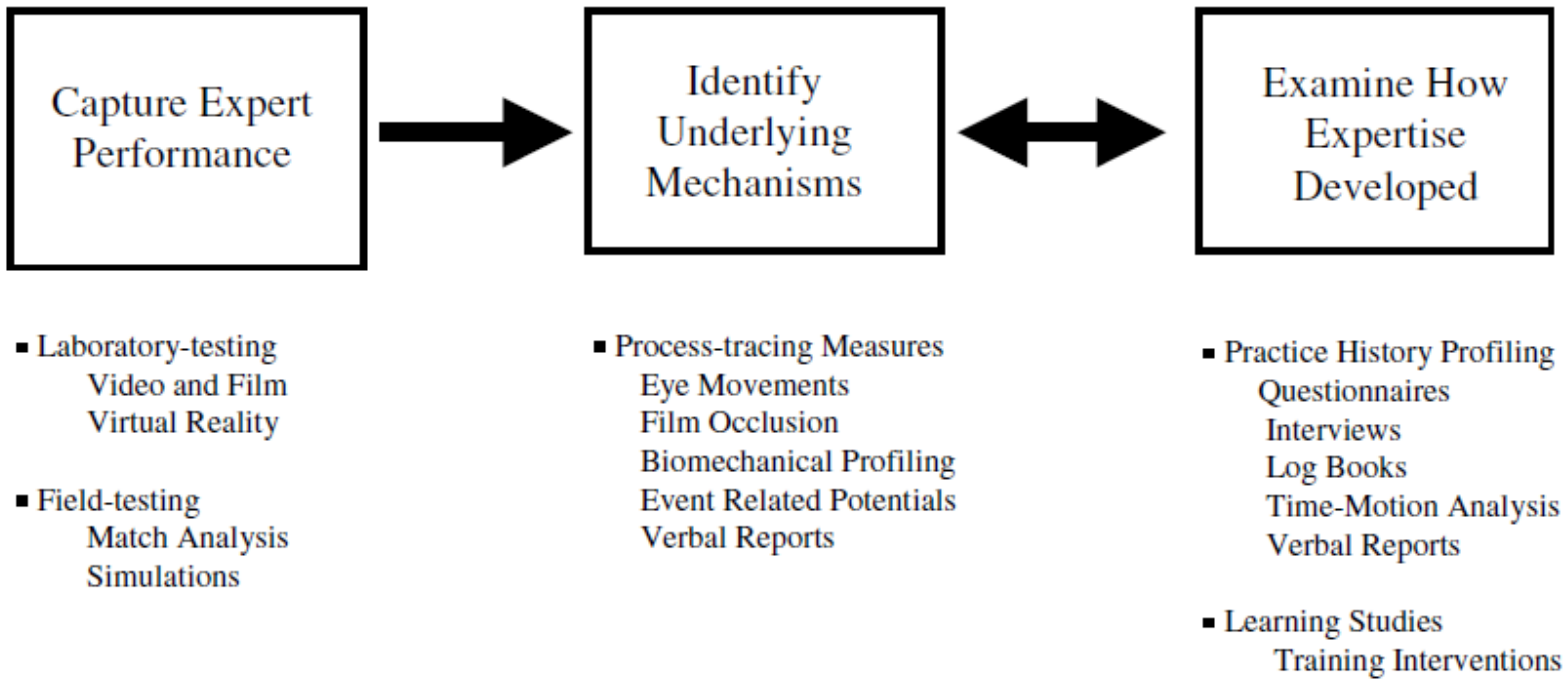


Figure 2 *Stages of Expert-Performance Approach* (A. M. Williams & Ericsson, 2005, p. 286)

During the first stage of the expert-performance approach, the expert-novice paradigm is applied when the representative task is identified to capture the performance of experts and non-experts in the controlled settings with reproducible test conditions (Ford et al., 2009; A. M. Williams et al., 2017). The examples of the tasks are video or film testing, virtual reality testing such as laboratory-testing or match analysis and simulations such as field-testing. During this stage the performance of coaches with different levels of expertise can be measured and compared under reproducible test conditions. For instance, expert athletes or coaches are compared to non-expert athletes or coaches (Ford et al., 2009; A. M. Williams et al., 2017).

The second stage identifies the underlying mechanisms of expertise performance via measures such as think-aloud verbal analysis protocol to measure experts' cognitive process, eye movement, film occlusion and other process-tracing measures. The aim of this stage is to compare the performance of expert to non-expert individuals and identify the distinguishing characteristics (Ford et al., 2009; A. M. Williams et al., 2017).

The final stage uses the knowledge obtained in the previous two stages to develop training interventions that facilitate faster acquisition of expertise. This stage aims to examine the development of expertise and understand how the underlying mechanism of expertise were acquired (Ford et al., 2009). This can be achieved by applying learning training intervention or questionnaires, interview, log books and other practice history profiling (Ford et al., 2009; A. M. Williams et al., 2017).

The expert-performance approach has been successfully applied previously to examine the difference in performance between expert and novice athletes in various sports (Ford et al., 2009; A. M. Williams et al., 2017). For example, the difference between athletes has been successfully identified in soccer where cognitive, visual, perceptual, anticipation skills have been examined (Coughlan, Williams, McRobert, & Ford, 2014; Helsen & Starkes, 1999; Reilly, Williams, & Nevill, 2000; Ward & Williams, 2003). It was demonstrated by the large volume of published studies that the expert-novice paradigm is one of the most popular models for examining visual perception expertise. This has been tabulated below in Table 1, Table 2 and Table 3. The next sections will provide summary of studies where the performance expert athletes,

sporting officials and coaches has been captured, evaluated and compared to non-experts.

The present research project has applied the expert performance approach to identify and capture the performance of expert coaches, to identify distinguishing factors between expert and novice coaches on their knowledge and diagnostic skills and to provide training intervention to improve novice coaches' knowledge and diagnostic skills on the tennis serve technique.

2.4.1. Research on athletes and sport officials

The expert-performance approach has been widely applied in the previous studies on athletes in many sports. Table 1 summaries studies where the expert-novice paradigm has been adopted to identify the difference between expert and novice athletes in various sports such as badminton (Abernethy, 1991, 2007), soccer (G. J. P. Savelsbergh et al., 2002), karate (Mori et al., 2002), surfing (E. Furley & Dorr, 2016), handball (Canal-Bruland et al., 2010; Loffing & Hagemann, 2014; D. Memmert, D.J. Simons, & T. Grimme, 2009), tennis (Farrow & Abernethy, 2003; Goulet et al., 1989; Isaacs & Finch, 1983; R. C. Jackson & Mogan, 2007; Rowe et al., 2009; Shim et al., 2005; Singer et al., 1996; N. J. Smeeton & Huys, 2011; Tenenbaum et al., 1996; Ward et al., 2002) , basketball (Hohmann & Munzert, 2007; Wu et al., 2013), volleyball (Arroyo et al., 2016), water-polo (Kioumourtzoglou et al., 1998), squash (Abernethy, 1990; Abernethy et al., 2000), baseball (Paull & Giencross, 1997) and football (Murray et al., 2007).

The primary aim of these studies was to compare the expert athletes with novices in their anticipation and visual search behaviours. The ability to see the anticipatory cue usages and to predict strokes direction were examined in badminton (Abernethy, 1991, 2007; Memmert et al., 2009). These studies reported that expert athletes demonstrated superior ability to predict the stroke direction compared to novices. In addition, experts used more proximal arm cues to identify the direction and speed of the stroke. In squash, studies focused on visual search characteristics and anticipatory skills of expert and novice players where experts were significantly more accurate in predicting badminton stroke direction and force (Abernethy, 1990; Abernethy et al., 2000).

Studies in tennis applied the expert-performance approach to examine the difference in prediction accuracy, visual search pattern, speed of decisional processes, anticipation ability, player's awareness of advanced visual information to respond, players' reactions and movements between expert and novice tennis players (Farrow & Abernethy, 2003; Goulet et al., 1989; Isaacs & Finch, 1983; R. C. Jackson & Mogan, 2007; Rowe et al., 2009; Shim et al., 2005; Singer et al., 1996; N. J. Smeeton & Huys, 2011; Tenenbaum et al., 1996; A. M. Williams, Ward, Knowles, & Smeeton, 2002). It was demonstrated that experts were more accurate in predicting the type of stroke and direction and they were more aware of the information that they used to identify stroke direction. Expert players also focused on the torso compared to novices who concentrated on the head when anticipating the stroke. In volleyball the procedural knowledge and perceptual abilities of expert and novice players were compared (Arroyo et al., 2016; Kioumourtzoglou et al., 1998). These studies reported experts' superior perceptual ability and greater procedural knowledge compared to novice athletes. Previous studies in handball examined the involvement of motor and perceptual experience in detecting deceptive intentions, anticipation and attention abilities of expert and novice players and goalkeepers (Canal-Bruland et al., 2010; Loffing & Hagemann, 2014). In these studies, experts outperformed novices in detecting deceptive intentions and prediction accuracy. The influence of expert knowledge on rapid stimuli perception, difference between expert and novice athletes on their anticipation, and visual search behaviour have been identified in soccer and football (Murray et al., 2007; Poulter et al., 2005; G. J. P. Savelsbergh et al., 2002). It was demonstrated that expert athletes were more accurate in predicting the direction of the penalty kick: their search strategies were more effective compared to novices. Experts also significantly improved their prediction accuracy after explicit and implicit learning compared to novices. In basketball, differences in anticipation skills between expert and novice players were demonstrated where expert players were more effective in anticipating of dribbling movement, focused attention, selective attention and visual reaction time (Hohmann & Munzert, 2007; Wu et al., 2013).

Studies in other sports such as karate, surfing, baseball have also applied the expert-performance approach to examine the decision time response, adaptation and anticipation skills of novice and expert athletes (E. Furley & Dorr, 2016; Mori et al., 2002; Nakamoto & Mori, 2012; Paull & Giencross, 1997). These studies reported

experts' superior anticipatory skills, better adaptation skills and shorter decision time. Table 1 presents a summary of the research where expert athletes outperformed novice athletes in the prediction of various strokes directions, accuracy, reactions, decision times, visual perception and other skills. Further, a meta-analysis performed by Mann, Williams, Ward and Janelle (2007) quantified the difference between expert and novice athletes, reporting the superior performance of experts over novices in picking up perceptual cues and visual search behaviours.

Table 1 Research summary on expert-novice paradigm: athletes

Author(s) and Year	Sport	Aim	Participants	Outcome
Abernethy, B. (1991)	Badminton	Document expert-novice differences in anticipatory cue usage.	20 expert players 35 novice players	Experts demonstrated the ability to use the earlier occurring, more proximal arm cues for prediction stroke direction and speed.
Abernethy, B. (2007)	Badminton	Examine the ability of badminton players of different skill levels to anticipate the direction of badminton strokes.	12 expert players 12 novice players	Experts outperformed novices in prediction of stroke direction.
Abernethy, B. (1990)	Squash	Compare the visual search characteristics of expert and novice squash players.	15 expert squash players 17 novice squash players	Experts were significantly more accurate than novices in predicting stroke direction under all five temporal occlusion conditions.
Abernethy, B., Gill, D.P., Parks, S.L., & Packer, S.T. (2000)	Squash	Examine the role of the pick-up of kinematic information as a basis for expert perception and skilled anticipation in racket sports.	Ten expert squash players 15 novice squash players	Experts outperformed novices in predicting the direction and force of squash strokes.
Arroyo, M.P.M., Dominguez, A.M., Arias, A.G., Garcia-Gonzalez, L., & Alvarez, F.D.V. (2016)	Volleyball	Compare the procedural knowledge of expert and novice volleyball players.	Eight expert volleyball players 11 novice volleyball players	Experts had a more in-depth, complex and higher quality representation of problems than novices.
Canal-Bruland, R., Van Der Kamp, J., & Van Kesteren, J. (2010)	Handball	Examine the involvement of motor and perceptual experience in detecting deceptive intentions.	26 expert players 20 novice players	Experts outperformed novices in detecting deceptive intentions.
Farrow, D., & Abernethy, B. (2003)	Tennis	Examine the capability of tennis players to predict the direction of an opponent's service in situ.	Eight expert tennis players Eight novice tennis players	Expert advantage was present in the prediction accuracy under the coupled response condition.
Furley, E., & Dorr, J. (2016)	Surfing	Investigate the decision-making skills of surfers as a function of surfing experience.	26 novice surfers 25 expert surfers	Experts demonstrated superior ability to predict surfable waves compare to novices.
Goulet, C., Bard, C., & Fleury, M. (1989)	Tennis	Analyse the performance of expert and novice tennis players' anticipation ability.	15 expert tennis players 14 novice tennis players	Experts concentrated on the shoulder/trunk areas of the server whereas novices focused on the head. Experts select valuable information during the preparatory phase and novices must see the serve until the impact phase to be as accurate as experts.
Hohmann, T., & Munzert, J. (2007)	Basketball	Examine the difference between experts and novices in anticipating skills.	16 expert players 18 novice players	Significant difference ($F = 5.576$, $p < .001$) was revealed between experts and novices in the anticipation of dribbling movements where experts demonstrated better accuracy at recognizing cross-over and behind-the-back dribbling than novices.

Isaacs, L.D., & Finch, A.E. (1983)	Tennis	Examine differences in beginning and intermediate tennis players' ability to anticipate the placement of the tennis serve under restricted serve conditions.	16 intermediate tennis players 34 beginning tennis players	Intermediate tennis players were more successful in plotting the latitude of the ball position.
Jackson, R., & Mogan, P. (2007)	Tennis	Examine player's awareness of the advance visual information that they used to judge tennis serve direction.	13 skilled tennis players 13 recreational tennis players 11 novice tennis players	Skilled tennis players demonstrated greater awareness of the information on which they predicted the direction of the tennis serve.
Kioumourtzoglou, E., Kourtessis, T., Michalopoulou, M., & Derri, V. (1998)	Basketball Volleyball Water-polo	Examine differences between experts and novices in perceptual abilities.	44 elite athletes 39 novice athletes	Elite athletes demonstrated better perceptual abilities than novices (prediction, selective attention, perceptual speed, focused attention, direction of moving object, visual reaction time, spatial orientation).
Loffing, F., & Hagemann, N. (2014)	Handball	Examine experiences and novice team-handball goalkeepers' anticipation ability.	14 expert goalkeepers 23 novice goalkeepers	Experts outperformed novices in prediction accuracy.
Memmert, D., Hagemann, N., Althoetmar, N. Geppert, S., & Seiler, D. (2009)	Badminton	Investigate the "easy-to-hard" principle, context interference conditions, and feedback effects for learning anticipatory skills in badminton.	60 novice players	A significant advantage for the random group was found in the retention test (depth error): $F(2, 57) = 3.75$, $p < .05$. Training with reduced feedback (66%) is no more effective than 100% feedback for novice players.
Memmert, D., Simons, D.J., & Grimme, T. (2009)	Handball	Examine the difference between expert and non-expert in attention abilities.	40 expert players 40 novice players	No difference in performance was detected between groups.
Mori, S., Ohtani, Y., & Imanaka, K. (2002)	Karate	Investigate the reaction times and anticipation of karate athletes.	Six experienced karate athletes Six novice karate athletes	Experts demonstrated superior anticipatory skills (in the reaction times and correct response to an opponent' attack).
Murray, N., Harris, C., & De la Pena, D. (2007)	Football	Test whether rapid stimuli perception is influenced by expert knowledge.	20 experienced football players 20 novice football players	Experts demonstrated faster recognition time and fewer saccadic eye movement compared to novices.
Nakamoto, H., & Mori, S. (2012)	Baseball	Examine the relationship between expertise in movement correction and rate of movement reprogramming within limited time periods, and to clarify the specific cognitive processes regarding superior reprogramming ability in experts.	Seven expert players Seven novice players	Experts demonstrated better adaption due to efficient reprogramming of prepared motor output.
Paull, G., & Giencross, D. (1997)	Baseball	Examine the decision time response and a prediction of the ball direction of novice and expert baseball players.	15 expert baseball players 15 novice baseball players	Experts outperformed novices in decision time and accuracy scores.
Poulter, D.R., Jackson, R.C., Wann, J.P., & Berry, D.C. (2005)	Football	Examine the efficacy of explicit and implicit learning paradigms during the very early stages of learning the perceptual-motor anticipation task of predicting ball direction from temporally occluded footage of soccer penalty kicks.	48 sub-elite goalkeepers	Significant improvements in horizontal prediction accuracy for the expert group.

Rowe, R., Horswill, M.S., Kronvall-Parkinson, M., Poulter, D.R., & McKenna, F.P. (2009)	Tennis	Examine the effect of disguise on novice and expert tennis player' anticipation of tennis ground strokes.	18 expert tennis players 62 novice tennis players	Expert demonstrated better accuracy in anticipation of the tennis strokes.
Savelsbergh, G.J.P., Williams, A.M., Van Der Kamp, J., & Ward, J. (2002)	Soccer	Examine skill-based differences in anticipation and visual search behaviour during the penalty kick.	Seven expert goalkeepers Seven novice goalkeepers	Experts demonstrated greater accuracy in predicting the direction of the penalty kick, longer response time and fewer corrective movements with joystick compared to novices. They also used a more effective search strategy.
Shim, J., Carlton, L.G., Chow, J.W., & Chae, W. (2005)	Tennis	Examine skilled and novice tennis players' ability to use visual information of an opponent's movement pattern to anticipate and respond.	13 skilled tennis players 12 novice tennis players	Skilled players demonstrated higher accuracy in predicting the type of stroke and direction.
Singer, R.N., Cauraugh, J.H., Chen, D., Steinberg, G.M., & Flehlich, S.G. (1996)	Tennis	Compare high-level and beginning tennis players in visual search patterns, anticipation, reactions and movements.	30 high-level tennis players 30 beginner tennis players	Experts were more accurate and faster in predicting ball direction than novices. Experts fixated less on head area compare to novices.
Smeeton, N.J., & Huys, R. (2011)	Tennis	Examine the role of movement dynamics and amplitude for the anticipation of tennis-shot direction.	19 low-skill players 15 intermediate-skill players	When dynamic information was presented both groups demonstrated superior performance compared to when it was absent. Movement's dynamics but not their amplitude provides information for tennis-shot direction anticipation.
Tenenbaum, G., Levy-Kolker, N., Sade, S., Liebermann, D.G., & Lidor, R. (1996)	Tennis	Examine anticipatory decisions of novice, intermediate and expert tennis players.	15 experts 15 intermediates 15 novices	Experts and intermediates demonstrated superior performance compare to novices in anticipatory decisions under short exposure durations only.
Ward, P., Williams, A.M., & Bennett, S.J. (2002)	Tennis	Examine the effect of manipulating the perceptual display on visual search during anticipation of a ground stroke using experienced ad inexperienced tennis players.	Eight experienced tennis players Eight inexperienced tennis plyers	Experienced tennis players demonstrated the superior anticipatory skills compare to inexperienced players (difference in percentage of viewing time, search rate and search order).
Wu, Y., Zeng, Y., Zhang, L., Wang, S., Wang, D., Tan, X., Zhu, X., Zhang, J., & Zhang, J. (2013)	Basketball	Identify difference in anticipation skill between experts and novices on a free throw.	15 elite players 15 novice players	The difference was identified and is caused by different visual perception between experts and novices (experts demonstrated more accurate response rate in action anticipation and better gaze stability).

In addition to extensive research on athletes there were also studies on sport referees. Decision-making and visual skills of referees were examined and compared between levels of expertise in soccer (Ghasemi et al., 2011; Spitz et al., 2016, 2017, 2018), Australian football (Larkin et al., 2011; Paradis et al., 2016), rugby unions (MacMahon & Ste-Marie, 2002; Nazarudin et al., 2015), handball (Souchon et al., 2013) and ice hockey (Wilson & Mock, 2013). In these studies expert referees significantly outperformed non-experts such as sub-elite, amateur, junior and assistant referees (Kittel, Larkin, Elsworthy, & Spittle, 2019). While the expert-performance approach has been widely applied in research on athletes and sport referees, less is known about the expertise of coaches and underlying mechanisms of expert performance (Sherman et al., 2001).

2.4.2. Research on coaches' visual perception and diagnostic ability

A range of studies have applied the expert-performance approach to identify the difference between novice an expert coaches in their visual perception and diagnostic ability in various sports such as tennis (Armstrong & Hoffman, 1979; DiCicco, 1990; Giblin, 2014; C. M. Jones & Miles, 1978; Petrakis, 1986; Woorons, 2001), volleyball (Bian, 2003; Grgantov et al., 2013; Yanofsky, 1998), golf (Sherman et al., 2001; Skrinar & Hoffman, 1979), swimming (Boyd, 2004; Leas & Chi, 1993; Moreno et al., 2006), gymnastics (Franks, 1993; Imwold & Hoffman, 1983), track and field (V.E.D. Pinheiro, 1990), climbing (Mitchell et al., 2020) and soccer (Grundel et al., 2013).

Expert-novice paradigm has also been used in coaching. Table 2 provides a summary of the studies that have applied the expert-novice paradigm in coaching. The primary aim of these studies was to compare the expert coaches with novice coaches in their diagnostic abilities, visual perception and search strategies. The tennis studies aimed to determine the difference between expert and novice coaches on their ability to identify common performance errors on tennis forehand and serve (Armstrong & Hoffman, 1979; DiCicco, 1990) and to examine the analytical perception of coaches (Schempp & Woorons, 2018), visual perceptual skills (Giblin, 2014; Woorons, 2001), anticipation ability (C. M. Jones & Miles, 1978) and visual observational patterns (Petrakis, 1986). In volleyball, three studies focused on expert and novice coaches' diagnostic abilities and visual perception (Bian, 2003; Grgantov et al., 2013; Yanofsky,

1998). Two studies examined coaches' perception of golf swing kinematics, difference in the internal model, and diagnostic skills between expert and novice coaches (Sherman et al., 2001; Skrinar & Hoffman, 1979). Three studies in swimming identified the difference between expert and novice coaches on their observational ability, diagnostic knowledge and skills and visual search strategies (Boyd, 2004; Leas & Chi, 1993; Moreno et al., 2006). Coaches' observation accuracy, perceptual recognition and visual search strategy have been compared in gymnastics (Franks, 1993; Imwold & Hoffman, 1983). Single studies in soccer, climbing and track and field applied the expert-performance approach to examine the difference between expert and novice coaches on their cognitive-perceptual mechanisms and visual search behaviour (Grundel et al., 2013; Mitchell et al., 2020; V.E.D. Pinheiro, 1990).

Overall, expert coaches possessed a deeper and more extensive knowledge of sport technique, they required fewer views of the video to identify technical errors, they had better diagnostic accuracy and had a greater ability to identify weaknesses and technical components of their respective sports. Expert coaches also focused more on relevant information compared to novice coaches.

Table 2 Research summary on expert-novice paradigm: coaches

Author(s) and Year	Sport	Aim	Participants	Outcome
Armstrong, C.W., & Hoffman, S.J. (1979)	Tennis	Determine the difference between expert and novice tennis teachers on their ability to identify common performance errors of the tennis forehand.	40 expert tennis teachers 40 novice tennis teachers	There was no or small difference (1.8%) between experienced and inexperienced tennis teacher in detecting common performing errors in the tennis forehand.
Bian, W. (2003)	Volleyball	Examine expert and novice coaches' diagnostic abilities of a volleyball skill.	Four expert coaches Four novice coaches	Experts demonstrated deeper and more extensive knowledge of technique.
Boyd, L. (2004)	Swimming	Investigate the observational ability and level of expertise of competitive swimming coaches.	Eight novice swimming coaches Eight squad swimming coaches Eight expert swimming coaches	Elite coaches require fewer views of the video stimuli to critique the swimmer's technique compared to novice and squad level coaches. Differences were identified in knowledge structures developed from the technical feedback provided by the coaches.
DiCicco, G.L. (1990)	Tennis	Determine the influences of playing and teaching experience on an individual's ability to report errors in a tennis serve.	Nine tennis professionals Nine advanced tennis players Nine physical education teachers Nine undergraduates	Players with high playing and high teaching experience demonstrated better ability to report errors in a tennis serve by identifying more abstract errors.
Franks, I.M. (1993)	Gymnastics	Examine the observation accuracy of expert and novice gymnastic coaches.	Seven novice coaches Seven expert coaches	Experts were superior in detecting differences in technique.
Giblin, G. (2014)	Tennis	Examine the effect of coaching expertise on the visual perceptual skills of coaches.	10 expert coaches 10 novice coaches	Expert coaches identified significantly more technical errors in the tennis serve than novices. Differences in visual behaviour identified where experts focused more on the centre of a body than novices.
Grgantov, Z., Jurko, D., & Milic, M. (2013)	Volleyball	Examine the difference between expert and novice coaches on evaluation of volleyball technique.	Six expert coaches Six novice coaches	Experts demonstrated superior diagnostic ability by using a wider range of evaluation marks than novices.
Grundel, A., Schorer, J., Strauss., & B. Baker, J. (2013)	Soccer	Examine the effect of playing experience on the perceptual-cognitive skills across soccer coaches and players.	17 amateur soccer coaches 20 expert coaches 18 inexperienced players 18 experienced players	Similarities were reported between coaches and players in decision-making tasks and differences in pattern-recognition performance.

Imwold, C.H., & Hoffman, S.J. (1983)	Gymnastics	Determine the relationship between teaching experience and selected factors involved in perceptual recognition and visual inspection strategy.	20 gymnastic coaches 20 veteran physical education teachers 20 pre-service physical education teachers	Experts were more accurate in error identification.
Jones, C.M., & Miles, T.R. (1978)	Tennis	Examine the perception of tennis serve landing position by expert and novice coaches.	32 professional tennis coaches 60 non-experienced tennis coaches	Experts outperformed novices in predicting the serve landing position.
Leas, R.R., & Chi, M.T.H. (1993)	Swimming	Examine the diagnostic knowledge and skills of expert and novice swimming coaches.	Six experts swimming coaches Six novice swimming coaches	The experts' diagnosis was more accurate, and they demonstrated greater amount of knowledge, depth and connectedness of the knowledge.
Mitchell, J., Maratos, F.A., Giles, D., Taylor, N., Butterworth, A., & Sheffield, D. (2020)	Climbing	Explore the feasibility and the utility of a novel methodology, combining eye tracking technology and cued retrospective think-aloud, to capture the cognitive-perceptual mechanisms that underpin the visual search behaviour.	3 expert climbing coaches 3 novice climbing coaches	Experts demonstrated fewer fixations of greater duration and fixated on distinctly different areas of the visual display compared to novices. Experts' complex knowledge relating to the principles of climbing movement enabled expert coaches to focus on the most relevant information.
Moreno, F.J., Saavedra, J.M. Sabido, R., & Luis, V. (2006)	Swimming	Examine visual search strategies of swimming coaches (technical analysis).	Eight experienced swimming coaches Eight non-experienced swimming coaches	In front-underwater videos, coaches focused longer on body roll and mid-water. In the side-underwater videos coaches fixated longer on upper-body.
Petrakis, E. (1986)	Tennis	Examine visual observational pattern of novice and expert tennis teachers.	Six novice tennis teachers Six expert tennis teachers	Experts demonstrated superior observational skills compare to novices.
Pinheiro, V.E.D. (1990)	Track and field	Identify empirical differences in the cognitive process used by expert and novice coaches.	Five expert track and field coaches Five novice track and field coaches	Experts acquired more cue interpretations and diagnostic decisions and demonstrated better accuracy in predicting the distance of the shot put.
Sherman, C.A., Sparrow, W.A., Jolley, D., & Eldering, J. (2001)	Golf	Determine differences between expert and novice golf coaches' internal model of golf swing kinematics.	10 professional golf coaches 10 amateur golf coaches	Coaches at different level of expertise had similar ability to identify fundamental characteristics of the golf swing. Internal model was influenced by the observed golfer's skill level.
Schempp, P.G., & Woorons, S. (2018)	Tennis	Examine analytic perceptions of expert and novice tennis coaches.	10 novice coaches 10 expert coaches	Experts attended to a greater number of "critical features" than did the novice coaches and demonstrated greater ability in perceiving, analysing and solving problems.
Skrinar, G. S., & Hoffman, S.J. (1979)	Golf	Examine the effect of information on golf teachers' ability to determine the presence or absence of selected critical aspects of the golf swing.	28 expert coaches	Presence or absence of the outcome did not affect the response between two groups.

Woorons, S.I. (2001)	Tennis	Examine the difference between expert and novice tennis instructors' perceptual capacities.	Four expert tennis instructors Four novice tennis instructors	Experts demonstrated superior performance in critical analysis, relevance to tennis and tennis instructions and in the use of evaluations, interpretations, understanding of the situation and the anticipation of future events.
Yanofsky, K. (1998)	Volleyball	Determine if there were differences in perceived performance due to the coaches' level and the age of athletes.	Eight university coaches Seven high school volleyball coaches Five junior coaches	No major differences in sorting and ranking athletes' performance detected.

Table 1 and Table 2 demonstrated that the expert-performance approach has been widely applied to explore anticipation and visual search behaviours, perceptual expertise, diagnostic abilities of expert and novice athletes and coaches in a range of sports (Abernethy, 2007; Abernethy et al., 2000; Arroyo et al., 2016; Canal-Bruland et al., 2010; E. Furley & Dorr, 2016; Giblin, 2014; Grgantov et al., 2013; Grundel et al., 2013; Loffing & Hagemann, 2014; Mitchell et al., 2020; Mori et al., 2002; Sherman et al., 2001; N. J. Smeeton & Huys, 2011; Wu et al., 2013). In these investigations, experts demonstrated superior visual perception, greater knowledge, and diagnostic abilities. Hence, the critical question of how to train less experts athletes and coaches such skills has arisen.

2.5. Video-based training in sport

Most of the studies presented in Table 1 above used a video-based method to identify the difference between expert and novice athletes on their anticipation and visual search behaviours. The video-based method has also been used in training for athletes and referees to improve their perceptual-cognitive and decision-making skills. There is, however, little evidence that video-based method has been used to develop coaches' knowledge and diagnostic skills of sports technique.

The perceptual training method has been applied to improve the anticipatory and perceptual skills of non-expert athletes (Abernethy, Wood, & Parks, 1999; Brenton, Müller, & Dempsey, 2019; Farrow & Abernethy, 2001; Farrow, Chivers, Hardingham, & Sachse, 1998; Singer et al., 1996; A. M. Williams, Ward, & Chapman, 2003; A. M. Williams et al., 2002). This method included the replication or simulation of the perceptual conditions of the real word setting in the sporting domain. Examples are postural cue identification and temporally occluded video-based displays (R.C. Jackson & Farrow, 2005). The main type of laboratory testing was filmed-based training methods, and was recognised as the successful way of improving anticipation and visual perception skills of athletes and umpires (Broadbent, Causer, Williams, & Ford, 2015; Larkin, Mesagno, Berry, Spittle, & Harvey, 2018; Larkin, Mesagno, Spittle, & Berry, 2015; A. M. Williams et al., 2003). This method involved the filming of appropriate sport actions such as tennis serve, overhead strokes in badminton or penalty kick in soccer, and presenting the film to participants with various instructions or feedback. For instance, the video was stopped in some research to highlight the relationship between certain elements such as key postural cues and penalty kick

placement (Farrow et al., 1998). Different approaches were used to train perceptual skills in sport settings such as explicit instruction, guided discovery and discovery learning (R.C. Jackson & Farrow, 2005).

Table 3 below represents the summary of studies that applied video-based training programs to improve perceptual-cognitive skills of athletes in various sports such as tennis (Day, 1980; Farrow & Abernethy, 2001; Farrow et al., 1998; Haskins, 1965; Scott, Scott, & Howe, 1998; Singer et al., 1994; N.J. Smeeton, Williams, Hodges, & Ward, 2005; A. M. Williams et al., 2002), squash (Abernethy et al., 1999), American football (Christina, Baressi, & Shaffner, 1990; Damron, 1995; Londerlee, 1967), football (Gabbett, Carius, & Mulvey, 2008; G. J. Savelsbergh, Van Gastel, & Van Kampen, 2010; Shafizadeh & Platt, 2012), baseball (Burroughs, 1984), soccer (Franks, McGarry, & Hanvey, 1997; Grant & Williams, 1996; McMorris & Hauxwell, 1997; Murgia et al., 2014; Ryu, Kim, Abernethy, & Mann, 2013; A. M. Williams & Burwitz, 1993), volleyball (Adolphe, Vickers, & La Plante, 1997; Starker, Edwards, Dissanayake, & Dunn, 1995), badminton (Hagemann, Strauss, & Canal-Bruland, 2006; Tayler, Burwitz, & Davids, 1994), cricket (Hopwood, Mann, Farrow, & Nielsen, 2011; N.J. Smeeton, Hibbert, Stevenson, Cumming, & Wiiliams, 2013), basketball (Gorman & Farrow, 2009), softball (Gabbett, Rubinoff, Thorburn, & Farrow, 2007), handball (Schorer, Canal-Bruland, & Cobley, 2010), hockey (A. M. Williams et al., 2003) and Rugby Union (Engelbrecht, Terblance, & Welman, 2016). The primary aim of these studies was to examine the effect of video training on visual perception, selection accuracy, anticipatory skills and cognitive decision making. Overall, these studies demonstrated significant improvement in response accuracy, anticipatory skills, prediction accuracy, reactive agility, and decision-making skills among athletes.

Table 3 Research summary on video-based training programs: athletes

Author/Year	Sport	Aim	Participants	Outcome
Abernethy, B., Wood, J., & Parks, S. (1999)	Squash	Determine the effect of perceptual training on anticipatory skill.	30 undergraduate students	Significant improvements in the anticipatory skill.
Adolphe, R.M., Vickers, J.N., & La Plante, G. (1997)	Volleyball	Examine the effects of training visual attention on gaze behaviour and accuracy.	9 international players	Significant improvement in visual tracking and service return accuracy.
Burroughs, W.A. (1984)	Baseball	Evaluate the effectiveness of visual stimulation training film approaches to enhancing the visual pitch recognition and pitch location skills.	59 collegiate players	Significant gains in location scores and nonsignificant changes in pitch recognition scores.
Christina, R.W., Baressi, J.V., & Shaffner, P. (1990)	American football	Explore the impact that video training could have on American Football linebacker's selection accuracy.	One experienced player	Significant improvements in response accuracy; no chance in response time.
Damron, C. (1995)	American football	Discover an instructional technique that can be used by football coaches in teaching offensive football players to recognise quickly the defence employed by the opponent team.	52 high school players	After training both groups were able to identify the formations with equal accuracy (approximately 95%).
Day, L.J. (1980)	Tennis	Examine the effect of video-based training on anticipatory skills.	21 advanced junior players	Improvements in prediction accuracy of tennis groundstroke type and direction.
Engelbrecht, L., Terblance, E., & Welman, K.E. (2016)	Rugby Union	Investigate the effectiveness of rugby-specific video-based perceptual training on the speed and agility.	26 club-level players	The improve in reactive agility was reported after the training.
Farrow, D., & Abernethy, B. (2001)	Tennis	Determine the effectiveness of two video-based perceptual training approaches designed to improve the anticipatory skills of junior tennis players.	34 intermediately skilled junior tennis players	Significantly improvements in predicting accuracy after the training intervention (implicit group).
Farrow, D., Chivers, P., Hardingham, C., & Sache, S. (1998)	Tennis	Investigated whether video-based perceptual training would improve beginning tennis players' return of serve.	24 Novice players	No significant improvements in decision-making accuracy.
Franks, I.M., McGarry, T., & Hanvey, T. (1997)	Soccer	Examine the effect of perceptual training on the anticipation ability.	18 experience players	Significant increase in accuracy for the experimental group.
Gabbett, T., Carius, J., & Mulvey, M. (2008)	Football	Investigate the effect of video-based perceptual training on pattern prediction ability and determined whether enhanced perceptual skills influenc ed the physiological demands of game-based activities.	16 elite players	Significant improvements of the decision-making skills.
Gabbett, T., Rubinoff, M., Thorburn, L., & Farrow, D. (2007)	Softball	Investigate whether a video-based perceptual training stimulus could improve anticipatory skill in softball fielders.	25 elite softball players	Significant improvement of decision-making accuracy.

Gorman, A., & Farrow, D. (2009)	Basketball	Investigate the efficacy of explicit and implicit perceptual training approaches designed to improve the pattern perception capabilities of skilled basketball players.	39 skilled basketball players	General improvement in decision-making performance.
Grant, A., & Williams, A.M. (1996)	Soccer	Examine the effect of video-based training on cognitive decision making.	16 novice players	Significant improvement in accuracy for the experimental group.
Hagemann, N., Strauss, B., & Canal-Bruland, R. (2006)	Badminton	Evaluate a program for training anticipatory skills.	63 novice players 20 national league players 21 local league players	Novices significantly improved decision-making performance compared to the control group.
Haskins, M.J. (1965)	Tennis	Determine whether training with the film significantly shortened response time.	11 experienced players	Significant improvement in response time, thus the training device appears to be successful.
Hopwood, M.J., Mann, D.L., Farrow, D., & Nielsen, T. (2011)	Cricket	Examine the effectiveness of visual-perceptual training for improving fielding performance in cricket.	12 highly skilled cricket players	Significant improvement of decision-making accuracy.
Londerlee, B. (1967)	American football	Examine the effect of training with motion pictures versus flash cards upon football play recognition.	28 high school players	The group trained with motion pictures had significantly shorter response times. Differences in intelligence, over the limited range used in this study, did not result in differences in response times.
McMorris, T., & Hauxwell, B. (1997)	Soccer	Examine the possibility of using a training video to improve the ability of novice goalkeepers to anticipate the direction of penalty kicks.	30 Novice players	Significant improvements in anticipation ability for the experimental group.
Murgia,M., Sors, F., Muroni, A.F., Santoro, I., Prpic, V., Galmonte, A., & Agostini, T. (2014)	Soccer	Test the effectiveness of a perceptual training concerning the anticipatory skills of soccer goalkeepers.	42 skilled goalkeepers	Significant improvement of accuracy for the experimental group.
Ryu, D., Kim, S., Abernethy, B., & Mann, D.L. (2013)	Soccer	Evaluate whether perceptual-skill learning would be enhanced when supplemented with guiding visual information.	28 university students	The guided perceptual-training group significantly improved anticipation skill.
Savelsbergh, G.J., Van Gastel, P.J., & Van Kampen, P.M. (2010)	Football	Improve the estimation of the direction of the ball during penalty kicks by changing the visual search behaviour.	30 novice goalkeepers	The perceptual training group demonstrated significantly better performance.
Schorer, J., Canal-Bruland, R., & Cobley, S. (2010)	Handball	Examine the influence of knowledge of result frequency schedules on perceptual learning and retention in an anticipation task.	47 novice goalkeepers	Improvement of decision accuracy for all groups.
Scott, D., Scott, L.M., & Howe, B.L. (1998)	Tennis	Examine the trainability of anticipation in intermediate tennis players.	6 intermediate players	Significant improvement for all participants.
Shafizadeh, M., & Platt, G.K. (2012)	Football	Investigate the effect of a cueing technique on novice goalkeepers' anticipation of trajectory in penalty kicks.	28 novice goalkeepers	Significant improvements in accuracy for experimental group.
Singer, R.N., Cauraugh, J.H., Chen, D., Steinberg, G.M., Frehlich, S.G., & Wang, L. (1994)	Tennis	Assess trainability of anticipatory skills for tennis.	34 novice players	Significant improvement in reaction to serves, faster anticipation times, improved accuracy in predicting serve type and location.

Smeeton, N.J., Hibbert, J.R., Stevenson, K., Cumming, J., & Wiiliams, A.M. (2013)	Cricket	Examine the effectiveness of interventions involving imagery, video, and outcome feedback in improving anticipation.	Junior cricket batters (34)	All experimental groups improved anticipation performance during training.
Smeeton, N.J., Williams, A.M., Hodges, N.J., & Ward, P. (2005)	Tennis	Examine the relative effectiveness of explicit instruction, guided discovery, and discovery learning techniques in enhancing anticipation skills.	33 intermediate players	No significant difference for decision-making accuracy was detected.
Starker, J.L., Edwards, P., Dissanayake, P., & Dunn, T. (1995)	Volleyball	Examine the role of experience and skill in the use of advance visual cues to decide where a volleyball service will land.	8 novice players 8 skilled players	The skilled players demonstrated higher accuracy in the prediction of shoot position.
Tayler, M.A., Burwitz, L., & Davids, K. (1994)	Badminton	Examine the effectiveness of video-based perceptual training on the anticipation of the badminton serve.	16 novice players	Significant improvement in performance on the anticipation for the experimental group.
Williams, A. M., Ward, P., Knowles, J.M., & Smeeton, N. J. (2002)	Hockey	Examine whether field hockey goalkeepers' anticipation skill could be improved through video-based perceptual training.	24 novice goalkeepers	No difference between the groups at the post-test. Slight non-significant improvement on the field test.
Williams, A.M., & Burwitz, L. (1993)	Soccer	Improve novice goalkeepers' anticipatory performance at soccer penalty kicks.	10 novice players	Significant improvement on the anticipation for the experimental group.
Williams, A.M., Ward, P. Knowles, J.M., & Smeeton, N.J. (2002)	Tennis	Examine the effect of training on the anticipatory performance in tennis.	32 novice tennis players	Significant improvements in anticipatory performance after training.

The body of research presented above clearly indicates that video-based training is an effective method to improve visual perception, response time and accuracy, decision-making skills for the athletes.

In addition to extensive research on training athletes, a small number of studies has focused on referees where a video-based method was applied. For example, a previous study of rugby union aimed to improve referees' mental model for decision-making (Mascarenhas, Collins, Mortimer, & Morris, 2005). This study aimed to pilot a video-based training program to develop a shared mental model of referees. A significant improvement of 17.43 per cent of the decision accuracy was reported. Another study in soccer applied an online video-based training method to improve referee's intuitive decision-making skills and reported a significant improvement in decision accuracy over the course (Schweizer et al., 2011). A video-based method was also recognised as valid measure to assess decision-making in soccer, Australian football, rugby union, basketball, handball and ice hockey (Kittel et al., 2019). To date, there has been no research examining video-based methods to train coaches on their diagnostic ability of technique.

2.6. Skill acquisition

Skill acquisition explains how learners acquire and develop skills. By understanding of how motor skills are acquired, improved and enhanced, sport coaches and physical education teachers will be able to provide instructions and feedbacks that lead to successful skills acquisition (Spittle, 2021).

Every individual is unique and possesses set of abilities that affect motor skill acquisition. For instance, some children runs faster than other because that has ability to do so. The notion of abilities is often used by sport coaches or instructors to predict future performance. However, according to research, the abilities underlying early performance can be different from abilities underlying later performance. Hence, it is crucial for sport professionals not to make assumptions about future performance of athletes based on current abilities, and apply various methods and approaches to develop motor skills further (Spittle, 2021).

Traditional approaches to skill acquisition characterised by more direct, behaviourist type of instructions that include repetitive-based drills. Traditional approaches are based on cognitive models of motor control where learner often acquire motor skill in

isolation from the game, and where the movement is broken down by separate components (Spittle, 2021; A. Williams & Hodges, 2005). The motor skills is continuously repeated until relatively permanent change is consistency is achieved (Spittle, 2021).

By contrast, constraints-led approaches are based on less direct instructions which encourage learners to discover new movement solutions (Spittle, 2021). Recent research has suggested that consistent reproduction of movements is not enough, and the development of unique functional movement solutions is the key for successful performance (Davids et al., 2013; Spittle, 2021). Constraints-led approach is the methodology of manipulating task constrains, which is based on dynamic system views of motor control and ecological theories where movement is self-organised (Spittle, 2021). Self-organisation of movement is achieved by applying constraints and results in individual movement pattern (Spittle, 2021).

The constraints-led approach has been previously applied to understand skill acquisition, expertise and talent development in sport (Araujo, Chow, & Passos, 2009; Handford, Davids, Bennett, & Button, 1997; Passos, Araujo, & Davids, 2016; Renshaw, Davids, Phillips, & Kerheve, 2012; Renshaw, Davids, & Savelsbergh, 2010; G. J. P. Savelsbergh, Davids, Van Der Kamp, & Bennett, 2003). It aimed to identify and understand the constraints that affect acquisition of movements (Davids, 2010). Constraints such as performer skill level, environment and task complexity refer to the boundaries within which the learner is challenged to search for the most efficient solutions. Thus, the learners need to adapt to the unique constraints through self-organization (Chow, Davids, Button, & Renshaw, 2016). The constraints-led approach requires a strong understanding of sport performance in order to manipulate the various constraints (Renshaw et al., 2010).

Skill acquisition in sport has received much attention as understanding of how learner develop new skills is critical for sport performance (Davids, Button, & Bennett, 2008). There are several existing theories of skill acquisition that allow coaches and other sport practitioners to create the most effective and appropriate model for developing motor skills (Davids et al., 2008).

Association theories explained the relationship between motor action and information where reflexes were used to test the assumptions (Skinner, 1938; Thorndike, 1927;

Woodworth, 1899). The main criticism for association theories is that reflexes were drove movement behavior whereas human have a choice about the movements (Davids, 2010). Neuromaturational theories explained motor behavior from neuromaturational perspective. Initially it was believed that DNA determines motor development (Davids et al., 2008). It was found later that specific environment and content explains the individual differences (Thelen & Smith, 1994). The Second World War led to the development of Fitt's stage theory of motor learning (Fitts, 1964). According to this three-stages theory, learning was a continuous process with gradual changes of information. The process included cognitive, associative and autonomous stages (Davids et al., 2008). In information-processing theories the central nervous system contains perceptual-motor information. The central nervous system stores motor commands which are acquired through learning (Davids et al., 2008).

All mentioned above theories played a significant role in optimising and adapting the movement. It provides the understanding of human motor behaviour and has been applied in physical therapy and sport coaching (Davids, 2010).

2.7. Coach education

The quote form Albert Einstein that "intellectual growth should commence at birth and cease only at death" reminds us that change, transformation, and growth is an integral part of the development. Coach education is a key component in coach transformation from novice to expert level (Hullinger & DiGirolamo, 2020). There are three fields that need to be considered to better understand coach learning and development: education, cognitive psychology and positive psychology (Hullinger & DiGirolamo, 2020).

The field of education provides theories on adult education which explain the process of coach development (Hullinger & DiGirolamo, 2020). In coaching there are several adult learning models: transformative learning (Mezirow, 1997), reflective practice (Dewey, 1910; Schon, 1983), experimental learning (Dewey, 1938; D. A. Kolb, 1984), and andragogy (Knowles, 1980).

Transformative model explains adult learning through changing frames of reference (Christie, Carey, Robertson, Grainger, & USC, 2015). Frames of reference is "the structure of assumptions through which we understand our experience" (Mezirow, 1997, p. 5). The individual's view of the world is shaped by these assumptions and

based on experience, education, culture (Christie et al., 2015; Hullinger & DiGirolamo, 2020). According to Mezirow (1997), changing these assumptions is challenging task as they became unconscious for individual. Thus, communicative skills, the new way of learning, the role of context and effective relationships are essential elements of the learning withing transformative model (Hullinger & DiGirolamo, 2020; Mezirow, 1997).

Reflective practise was defined as “turning a subject over in the mind and giving it serious and consecutive consideration” (Dewey, 1938, p. 3). It is characterised by the active engagement of the learner who asks questions and applies learning feedback to improve the quality of their work and thinking (Hullinger & DiGirolamo, 2020).

Experiential learning model refers to the learning though day-to-day experience (Hullinger & DiGirolamo, 2020). Kolb (1984) stated that the individual can grow and develop from any experience. The reflection, interpretation and experimentation are the key elements for successful learning (Hullinger & DiGirolamo, 2020).

Andragogy model is an adult learning theory where learner’s active engagement, responsibility for the learning process and understanding the role of educator are key principles (Knowles, 1980). The application of these principles contributes to the increased the motivation and improved outcomes (Hullinger & DiGirolamo, 2020).

Positive psychology highlights the person-centred learning and attribute of the environment such as genuineness, acceptance, empathy (Rogers, 1980). In the coaching context this refers to the conditions where coaches can reach their full potential through nurturing their mind, body and spirit (Hullinger & DiGirolamo, 2020).

Cognitive psychology explains the cognition of expertise and helps to understand the process of transformation from novice coach to expert coach (Hullinger & DiGirolamo, 2020). The past thirty years have seen rapid advances in the field of coaching expertise with the focus on identifying attributes of coaching expertise and the main characteristics that distinguish an expert from a non-expert (Navin & Vinson, 2020) Gilbert, 2009).

The major areas of interest were identification of expertise attributes and understanding the development and mechanisms of expert performance (Abernethy, 2013; Bell, 1997; Cote & Gilbert, 2009; Gilbert & Cote, 2013; Nash & Collins, 2006; Nash et al., 2012; Singer & Jannelle, 1999; Wharton & Rossi, 2015; Williams & Ford,

2008; Wiman, Salmoni, & Hall, 2010). As a result, the knowledge on coaching expertise has grown significantly. The research had indicated that expertise is characterised by a hierarchical knowledge structure, fast-access recognition capability, problem categorisation, faster pattern recognition, flexibility and continuous development of expertise. Other attributes of coach expertise highlighted in the literature are extensive, specialised knowledge, an ability to store and organise knowledge about sport and athletes in the long-term memory, a capability to accurately perceive stimuli in game situations, athletic performance and quicker ability to process large sensory information (Berliner, 1994; De Marco & McCullick, 1997; Glaser, 1987; Navin & Vinson, 2020, Nash et al., 2012; Tan, 1997; Wharton & Rossi, 2015). Expert coaches possessed deeper knowledge of a subject matter (Johnson, 1988) and demonstrated deeper understanding of the skill (Leas & Chi, 1993). Conscious shift from automaticity to conscious thinking and deliberate practice have also been identified as attributes of expertise (Foer, 2011; Hullinger & DiGirolamo, 2020). Conscious shift refers to the process of moving from "autopilot" perception to conscious attention (Foer, 2011). Deliberate practice requires full concentration and persistence in training (Hullinger & DiGirolamo, 2020). Regardless of the extensive research there is still debate in the coaching science literature on the definition and the attributes of coaching expertise (Navin & Vinson, 2020).

All three fields mentioned above are essential for understanding of sport education and the professional development of sport coaches, and raising the standard of their practice (Hannays, 2020). For the recent years there has been an increase in the number of the literature on sport coach education (Trudel, Milestetd, & Culver, 2020). For instance, the number of articles on Google Scholar has increase from 112 articles for the period from 1980 to 1999 to 315 publications for the period from 2012 to 2017 (Trudel et al., 2020). The research on formal coach education looked at the programs provided by national governing bodies and by higher education institutions (Trudel et al., 2020). The focus was made to coach development and education programs (Allan, Vierimaa, Gainforth, & Cote, 2018; Dieffenbach & Wayda, 2010; M. B. Evans, McGuckin, Gainforth, Bruner, & Côté, 2015; Galatti et al., 2016; Langan, Blake, & Lonsdale, 2013; Lefebvre, Evans, Turnnnidge, Gainforth, & Côté, 2016; J. Lyle, 2007; Rynne, Mallett, & Tinning, 2006), mentoring in sport coaching (R. Jones, Harris, & Miles, 2009) and coaches learning (C. J. Cushion et al., 2010; He, Trudel, & Culver,

2018; Walker, Thomas, & Driska, 2018). Despite of the increasing attention to coach education, there is lack of the studies that provide the quality control of coaching programs (Stoszkowski et al., 2021).

2.7.1. Online coach education

COVID-19 has dramatically changed education in many fields of expertise worldwide where online education has become inevitable and only one possible way of learning during the coronavirus pandemic (World Economic Forum, 2021). Prior to COVID-19, online educational tools have been available in many areas including but not limited to coaching. Nevertheless, a limited number of studies have examined development and evaluation of online coaching courses in various sports. To date, no study has explored online tennis coaching courses, especially with the focus on the technical aspects coaching the serve.

Several studies have previously developed and demonstrated the effectiveness of online educational tools in different areas such as mental health care (Gayed et al., 2018; Pearce, Pargament, Oxhandler, Vieten, & Wong, 2019), meteorology and hydrology (Wang & Zhi, 2009), teaching (Lan & Chang, 2012), transport (Chalkiadakis, Iordanopoulos, & Malin, 2019), dentistry (Abdullah, 2014), management (Murphy, Keiffer, Neal, & Crandall, 2013) and public services (S. L. Smith & Kelloway, 2016). So far, however, there has been little research on the efficacy of online education programs for sport coaches (C. Cushion & Townsend, 2019).

A limited number of studies have evaluated online programs for sport coaches although there are many coach educational programs available online such as Swimming Australia's online learning program, (Swimming Australia, 2020) the Tennis Australia online learning platform *Bounce* (Tennis Australia, 2020a), the US Lacrosse online coaching course (US Lacrosse, 2020), and others. For example, a video-based online training program was previously developed and evaluated in soccer (Schweizer et al., 2011). The program aimed to improve soccer referees' decision-making skills. As a result, the improvement in decision-making skills was reported (Schweizer et al., 2011). A study in gymnastics coaching developed and validated an online educational course for future physical education students indicated significant improvement in knowledge for the experimental group (Petrov, 2018).

A comprehensive study commissioned by Swimming USA employed the utilisation-focused evaluation to assess the effectiveness of the online coaching program (*Foundation of Coaching*) (Driska, 2018). The program included two courses that cover several introductory topics such as practice organisation and teaching the basic swimming stroke technique in which employed problem-based learning approaches. The content was presented via talking slide shows, video demonstrations and video interviews with experts. Each session finished with a quiz followed by the final exam where a minimum score of 80per cent was required to pass the course. Semi-structured interviews were then conducted with 21 coaches after they completed the online coaching course to assess the effect of the program on coaches' knowledge, attitudes and behaviours. During the interview coaches were asked open-ended questions that related to the four key topics: general impression of the course; specific knowledge learned from the course and the implementation of this knowledge in coaches' practice; and specific attitudinal attributes and behavioural outcomes. The study reported a strong effect on coaches' knowledge of skills, drills and pedagogy as reported by 14 coaches during the interviews.

Another study evaluated the Heads-Up Football online coach training, and reported that the online training reduced the injury of the athletes in which coaches who completed the training were able to decrease the number of collisions during the practice compared to coaches who did not have the training (Kerr et al., 2015).

The online education course for youth sport coaches with a focus on sport concussion prevention was also previously presented in the United States of America (Glang et al., 2010). The program consisted of three modules that included various scenarios related to concussion prevention and management practice. Pre-test and post-test measures were applied to demonstrate the effect of the program on coaches' knowledge. It was reported that the course improved coaches' knowledge about sport concussion, management, and prevention.

There is an abundance of learning material online for tennis coaches ranging from self-styled YouTube videos of coaches sharing their knowledge and expertise to formal courses offered by various national sport organisations. For example, the International Tennis Federation Tennis Coach Education Program included on-court presentations, drills and exercise videos, biomechanical stroke analysis, articles and interviews with coaches and players (Over & Sharp, 2008). The Royal Spanish Tennis

Federation introduced online education plans after it was found that one of the main reasons why coaches did not participate in educational events was due to the lack of time. The Royal Spanish Tennis Federation had reported that according to coaches' feedback and the number of enrolments, the online education plans have been proven to be successful (Sackey-Addo & Camarero, 2016).

Despite existing research on online training for sport coaching, no studies have been previously attempted to develop and assess the effectiveness of online coach training courses in tennis. There is a knowledge gap in the literature about the effectiveness of online coach education courses in tennis especially for technical elements such as the serve, forehand and backhand.

2.8. Examination of the tennis serve technique

There are many studies that examined tennis serve technique from the biomechanical perspective in which this knowledge has grown significantly (Elliott, 2006; Elliott, Reid, & Crespo, 2003; ITF, 2007; Kovacs & Ellenbecker, 2011; Tennis Australia, 2010, 2013). However, there is no research examining coaches' knowledge of the tennis serve technique which is one of the key factors affecting coaches' performance and athletes' development (Elliott et al., 2003).

The flat tennis serve is the most important stroke in tennis as the outcome of a match is significantly determined by its successful execution (Antunez et al., 2012). The technical complexity of the serve is one of the reasons why only a few players can consistently perform the serve with a high level of accuracy and speed (Kovacs & Ellenbecker, 2011). The flat serve is one of three types of tennis serves and is characterised by faster ball speed and reduced rotational spin (Sheets, Abrams, Corazza, Safran, & Andriacchi, 2011).

A number of studies have been published on tennis serve biomechanics (Antunez et al., 2012; De Subijana & Navarro, 2010; Durovic, Lozovina, & Mrduljas, 2008; Elliott, 2006; Elliott et al., 2003; Ivancevic et al., 2011; Knudson, 2007; Kovacs & Ellenbecker, 2011; Martin et al., 2014; Roetert, Ellenberker, & Reid, 2009). A breakdown of the biomechanical elements of the serve including the technical elements, body elements and phases of the tennis serve that have been identified in these studies is demonstrated in Table 4.

Table 4 The technical elements, body elements and phases of the tennis serve

Technical elements	Body elements	Phases
Grip	Knee	Start
Stance	Hip	Release
Ball toss	Shoulder	Loading
Co-ordination of 2 arms	Elbow	Cocking
Trophy position	Wrist	Acceleration
Knee flexion	Leg(s)	Contact
Hip rotation	Arm(s)	Deceleration
Trunk rotation	Chest	Finish
Swing	Feet(foot)	
Type of swing	Hand(s)	
Position of the non-racket arm	Back	
Loading	Eyes	
Leg drive	Upper body	
Shoulder-over-shoulder	Body	
Twist	Head	
External/internal rotation of the shoulder	Trunk/torso	
Shoulder angle at maximum external rotation	Toe	
Shoulder and arm alignment	Fingertips	
Non-racket arm movement	Forearm	
Upper arm elevation	Palm	
Elbow extension		
Elbow flexion		
Weight transfer		
Wrist flexion/extension		
Shoulder angle between arms and trunk		
Pronation (as a general concept)		
Forearm pronation		
Hip extension		
Contact point		
Landing in arabesque position		
Follow through		
Eye focus		
Separation angles		
Type of serve (step-up/platform)		
Source: (Elliott, 2006; Elliott et al., 2003; ITF, 2007; Kovacs & Ellenbecker, 2011; Tennis Australia, 2010, 2013)		

The tennis serve can be divided into the following phases:

1. Start. During this phase the feet are perpendicular to the net, front foot angled towards the net post, and back foot behind the front, parallel to the baseline, shoulder width apart. Non-hitting hand supports the ball and the throat of racket. Grip is continental;
2. Release phase. This includes the release of the ball from non-serving hand;
3. Loading phase. This starts after the release phase and finishes when the lower body is fully loaded. The fully loaded position coincides with the elbow lowest vertical position and maximum knee flexion;
4. Cocking phase. This starts at the end of the loading phase until the maximal shoulder external rotation coinciding with the tip of the racket head pointing towards the ground;
5. Acceleration phase. This occurs at the end of the cocking phase until the contact phase.
6. Contact phase. This is a very short period where the ball and racket impact. The elbow extension is up to contact. The racquet follows an upward swing path;
7. Deceleration phase. This follows the contact unit the end of upper and lower body deceleration of the serve;
8. Finish phase. This is the short period at the end of the deceleration and before the initial movement to prepare for the next stroke (Kovacs & Ellenbecker, 2011, p. 505)

Despite extensive research on tennis serve biomechanics, no attempts have been made to understand tennis coaches' internal model of the flat tennis serve technique.

2.9. Summary of Chapter 2

The purpose of this review was to provide theoretical fundamentals on coaching expertise and knowledge. It also aimed to explain how expertise can be better understood and improved.

Expertise has been well studied in the sport realm. As a result, knowledge was recognised as a critical attribute of expertise. Extensive research has been conducted on coaches' knowledge in many sports where the expert-novice paradigm was applied. However, limited research exists in tennis. Moreover, no attempts have been

made to examine the coaches' internal model although it plays a critical role in the diagnostic process of athlete's performance.

The Expert Performance Approach was recognised as a guiding framework to understand coaching expertise. A large body of research applied this approach to investigate the expertise of athletes. Less attention was given to referees and coaches. No studies applied this framework on the coaches' knowledge in tennis.

It was reported by many researchers that it was possible to improve perceptual-cognitive and decision-making skills by applying video-based methods. This was primarily performed previously on athletes and referees. However, to date no attempts have been made to train coaches.

It was established that the recognition of the key cues is a vital attribute of coaching expertise. Surprisingly, no studies have attempted to train coaches to recognise key technical cues on technique.

Finally, online training courses have been developed and validated in many areas. However, in sport the research is scarce. No previous studies have attempted to develop online coaching training on the serve technique in tennis. The next chapter will explain general methodology that has been used in this thesis.

Chapter 3 General Methodology

As noted in chapter 1, this thesis has been constructed using the pragmatism research paradigm to guide the methods used in each study of this thesis (Liamputtong, 2017). Pragmatism is a set of believes about reality and knowledge (Kaushik & Walsh, 2019), “a way of thinking about and making sense of the complexities of the real world” (Patton, 2002, p. 69).

The mixed methods approach employed in each study has been determined by what would best address the broad research problem and the specific aims outlined in Chapter 1. The end result is a multi-layered, mixed methods approach, whereby both quantitative and qualitative data has been collected and analysed (Liamputtong, 2017).

The purpose of this chapter is to provide a detailed description of the various research methods used in this investigation. This includes a variety of both qualitative and quantitative data collection methods to ensure a rigorous and, where needed, triangulated analysis.

3.1. Participants

Although certain characteristics of expert coaches have been identified and summarised in Chapter 2, there is no clear definition of an expert coach (Ford et al., 2009). Therefore, a Tennis Australia Coach Expertise Continuum has been developed to define experts and novices for this study. The expertise continuum was based on the Tennis Australia coaching certification (Tennis Australia, 2020b) and presented in Figure 3. Tennis Australia Coach Certification includes six levels of accreditation and education certification: Foundation Coach, Community Coach, Junior Development Coach, Club Professional Coach, Master Club Professional Coach and High Performance Coach (Tennis Australia, 2020b). The Junior Development Coach is the first level that includes tennis serve technique fundamentals (Tennis Australia, 2020d). Therefore, for the purpose of this study, Junior Development coaches were considered novices. High Performance is the highest level in Tennis Australia’s certification (Tennis Australia, 2020b). Thus, High Performance coaches were considered experts. The full description of Junior Development and High Performance Coach qualifications can be found in Appendix A Tennis Australia Coaching Qualification Description.

.

Figure 3 Tennis Australia coach expertise continuum

The multiple-standard participant sampling method was used for the recruitment and selection of participants. This method has been successfully applied in previous research on coaching (Bian, 2003; A. Smith et al., 2012; Solomon & Lee, 1991; Woorons, 2001).

The criteria for participation in each study were:

- Professional certification: all coaches must have Tennis Australia Coach Certification;
- The minimum number of years of coaching experience was one for novices and ten for experts;
- All participants must be currently coaching.

3.2. Mixed methodology

This investigation employed a mixed methods approach to data collection and analysis (Johnson, Onwuegbuzie, & Turner, 2007). Mixed methods research design has been recognised as the third major research approach along with qualitative and quantitative methods. It allows deeper understanding of the phenomena being examined. This method considers different perspectives and synthesises ideas from quantitative and qualitative research (Johnson et al., 2007). The combination of two methods allows data to be examined from two different perspectives and answers different types of questions. The quantitative method provides breadth and the qualitative provides depth (I. Jones, Holloway, & Brown, 2013). Mixed methodology has been recognised as an appropriate approach to research in the coaching domain (Vergeer & Lyle, 2013). The application of this method provides three advantages: 1) the mixed methods approach enables corroboration of findings through triangulation which is a validation technique used by researchers to look for any variances in the data he chain was terminated if a coach started to discuss; 2) Qualitative data

plays an important role in clarification and validating the quantitative results (Johnson et al., 2007); and 3) by employing both modes of enquiry, the researcher attempts to counterbalance the weaknesses of both types of research methods, and to gain a deeper understanding of the data (Johnson et al., 2007; I. Jones et al., 2013).

The application of mixed methodology complemented the analysis based on the qualitative approach, and allowed the researcher to explore the difference between novice and expert tennis coaches at a deeper level.

The exploratory sequential design has been applied in this thesis when qualitative data analysis has been performed first followed by the quantitative analysis of the data developed during qualitative analysis (Harrison, Reilly, & Creswell, 2020).

3.3. Data collection using in-depth semi-structured interviews

An in-depth interview is a qualitative data collection technique (Guion, Diehl, & McDonald, 2011). The semi-structured interview method provides the researcher with the opportunity to ask questions that are relevant to the aims of the investigation and use a conversational style to explore participants' understanding of the phenomena being examined in detail. This method of data collection also allows the researcher to ask open-ended questions to reveal information that cannot be captured in a quantitative survey (Guion et al., 2011; R. Jones, Bezodis, et al., 2009).

The in-depth interviews method provides the three advantages: 1) It allows the research to explore what is not seen; 2) An extensive amount of detailed data can be collected; and 3) An interview allows for data saturation (S. M. Kolb, 2012).

Data saturation is reached when the researcher is not finding any new information. It allows the researcher to obtain a better understanding of the data and reflect of the participant's perspective (S. M. Kolb, 2012).

The interview guides were designed for studies one and two to ensure comparability and consistency between interviews (A. Smith et al., 2015) and can be found in Appendix B (Interview Guides). Each interview began with general information about the project, the explanation of the procedure and the participants signing the consent form (Appendix C Consent Form for Participants Involved in Research - Interview) in accordance with Victoria University research ethics guidelines. The second part included the mixture of structured questions and clarification questions.

Pilot interviews for all three studies were conducted to determine the appropriateness of the interview questions, timing of the interview and to insure the general robustness of the data collection process. Interviews were transcribed verbatim and each transcription was analysed using NVIVO qualitative software (NVIVO, 2018) by applying the Grounded Theory Approach (S. M. Kolb, 2012).

3.4. The Grounded Theory Approach to data analysis

A qualitative research methodology based on the Grounded Theory Approach has been utilised in this investigation. The Grounded Theory Approach is one of the qualitative designs that is used in social science (B. G. Glaser & Strauss, 1967). This method focuses on the interpretation of the individual's experiences and understanding of events (Creswell, 2007; Golafshani, 2003; S. M. Kolb, 2012). In this approach a researcher develops the theory from the data, rather than applying theory to the data (S. M. Kolb, 2012). The Grounded Theory Approach has been successfully applied in previous studies of similar purpose in the coaching of running, golf and gymnastics (J. Cote et al., 1995; R. Jones, Bezodis, et al., 2009; A. Smith et al., 2012).

When applying the Grounded Theory Approach the first step is "theoretical sampling" which aims to check out the emerging theory, and develop concepts and categories (Hassmen, Keegan, & Piggott, 2016). The process of data collection is controlled by the emerging theory where the researcher identifies "what groups or sub-groups to turn to next in data collection" (B. G. Glaser & Strauss, 1967, p. 45).

The Grounded Theory Approach involves simultaneous coding and analysing the data. Coding is an integral part of the data analysis. It involves the classification and sorting of information and examining relationships in the data (S. M. Kolb, 2012). During these processes, data reduction naturally occurs as information about a research topic may be repeated by one or more participants. Saturation occurs when several participants provide the same or similar responses to a question. This process allows researcher to create categories, identify properties and dimensions of the data (S. M. Kolb, 2012).

The coding process consists of open coding which is developing categories, axial coding which is interconnecting the categories, and selective coding which is building a story that connects the categories producing a set of theoretical propositions (Corbin

& Strauss, 2008). The schematic algorithm of the data analysis process for this investigation is presented in Figure 2.

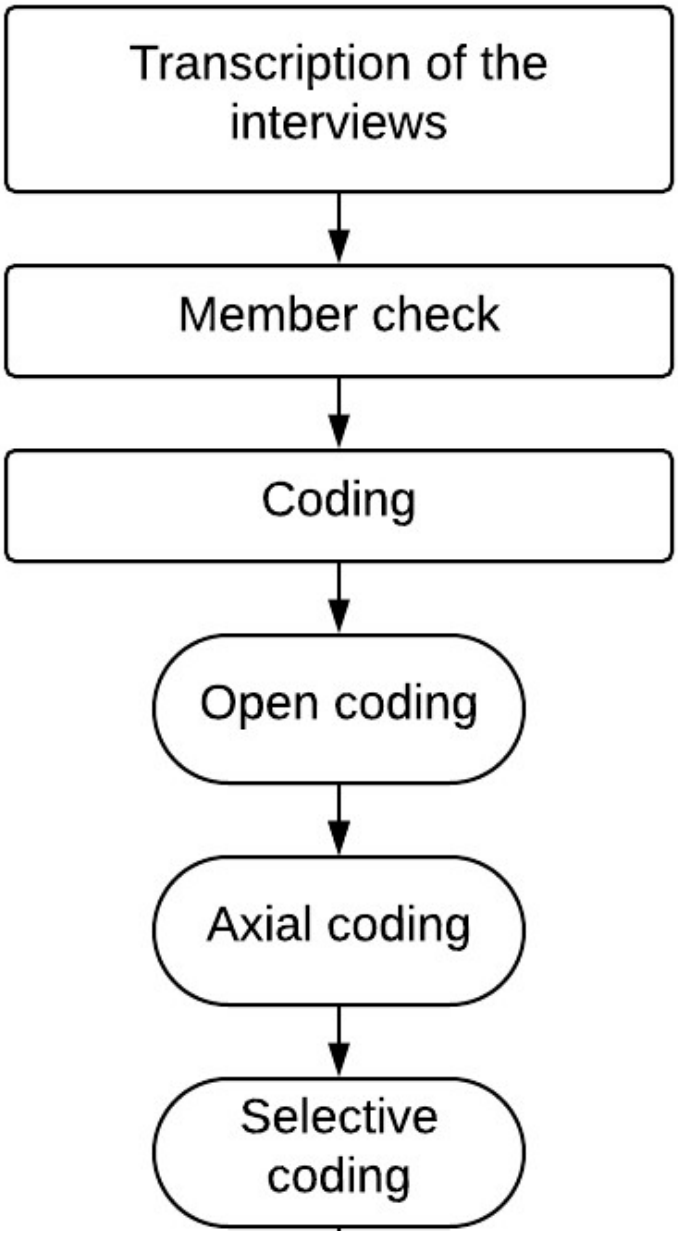


Figure 4 Data analysis algorithm for study one, study two (phase one) and study three

The initial transcription of the data was followed by member checking. Performing a member checking ensured that what participants said during the interview matches the transcribed report. It is achieved when a researcher returns to the participants to

get clarification on the data collected. In addition, comments or additional thoughts can also be added by participants (Braun & Clarke, 2006). After that, the process of coding was performed that included open coding, axial coding, and selective coding.

During open coding where 'meaning units' were identified (S. M. Kolb, 2012) which represented the portion of data or a single idea related to the tennis serve technique such as "shoulder-over-shoulder rotation", "eye contact", and "follow-through phase". All interviews were systematically analysed line-by-line.

Sub-categories were created by identifying the common features between meaning units during axial coding. This process required from the researcher to apply inductive and deductive thinking to identify the common features between meaning units (B. G. Glaser & Strauss, 1967). Axial coding was completed by comparing meaning units, identifying common features that meaning units shared and organising them into groups (J. Cote & Salmela, 1995). For example, meaning units such as "head", "shoulder" or "knee" formed the "body element" sub-category. Relationships and connections between categories were also established. For instance, "body elements", "technical elements", "phases" and "key flexion points" sub-categories formed the "biomechanical factors" category. The researcher continued to ask questions and make comparisons to relate the sub-categories to a category which enhanced the reliability of the decision-making process (S. M. Kolb, 2012).

Selective coding is the process of identification of a core category followed by systematic connection of the chosen category to other categories (B. G. Glaser & Strauss, 1967). It involves the validating of similarities and relationships between categories and finally refinement or cleaning of the data (S. M. Kolb, 2012).

During all stages of data analysis a constant comparison method and theoretical sampling were applied which are two significant strategies in the Grounded Theory Approach (B. G. Glaser & Strauss, 1967). The constant comparison method is a technique that allows the researcher to develop concepts during the simultaneous coding and analysing processes (S. M. Kolb, 2012). The constant comparison method consists of four stages: 1) "Comparing incidents applicable to each category"; 2) "Integrating categories and their properties" 3) "Delimiting the theory" and 4) "Writing the theory" (B. G. Glaser & Strauss, 1967, p. 105). When applying this method, the researcher repeatedly examined the properties and dimensions of the sub-categories

and categories in order to reach data saturation. Data saturation was achieved when no new sub-categories were identified and no new concepts were developed (J. Cote et al., 1995). This method requires simultaneous processes of data collection and analysis. When data collection has taken place, the data was compared which led to the concepts and categories were developed. With the progress of the study, new data was compared to existing “grounded” concepts and categories (Hassmen et al., 2016). The purpose of this process is to generate concepts which are mutually exclusive, and define clearly properties of developed categories and sub-categories (Hassmen et al., 2016). When more theoretical sampling has occurred, the researcher compared concepts in a more abstract analysis to develop core categories which were a fundamental for the theory (Corbin & Strauss, 2008; Hassmen et al., 2016). Finally, a statistical analysis was performed and will be presented in Section 3.5.

3.4.1. Creating reasoning chains for the analysis

The reasoning chains were examined to facilitate deeper analysis of coaches’ knowledge. A reasoning chain terminology has been introduced in the literature review in Section 2.2. In this investigation, a reasoning chain was defined as a relationship that connects one or more findings related to the tennis serve technique. Findings referred to the information related to the tennis serve technique such as “ball toss”, “kinetic chain”, “shoulder rotation”. The potential causal relationships between these findings were examined and each of these statements was referred to as “reasoning chain”. A coach may first identify the specific movement or element of the serve and then explain the reason why it should be executed this way and how it can affect the other components of the serve. For example: “…the ball toss should be in front of you at 12 o’clock. In that way you can get power from the back hip which affects your drive up to the ball”. There are three findings related to each other: 1) “ball toss at 12 o’clock” which affects 2) “power from the back hip” which in turn affects 3) “drive up”. Three findings related to each other was considered a relationship and was scored as one reasoning chain. The chain was terminated if a coach started to discuss a different aspect of the serve (Leas & Chi, 1993). In this thesis, the number of reasoning chains reflects the coherence and connectedness of coaches’ knowledge of the tennis serve technique.

3.5. Quantitate analysis

The quantitative analysis used in this investigation included the quantification of the qualitative data followed by statistical analysis using one-way MANOVA, one sample t-test and Poisson Regression in Generalised Mixed Linear Model analysis to examine the difference between two groups on certain parameters of the internal model.

Quantification of the qualitative data method was successfully applied in coaches' decision-making research in gymnastics and was acknowledged to be the appropriate approach to research design in the coaching domain (Vergeer & Lyle, 2013). The quantification focused on the of the number of parameters identified during the qualitative analysis such as "technical elements" and "body elements". This produced a matrix that was entered into SPSS to conduct a one-way Multivariate Analysis of Variance (MANOVA) test.

A MANOVA compares two or more groups on a range of characteristics (Pallant, 2016). In this study, it aimed to test if expert and novice coaches were significantly different on identified components of the internal model.

Poisson regression in a generalized mixed linear model was required as there was a small sample size (n=9) and there were dependant variables such as strengths, weaknesses, concepts. The linear model is used to derive an effect statistic by linking a dependent variable to covariates (W.G. Hopkins, S.W. Marshall, A.M. Batterham, & J. Hanin, 2009). Employing the Poisson regression analysis method in a generalised mixed linear model allows the researcher to predict a response variable which is affected by multiple covariates (Consul & Famoye, 1990).

One potential way to minimise the risk of Type I error is to increase the sample size. The design of the methodology of the current investigation was based on previous studies with a similar purpose, and where a small sample size was used to investigate coaches' knowledge (R. Jones, Bezodis, et al., 2009; Leas & Chi, 1993; Sherman et al., 2001; Thompson et al., 2009). A Type II error may be minimised by increasing significance level which would reduce the chance of type II errors but increase the probability of a Type I error. Therefore, the significance level of 0.05 was considered as appropriate for this investigation.

3.6. Think-aloud protocol

Think-aloud protocol is one of the techniques used to compare the performance of expert to non-expert individuals (Jaaskelainen, 2010). It is a research method where "subjects are asked to perform a task and to verbalise whatever crosses their mind during the task performance" (Jaaskelainen, 2010, p. 371). The think- aloud protocol was established as a reliable method in the research to examine the high-level thinking process and individual differences (Charters, 2003) and has also been previously used in several studies on cognitive-perception in sport (De Groot, 1978; K.A. Ericsson & Simon, 1993; Leas & Chi, 1993; H. L. Swanson, O'Connor, & Cooney, 1990; Ward & Smeeton, 2003).

When applying this method, the participants are instructed to give expression of their thoughts rather than solution to the presented problem (A. M. Williams et al., 2017). Investigators allowed participants to express freely their thoughts, ideas and opinions. It provides participants the opportunity to express their own insights. As a result, it increases the quality of knowledge generated (Golafshani, 2003). In this investigation coaches in study one and two were instructed to express their thoughts during the task rather than to express their solution which is the key factor when applying this method (K.A. Ericsson & Simon, 1993).

3.7. Problem Based Learning Approach

Problem-based learning (PBL) is an approach where realistic scenarios of problems and questioning are used that can be transferred into real situation. This approach has been widely recognised as a valuable learning approach in medicine, education and sport (Barrow & Tamblyn, 1980; Bound & Feletti, 1991; Engel, 1999; Hubball & Robertson, 2004; Kirk, 2000; Morante, 2008; Oates, 1992; Wilkerson & Gijselaers, 1996).

Recent evidence suggests the following benefits of PBL: 1) developing decision-making and problem-solving skills; 2) ability to extend learning beyond the given scenario; and 3) enhance the integration between practise and theory (R. L. Jones & Turner, 2006). Compared to traditional didactic coach education practises, PBL allows students to engage with new situations and to build the repertoire of scenarios and strategies for problem solving in unique and uncertain situations.

Problem-based learning has been used in study three of this investigation to develop coaches' critical thinking and reasoned decision-making. In this study coaches performed the task based on their day-to-day coaching activity – analysing the technique of the players. In addition, the Problem Based Learning Approach has a potential to assist coaches with the opportunity to connect their knowledge with real practice (R. L. Jones & Turner, 2006).

3.8. Quality standard of the research

This section acknowledges the quality standard and explains the measures that have been undertaken to enhance validity and reliability of the research. Firstly, methodological triangulation (Johnson et al., 2007) and member checking (Braun & Clarke, 2006) have been applied to ensure the credibility of the research (Korstjens & Moser, 2018). Methodological triangulation takes place when different methods are used to study the research problem. In the present study methodological triangulation was applied to enhance the validity and trustworthiness of the data analysis by combining qualitative and quantitative data analysis methods (S. M. Kolb, 2012). This technique allowed the researcher to obtain rich data, stimulated creativity in the data analysis process, integrate theories and enhance the trustworthiness of the research (Johnson et al., 2007).

The member checking method was applied to achieve the credibility and reliability of data collection and analysis. In the current investigation the researcher sent the transcripts back to the participants and asked them to review and verify the interpretative accuracy. If the script returned with a correction from the participant, it was edited and sent again to the participant until the final confirmation was received. Although it has been stated that member checking cannot be used to enhance the rigor of qualitative research within sport and exercise psychology (B. Smith & McGannon, 2018). This method was used in the present research to ensure that what participants said during the interview matched their transcribed report as many tennis-specific terminologies have been mentioned by the participants (Braun & Clarke, 2006).

The transferability of the research has been enhanced by providing a detailed description of participants, data collection and analysis such as providing an interview guide and describing the step-by-step data collection process (Korstjens & Moser,

2018). Reflexivity has been applied to minimise the effect of the researcher's biases and to ensure objectivity (S. M. Kolb, 2012). The researcher could not remove or distance herself from the study completely. Therefore, reflexivity was carefully considered in the present study by the researcher to assure internal validity. The researcher was aware of her position and tried to minimise the influence of her assumptions and beliefs on the research (I. Jones et al., 2013). This was achieved by writing a diary of the research process and continuous reflection and examining the entire process of the research (S. M. Kolb, 2012; Korstjens & Moser, 2018; Nadin & Cassell, 2006). An example of the entry in the researcher's diary:

> "2/12/2017 Task: Create sub-categories for the internal model. Printed out the list of meaning units and looked at the list to find similarities between meaning units. When looking at the list, being mindful about my previous coaching knowledge and experience and I tried to look at the data with fresh eye. The "technical element" sub-category was easy to identify as well as the "body elements". When I assigned these meaning units to the sub-category, I removed meaning units that already have been labelled and formed the new list to identify more sub-categories. Then the "phases", "reasoning chains" sub-category emerged. Once again, I removed labelled meaning units from the list and looked at the data again. I've noticed that there were meaning units containing measurement and quantification and grouped these meaning units together – need to think how to name this group – discuss with my supervisor. There were also meaning units that contained the words "important", "critical". I've grouped them together as well – don't know what they are and if this sub-category can relate to any other identified sub-categories – will think about it later. There are meaning units relating to physics – need to look at the literature to find out more. To do: look at tennis scientific literature/biomechanics, print out separate lists of sub-categories, name unassigned sub-categories, look if sub-categories are related to each other in some way or another".

External reliability was enhanced by considering the following aspects: methods of data collection and analysis were explicitly explained; the choice of participants was fully described; the main terms and units of analysis were provided (Zohrabi, 2013).

To ensure the rigor of the present study the following criteria were satisfied. Firstly, a rationale for using the mixed method was presented. Secondly, the specific data

collection procedures were reported for both qualitative and quantitative approaches such as sampling procedure. Thirdly, a mixed method design type (exploratory sequential design) was included. Finally, the integration of both approaches was discussed and explained how quantitative analysis supported the findings of the qualitative analysis (Harrison et al., 2020).

3.8.1. Limitations

The small sample size can be a potential limitation of the current research. However, this study is more qualitative in nature, as the quantitative method was applied to reach a deeper understanding of the qualitative data. The small sample size was appropriate for qualitative research as the primary goal was to gain insight into the coaches' knowledge rather than to estimate a population value (Bian, 2003; Leas & Chi, 1993). In addition, this sample size was previously used in previous studies that successfully identified the expert-novice difference (Bian, 2003; Giblin, 2014; Mitchell et al., 2020). The results, however, cannot be generalised beyond the flat tennis serve technique. Also, generalisations should not be made about the entire tennis coach population due to the small sample size.

The nature of think-aloud protocol should also be taken into consideration as this method was new for participants. This may potentially affect coaches' ability to articulate their thoughts and influence their verbal skills by limiting the amount of data collected during the interview.

3.8.2. Establishing validity and reliability

Examining negative cases is one of the strategies implemented to reduce the effect of researcher's biases and to assure the internal validity of the research. Negative cases include cases where data is initially considered not significant and does not fit into the emerging theory, but can lead to new insights and conclusions later (S. M. Kolb, 2012). In the present work negative cases were investigated by the researcher to obtain a better understanding of the data. Negative cases assist the researcher in gaining a better understanding of the data, and it is important for the accurate reflection of the perspective of participants (S. M. Kolb, 2012).

When observing the tennis serve technique, tennis coaches may change their location to look at the service action from different angles. Therefore, to establish ecological validity of the diagnostic task the players were recorded from four different

perspectives to provide the coaches with the optimal observational view to identify all potential key actions (Morrison & Knudson, 2002).

Video-based method has been previously recognised to have high construct validity when comparing different skill levels on decision-making skills (Kittel et al., 2019). The present research applied the video-based method to examine the difference between experts and novices on their diagnostic ability when viewing the tennis serve.

Chapter 4 Study 1: The internal model of the flat tennis serve technique

4.1. Introduction

Knowledge is an integral component of coaching expertise and it plays a significant role in coaches' decision making process (S. M. Kolb, 2012; J. Lyle & Cushion, 2017). For example, during the technique analysis the internal model of a technically correct motion is compared with the observed movement, and feedback to an athlete is formulated (Leas & Chi, 1993; Lees, 2002; Sherman et al., 2001; Thompson et al., 2009). Therefore, it is crucial to understand the internal model of coaches as the feedback is highly influenced by the characteristics of their internal model (V.E.D. Pinheiro & Simon, 1992). One of the approaches to understand coaches' knowledge is the Expert Performance Approach.

The Expert Performance Approach has been recognised as a guiding framework for research into sport coaching and learning (K. A. Ericsson & Smith, 1991). It has been widely applied in sport to differentiate experts from novices (Abernethy, 1991, 2007; Farrow & Abernethy, 2003; Ford et al., 2009; E. Furley & Dorr, 2016; Goulet et al., 1989; Isaacs & Finch, 1983; R. C. Jackson & Mogan, 2007; Mori et al., 2002; Rowe et al., 2009; G. J. P. Savelsbergh et al., 2002; Shim et al., 2005; Singer et al., 1996; N. J. Smeeton & Huys, 2011; Tenenbaum et al., 1996; Ward et al., 2002). However, no research has applied the Expert Performance Approach to tennis coaches' knowledge.

A limited number of studies have attempted to investigate the internal model of coaches (J. Cote et al., 1995; J. Cote & Salmela, 1995; R. Jones, Bezodis, et al., 2009; Leas & Chi, 1993; A. Smith et al., 2012; A. Smith et al., 2015; Thompson et al., 2009). This has been done by examining technical parameters that coaches have associated with specific technique such as freestyle swimming stroke. To date no attempts have been made to examine coaches' internal model in tennis. This study aimed to investigate the internal models of expert and novice tennis coaches and identify the key distinguishing characteristics between the expert and novice coaches.

4.2. Methods

In this investigation, a one-on-one semi-structured interview was conducted with each participant to explore the coaches' internal models on the flat tennis serve technique. This section will explain data collection and data analysis methods that have been used in the present study.

4.2.1. Participants

The multiple-standard participant sampling method was used for the coaches' selection. The detailed description for participants selection criteria was presented in Section 3.1. In this study eight male tennis coaches representing two different levels of expertise (novices n=4 & experts n=4) were chosen to participate in a one-on-one semi-structured interview. The participants were aged between 18 and 49 years. Expert coaches were involved in coaching activities for an average of 25.5 ± 4.5 years, and have played tennis for an average of 13.5 ± 1.3 years. Novice coaches were involved in coaching activities for an average of 1.5 ± 0.6 years, and have played tennis for an average of 9.3 ± 3.3 years.

The sample size for this study was considered to be appropriate as the main goal was to gain insight into the coaches' knowledge rather than to estimate a population value (Bian, 2003). The number of participants was guided by previous studies where knowledge of sport coaches was successfully examined by applying the Grounded Theory Approach (R. Jones, Bezodis, et al., 2009; Leas & Chi, 1993; Thompson et al., 2009).

4.2.2. Procedure

In this investigation a one-on-one semi-structured interview was conducted with each participant to explore the coaches' internal models on the flat tennis serve technique. Data collection using in-depth semi-structured interviews method was described in detail in Section 3.3.

Initially, an invitation email with the information about this research (Appendix D Information to Participants) along with consent forms (Appendix C Consent Form for Participants Involved in Research - Interview) was send to participants via the Tennis Australia coaching database. Once a coach contacted the researcher the interview time and a venue were finalised. The location and the time of the interview was then chosen according to participants' availability.

The think-aloud protocol was implemented during the interviews (De Groot, 1978). The participants were instructed to express their thoughts verbally during the interview which is the key factor when applying this method (K.A. Ericsson & Simon, 1993). The interview guide was developed and is presented in Appendix B (Interview Guides, Study One). Each interview began with general information about the project, the

explanation of the procedure, signing a consent form (Appendix C Consent Form for Participants Involved in Research - Interview) and completing a short questionnaire (Appendix E Pre-Interview Questionnaire). The participant was then asked to describe their vision of the ideal flat tennis serve technique for a high-performance adult player. Further open-ended questions to clarify terminology used by the participant were asked until data saturation was achieved. For example: “You mentioned that the trophy position should be good. Can you explain the specific characteristics of a good trophy position?” Or “You said that the player should have an open racket face. Can you explain what you meant by an open racket face?”. Each participant was given enough time to describe the serve for as long as they needed. The interviews typically lasted between 30 to 45 minutes. All eight interviews were transcribed verbatim. Minor editing was performed on the data such as deidentifying the participants such as “Bill” to “Coach 1” to ensure anonymity.

Data saturation is reached when the researcher is not receiving any new information. It allows the researcher to obtain a better understanding of the data. It is also important for the accurate reflection of the perspective of participants (B. G. Glaser & Strauss, 1967). In this study data saturation was reached when the participant did not add any new information about the tennis serve technique and when the researcher reached a full understanding of specific terminologies used by a coach.

4.2.3. Data analysis

This study employed a mixed methodology (Johnson et al., 2007) as described in Section 3.2. The qualitative data analysis was based on the Grounded Theory Approach (B. G. Glaser & Strauss, 1967) which is described in detail in Section 3.4. The quantitative analysis focused on quantification of the sub-categories and categories identified during the qualitative analysis. Multivariate analysis of variance (one-way MANOVA) and one sample t-test were performed to investigate the differences between experts and novices in their internal model components.

The schematic algorithm of the data analysis process and its description are presented in Figure 4 in Section 3.4. After all the interviews were transcribed verbatim, member checking was used to ensure the credibility and reliability of the data collection: all interviews transcripts were sent to each participant to review and verify the interpretive accuracy (Braun & Clarke, 2006). If the script returned with a correction form the

participant, it was edited and sent again to the participant until final confirmation was received.

The transcribed interviews were analysed using NVIVO 11 Pro qualitative software (NVIVO, 2018) to classify and sort information and to examine relationships in the data. It was performed through coding of key words and phrases related to the tennis serve technique and then categories into key themes and sub-themes.

As soon as all interviews were transcribed verbatim, the investigator read the transcripts numerous times to familiarise herself with each interview which helped to facilitate further process of the content analysis (J. Cote & Salmela, 1995). Subsequently, open coding was conducted where “meaning units” were identified. All eight interviews were systematically analysed line-by-line. Sub-categories were created by identifying the common features between meaning units. Relationships and connections between sub-categories were then established. The researcher continued to ask questions and make comparisons between sub-categories in order to relate them to a category (S. M. Kolb, 2012). Finally, sub-categories were connected to the core categories. The researcher looked again at the properties and dimensions of the sub-categories and categories in order to reach data saturation (J. Cote et al., 1995).

The next step was to identify reasoning chains that represented the coherence and connectedness of coaches’ knowledge. This was completed by identifying the sentences where two or more findings were connected. For example: “The more twist they can get across the torso the more elastic energy they’re going to get on the way out to really allow them to unwind to get up to the ball well”. In this sentence the following findings were connected: “twist across the torso”, “elastic energy” and “up to the ball”. These three connected findings were scored as one reasoning chain. The number of reasoning chains and its’ lengths reflect the coherence and connectedness of coaches’ knowledge of the tennis serve technique.

To enhance the reliability of the decision-making process for creating meaning units and developing sub-categories and higher categories, the researcher constantly asked specific questions during the entire process such as: “What are the similarities in the content of each sub-category?”; “Are there any contradictions in the content of

the category?"; and "Are all meaning units regrouped into an appropriate sub-category?" (J. Cote et al., 1995).

The quantitative analysis included quantification of the qualitative data followed by statistical analysis (one-way MANOVA and one sample t-test) to examine the difference between two groups on technical/body elements, concepts, reasoning chains, important elements and key flexion point parameters. Quantification of the qualitative data method was successfully applied in the coaches' decision-making research in gymnastics, and was acknowledged to be the appropriate approach to research design in the coaching domain (Vergeer & Lyle, 2013). The quantification focused on the number of: technical elements, body elements, phases, concepts, reasoning chains, important elements identified by every coach during the interview. This produced a matrix that was entered into SPSS to conduct a one-way Multivariate Analysis of Variance (MANOVA) test. A MANOVA compares two or more groups on a range of characteristics (Pallant, 2016). This study investigated differences between expert and novice coaches on various components of the internal model of the tennis serve technique.

One potential way to minimise the risk of Type I error is to increase the sample size. The design of the methodology of the current investigation was based on the previous studies with similar purpose in which the small sample size was applied to investigate the coaches' knowledge (R. Jones, Bezodis, et al., 2009; Leas & Chi, 1993; Sherman et al., 2001; Thompson et al., 2009). Type II error may be minimised by increasing significance level which would reduce the chance of Type II error, but increase the probability of Type I error. Therefore, the significance level of 0.05 was considered as appropriate for this research.

4.3. Results

The purpose of this study was to investigate the internal models of expert and novice tennis coaches, and to identify the key distinguishing characteristics between them. Expert and novice internal models were successfully developed during the qualitative analysis. The expert internal model represents the knowledge of four expert tennis coaches. The novice internal model represents the knowledge of four novice tennis coaches. The key distinguishing characteristics between levels were identified during qualitative and quantitative analysis. The results are presented in two sections: qualitative analysis followed by quantitative analysis.

4.3.1. Qualitative analysis

The initial analysis demonstrated that experts were more expressive and confident when describing the technique. The extraction from the interview with one of the expert coaches is presented below to better illustrate the data.

> "Some of the things that I look at as a tennis coach in terms of my framework is, I look globally to start with. So, what are the key underlying principles behind an effective serve? So things like, I have a few non-negotiables. Does it have rhythm? Does the serve look balanced? Do they have a good throwing motion, a good throwing action? And biomechanically is there, does the action look efficient? So, almost kind of like an effortless production of power. So, I look to see whether the biomechanics of the serve are within acceptable ranges. So for my own philosophy is that I want the serve to be, and the action to be relatively simple. So, not too complex as to how it's, how the, how it's manufactured if that makes sense. So smooth, simple, but obviously operating within ranges of acceptability. So, for example do they have a well-balanced ready position? Do they create momentum with their body that will help to drive them up to the ball? Is it smooth, so that it doesn't have any kinks in it, which may break down under pressure? So, so is it, are the angles and the, the angles that I look at in the trophy position? Do they fit within a range of acceptability for example, when the ball is at the highest point of the ball toss? Are they in their ideal ready position with the racquet up at the high point of the toss? So I suppose ideal ready position is a based on my coaching experiences. My knowledge about what a professional, what a good professional server looks like, and then based on my experience and my own qualifications and, for example one checkpoint for me is that an ideal, at the top of the toss, in their trophy position I look at how much knee flexion there is, which gives an indication of leg drive. I look at, to make sure that from a throwing mechanics point of view that there's a good 90 degrees under the arm, 90 degrees between hand and elbow, I look at how much separation angle they have, so have they turned their upper body slightly further than their hips in the ready, in the trophy position? But also do they have a slight shoulder tilt as well which will help with the shoulder over shoulder motion for the serve. Yeah balance is, so balance is one of my non-negotiables. So again, balance for me operates in three

places. One is prior to starting the serve is a stance. Well I not prescriptive around stance in terms of, because you can have a platform stance, or a step up. I think they both have advantages, so I don't, I'm not prescriptive as to what that is that's more about their, the player and what they feel more natural doing. As long as the stance is, as I said it provides a stable base of support, and then allows the player to hit a variety of different serves all from that same stance. So that's prior to starting the service motion. And then obviously during the service motion is that balance for me relates to the impact point above their head. So again the impact point operates on three planes, front to back, side to side, up and down. So are they, have they placed the ball in an area where they can make contact in an ideal position to maintain their balance through impact? And then the final part would be after impact when the, after they've delivered the serve and they're landing, are they landing in an arabesque position? Yeah so depending on the serve but ideally for the flat serve contact point is in a 12 o'clock position. Okay so, and I measure 12 o'clock being the ball toss if I measure a line from the front foot, so at impact it should be about 12 o'clock on the face of the clock. And then obviously a little bit dependant on their intent after the serve, depending on maybe how far forward that is. For example if they would, following the ball in for a serve and volley, then that ball toss is at 12 but it might be slightly further in front, versus someone who was just trying to hit it flat and stay back. Yeah, so I think, and again I'm probably referring to some biomechanical information but I think it's, the ideal angle for knee flexion is 110 degrees plus or minus 10 degrees. But it's not so much about necessarily the depth, I think it's more about how they get out of the knee bend position. So the knee bend is really to help the extension. So sometimes some players have a slightly lower knee bend, but they can still fire out and get enough I suppose ground reaction force to drive through the serve. You know, too much knee bend can hamper the timing of the serve and the impact point. So I suppose the way I would describe it is I want the, again the action to be relatively simple to get to the trophy position. So nice and smooth…What we know as well is that there are different types, if we're speaking specifically about the back swing, there are different types of back swing. The, you know you can take the racquet straight back, you can kind of abbreviate it to the side, or you can take it straight up like Pat Rafter or, but what we know that at any time the

arm comes up in front of the chest, that's a precursor for shoulder injury. So as long as it doesn't get to, into ranges where it could be, cause injury, then as long as it's smooth and simple, as long as we get to that point, by the time the ball reaches the top of the toss and they're in that trophy position with the racquet up, good angle that, then I don't mind exactly what it looks like, as long as it's smooth and efficient. Well again, the toss depends, some people have quicker action and some have slower ones, but I think the general rule is that the ball toss should be approximately, I think is it one and a half times the height of the player. One and a half times again above the player. So yeah. Plus or minus, you know. So a couple of things I look for, obviously from the leg drive perspective is that the, probably a little bit more males than females. But it's still evident that it's the importance of the back leg drive and the back hip which instigates the shoulder over shoulder. So, just couple of things that I look for, is the back hip on the serve starting to go slightly higher than the front hip? It should be, if I'm side on to the net, then as I drive up to impact the back hip should be starting to come higher than the right hip before it starts to come around. So I look at, sometimes the analogy that people, that coaches look at is that actually the shirt on the player, and if the, when they're driving up to impact, if the shirt is lifting up at the back that sometimes is a, I suppose that's an anecdotal way to see if they've got some hip drive. Because if, without the back hip coming up over the front hip, then often you don't see the shoulder over shoulder, which is important for the yeah, for in terms of getting to the impact point and for, yeah. Obviously links into pronation and internal rotation. Obviously linked to the, yeah linked to the grip. The view is obviously continental grip is the one that provides ideal I suppose hand position for internal rotation. So they know and they say that internal rotation provides about 40% of the pace, the power on the serve is the internal rotation. So without a continental grip or a 12 o'clock ball toss, then you'll be more limited with your pronation and your internal rotation, and also without effective led drive then. You won't be able to externally rotate which means you can't internally rotate, if that makes sense" (Expert coach 1).

By contrast, novice coaches were less confident and less expressive when describing the tennis serve. The extraction from the interview with one of the novice coaches is presented below.

> “Yep, so it will be like a continental grip serve, and then you’d have, obviously the right foot, so you’d have about a feet in between both of your feet. And throwing the ball up at one o’clock on the little clock. Not using any spin and just basically hitting it as hard as you can. So making sure you’re moving into the court, and driving up as well, I guess. There’s not too much else there is to it, I don’t think. Well, you’ll land on your left foot. And you’ll drive up with your left as well. So you’re jumping up into the ball and court, moving into the court as well and then getting ready for the next shot, I guess, with a split step. Then besides that, I can’t think of anything else you’d do” (Novice coach 1).

The expert and novice coaches’ internal models of the high-performance flat tennis serve technique are presented in Figure 5 and Figure 6. The model’s design was based on the previous study in golf where key technical parameters including sub-categories and meaning units were presented (A. Smith et al., 2015).

The expert model is presented in Figure 5 and included seven components: “technical elements”, “body elements”, “phases”, “key flexion points”, “concepts”, “important elements” and “reasoning chains”. These components formed two main categories: the “biomechanical factors” and the “functionality”. Examples of meaning units illustrated the type of data from which sub-categories were formed such as “grip”, “knee”, “impact”.

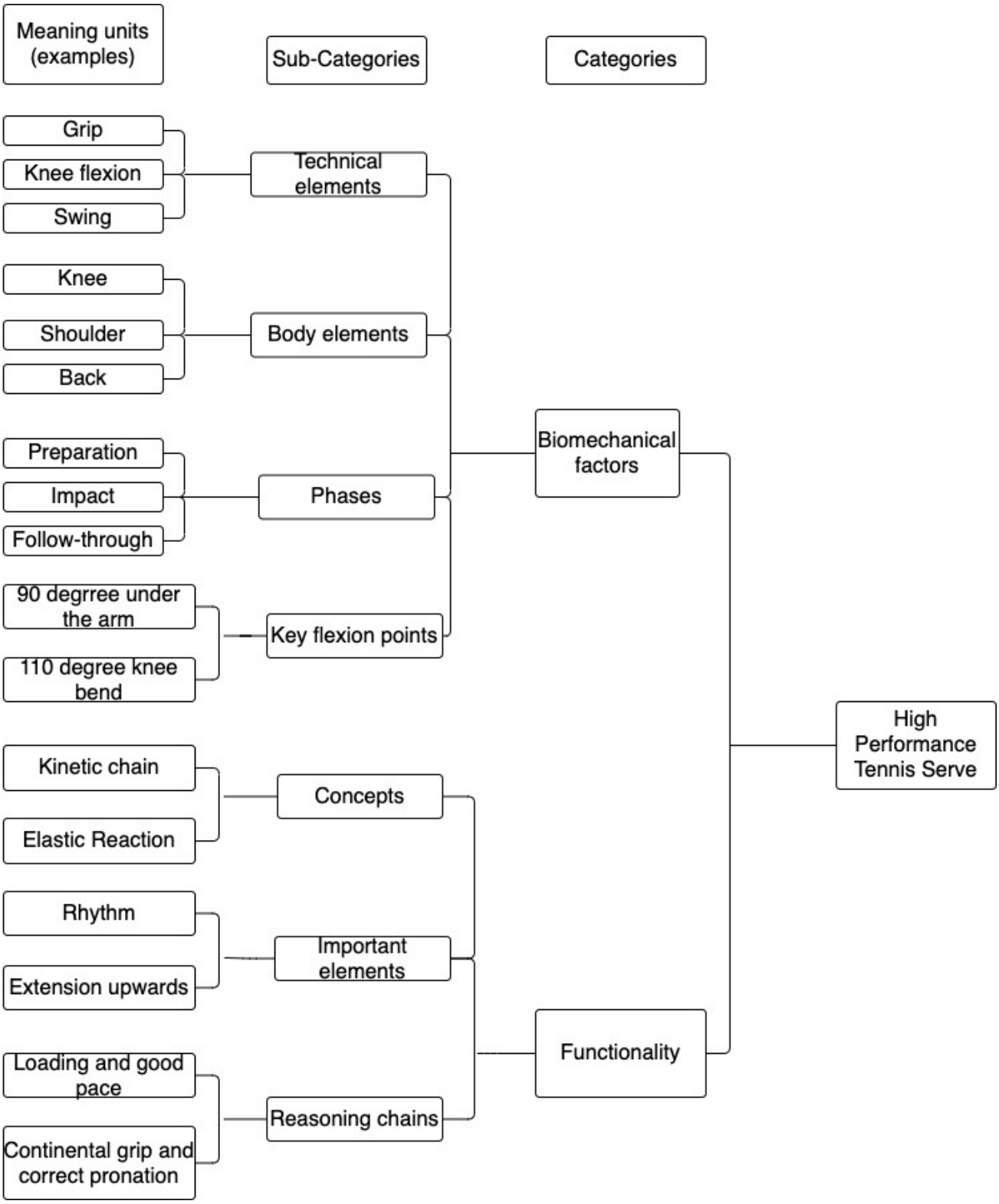


Figure 5 Expert internal model of the flat tennis serve technique

Novice internal model is presented in Figure 6 and included six components: “technical elements”, “body elements”, “phases”, “concepts”, “important elements” and “reasoning chains” (sub-categories). These components formed two main categories: the “biomechanical factors” and the “functionality”. Examples of meaning units were included to illustrate the type of data from which sub-categories were formed such as “kinetic chain”, “rhythm”, “knee bend and elevation”.

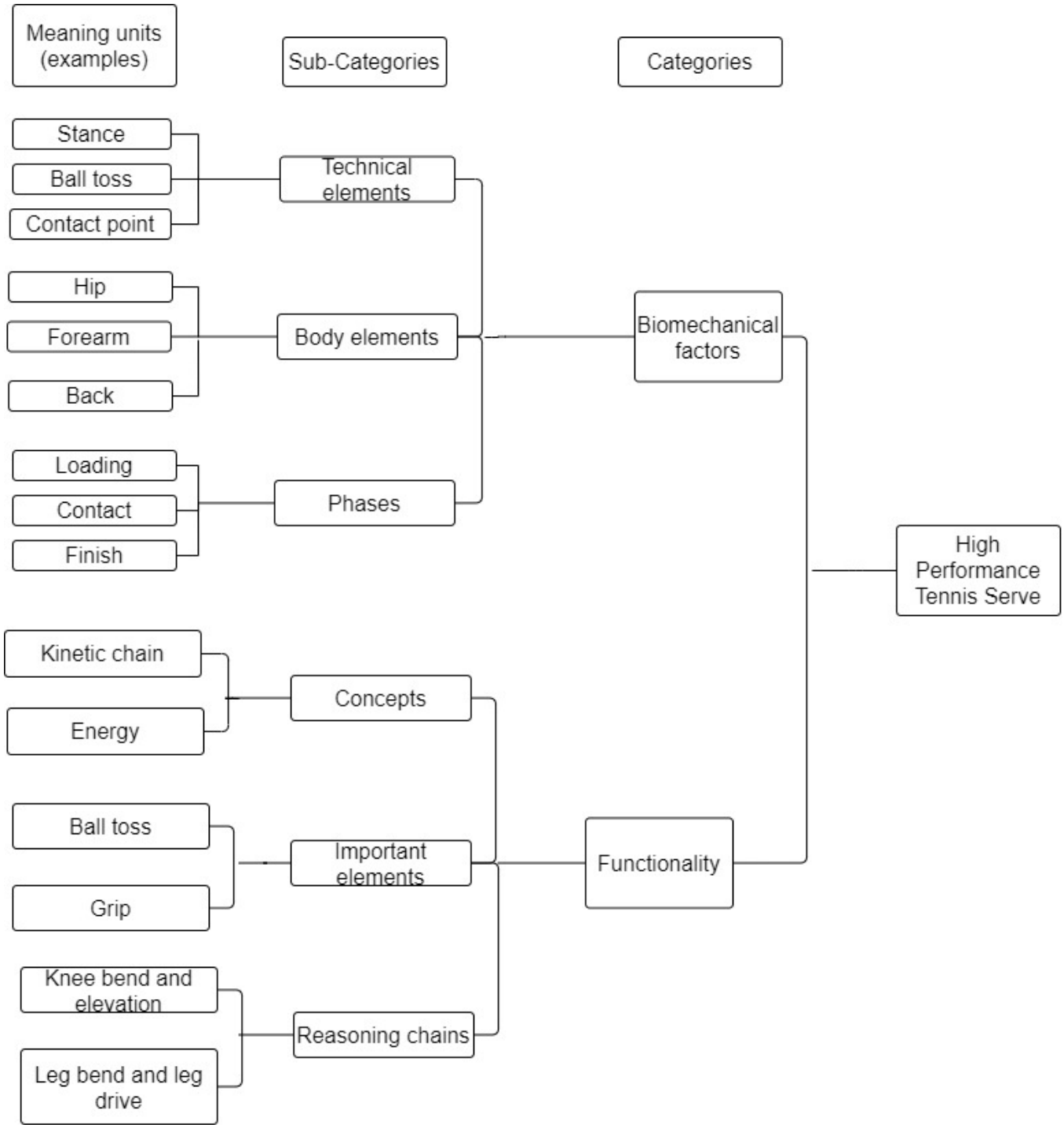


Figure 6 Novice internal model of the flat tennis serve technique

The detailed description of every component of the model (sub-category) is presented in Tables 5-9. The identified elements were compared to existing knowledge about the tennis serve in the scientific literature on the technical elements (Elliott, 2006; Elliott et al., 2003; ITF, 2007; Kovacs & Ellenbecker, 2011; Tennis Australia, 2013). The "☑" in

the tables indicates that the element was mentioned by coaches during the interview and "☐" that element was not identified. The following section will explain "biomechanical factors" category followed by "functionality".

The "biomechanical factors" category related to the coaches' knowledge of tennis serve technique from biomechanics perspective and includes "technical elements", "phases", "body elements" and "key flexion points".

The "technical elements" component represented coaches' knowledge on the technical terminology of the tennis serve technique. Table 5 compares elements the existing in the scientific literature and those identified by coaches in this investigation and showed which technical elements were identified by both groups such as "grip", "stance", "ball toss") and which elements were mentioned only by experts (e.g. "type of swing", "leg drive") or novices (e.g. "weight transfer", "elbow extension"). It also demonstrated that two technical elements were not identified either by expert coaches or by novices: "trunk rotation", "shoulder angle at maximum external rotation". The results revealed noticeable differences and similarities between experts and novices.

Table 5 Technical elements of the flat tennis serve

Technical elements	Novices	Experts
Grip	☑	☑
Stance	☑	☑
Ball toss	☑	☑
Co-ordination of 2 arms	☑	☐
Trophy position	☑	☑
Knee flexion	☑	☑
Hip rotation	☑	☐
Trunk rotation	☐	☐
Swing	☑	☑
Type of swing	☐	☑
Position of the non-racket arm	☑	☑
Loading	☑	☑
leg drive	☐	☑
Shoulder-over-shoulder	☐	☑
Twist	☐	☑
External/internal rotation of the shoulder	☑	☑
Shoulder angle at maximum external rotation	☐	☐
Shoulder and arm alignment	☐	☑
Non-racket arm movement	☑	☑
Upper arm elevation	☑	☑
Elbow extension	☑	☐
Elbow flexion	☐	☑
Weight transfer	☑	☐
Wrist flexion/extension	☑	☑
Shoulder angle between arms and trunk	☐	☑
Pronation (as a general concept)	☐	☑
Forearm pronation	☑	☑
Hip extension	☐	☑
Contact point	☑	☑
Landing in arabesque position	☐	☑
Follow through	☑	☑
Eye focus	☑	☐
Separation angles	☑	☑
Type of serve (step-up/platform)	☑	☑

The “body elements” component included the body parts involved in the tennis serve motion. Table 6 demonstrates body elements that expert and novices identified during the interview task. It also compares the identified body elements with existing body elements in the tennis scientific literature (Elliott, 2006; Elliott et al., 2003; ITF, 2007; Kovacs & Ellenbecker, 2011; Tennis Australia, 2013). Similarities and differences between experts and novices were identified: some of the body elements were mentioned by both groups (e.g. “knee”, “hip”, “shoulder”) and some were identified by experts (e.g. “head”, “toe”, “fingertips”) or novices only (e.g. “eyes”). Interestingly, that experts nor novices identified “torso” and “palm” body elements.

Table 6 Body elements of the flat tennis serve

Body element	Novices	Experts
Knee	☑	☑
Hip	☑	☑
Shoulder	☑	☑
Elbow	☑	☑
Wrist	☑	☑
Leg(s)	☑	☑
Arm(s)	☑	☑
Chest	☑	☑
Feet (foot)	☑	☑
Hand(s)	☑	☑
Back	☑	☐
Eyes	☑	☐
Upper body	☑	☑
Body	☑	☑
Head	☐	☑
Trunk/torso	☐	☐
Toe	☐	☑
Fingertips	☐	☑
Forearm	☑	☑
Palm	☐	☐

The “phases” component refers to the phases of the tennis serve technique such as “start”, “release”, “loading”, “cocking”, “acceleration”, “contact”, “deceleration” and “finish” (Elliott, 2006; Elliott et al., 2003; ITF, 2007; Kovacs & Ellenbecker, 2011;

Tennis Australia, 2013). Table 7 demonstrates the phases identified by novices and experts. Both experts and novices identified all eight phases of the serve.

Table 7 Phases of the flat serve

Phase	Novices	Experts
Start	☑	☑
Release	☑	☑
Loading	☑	☑
Cocking	☑	☑
Acceleration	☑	☑
Contact	☑	☑
Deceleration	☑	☑
Finish	☑	☑

The “key flexion point” referred to quantitative biomechanics that coaches mentioned during the interview: the emphasis on measurements and quantification when analysing movements of the human body (Jennett, 2008). Only experts identified the following quantitative biomechanics parameters that formed the “key flexion points” components of the internal model: “90 degrees between forearm and shoulder in the trophy position”; “knee bend is approximately 100 degrees”; “knee bend is approximately 100 degrees”; “90 degrees between shoulder and body in the trophy position”; “90 degrees under the arm”; “knee flexion is 110 degrees plus or minus 10 degrees”. Overall, the analysis demonstrated noticeable difference and similarities between expert and novice coaches in all components of “biomechanical factors”.

The second category of the internal model was “functionality” and included “concepts”, “important elements” and “reasoning chains” components. This category referred to the coaches’ understanding of tennis serve technique, the ability to recognise the connections and relationships between technical cues, and apply various biomechanical and physics principles to the technique.

The “concepts” sub-category was formed by biomechanical and physics concepts that coaches applied when describing the technique. Table 8 shows the concepts that were identified in the interview and compares expert coaches with novice coaches. Expert

coaches demonstrated greater knowledge in physics and biomechanics compared to novices who mentioned only “kinetic chain” and “energy”.

Table 8 Concepts identified in the interview

Concept	Novices	Experts
Kinetic chain	☑	☑
Balance	☐	☑
Ground up	☐	☑
Ground reaction force	☐	☑
Energy	☑	☑
Elastic reaction	☐	☑
Rhythm	☐	☑
Linear drive	☐	☑
Momentum	☐	☑

The “important elements” component referred to those elements that coaches characterised during the interview as “important”, “critical”, “significant” or verbally emphasised the importance of elements in the technique. Table 9 demonstrates aspects of the technique that were recognised as important by coaches. Expert coaches outperformed novices by identifying wider range of important elements: novice coaches identified only three important elements such as “ball toss”, “good trophy position” and “grip”.

Table 9 Important elements of the flat serve

Important elements	Novices	Experts
Earlier parts are in place	☐	☑
Knee bend	☐	☑
Horizontal and vertical separation angles	☐	☑
Ball toss	☑	☐
Stance	☐	☑
Loading of the back led and back hip	☐	☑
Extension upwards	☐	☑
The back leg drive and the back hip	☐	☑
Shoulder over shoulder rotation	☐	☑
Good trophy position	☑	☑
Feelings of the players what is right	☐	☑
Balance	☐	☑
Kinetic chain	☐	☑
Wrist and elbow pronation	☐	☑
Good throwing mechanics	☐	☑
Rhythm	☐	☑
Timing in the knee band	☐	☑
Grip	☑	☑

The extraction from the interview below highlights reasoning chains that have been identified. The information related to the reasoning chains are shown in upper case.

> "Yeah, so again, first and foremost I think is the GRIP, finding the true continental, WHICH is in the ABILITY TO SLICE to slice and HIT THE FLAT SERVE, and PRONATE correctly; then right from the way they hold the ball toss, having the ball on the fingertips; the good posture; the WIDE BASE in the feet SO that they've got BALANCE. Symmetry with the motion, so the way they rock the body back and the arms go down together; then including the HIPS ROCKING FORWARD with that SO that he gets a lot of LOAD on the front leg, again, keeping the posture as they load and good knee bend…It's more biomechanics rather than what spin. And again, in the FEET CLOSE TO EACH OTHER so that they're LOADING THE FRONT LEG well, AND just the BACK LEG PARTIALLY; good elevation up and out through the ball; GOOD SPACE FROM THE RACKET TO THE BACK OF THE HEAD, SO they're getting plenty

of CHEST STRETCHING and ENERGY up to the ball, getting that full extension up to that one line; landing in the court on the left leg, having a nice big kick behind to counterbalance on the right leg" (Expert Coach 4).

The "reasoning chains" component represented the connectedness of the coaches' knowledge and the ability to understand the connection between technical elements and how one element may affect another. The examples of reasoning chains identified were: "Throwing mechanics AND follow through AND point in the swing where the racquet's moving the fastest", "Twist across the torso AND elastic energy AND get up to the ball", "Continental grip, 12 o'clock ball toss and leg drive AND pronation AND internal rotation AND external rotation". The "AND" in the sentences above means that one part of reasoning chain ends, and another starts. Expert coaches emphasised wider range of reasoning chains compared to novices. Numerical characteristics for this component will be presented in Section 4.3.2. Overall, the qualitative analysis demonstrated noticeable similarities and differences between expert and novice coaches in the "functionality" category.

4.3.2. Quantitative analysis

Quantitative analysis was performed on the components of the internal model to identify statistically significant difference between expert and novice tennis coaches. The quantification of the qualitative data was performed first to transform qualitative data into numerical data. This was done by identifying the numeric information for every coach for every component of the model such as number of concepts and technical elements. This numerical data was then inserted into SPSS software and MANOVA analysis was performed (Pallant, 2016). Five dependent variables were used: technical elements, body elements, reasoning chains, important elements, and concepts. The independent variable was level of coaches. A one sample t-test was used to determine the difference between groups on key flexion point variables.

Initial assumption testing was performed (Box's Test of Equality of Covariance matrices, Pillai's Trace, Levene's Test of Equality of Error Variances). Pillai's Trace test was chosen as the as the most robust test when the sample size is small (Tabachnick & Fidell, 2013). As a result, no violations of assumptions were detected. The inspection of the mean scores revealed that expert coaches outperformed novices on all variables which is shown in Table 10.

Table 10 Summary of statistical analysis for internal model components

	Level of coach	Mean	Std. Deviation	Significance
Technical elements	Expert	10.75	3.862	.59
	Novice	9.25	3.500	
	Total	10.00	3.505	
Reasoning chains	Expert	6.00	2.944	.035
	Novice	1.25	1.893	
	Total	3.62	3.420	
Concepts	Expert	2.25	.500	.004
	Novice	.50	.577	
	Total	1.38	1.061	
Body elements	Expert	13.50	3.109	.85
	Novice	13.00	3.916	
	Total	13.25	3.284	
Important elements	Expert	2.75	1.708	.09
	Novice	.75	.957	
	Total	1.75	1.669	

Table 10 demonstrates that only three variables achieved statistical significance of $p<0.05$: 1) reasoning chains ($p= .035$); 2) concepts ($p= .004$) and 3) key flexion points ($p= .015$).

4.4. Summary of key findings

The aims of this study were to investigate the internal model of expert and novice tennis coaches on the high-performance flat tennis serve technique and to identify the key distinguishing characteristics between levels. As a result, the tennis coaches' internal models were successfully developed and the key distinguishing characteristics between experts and novices identified. The significance of these findings lies in the areas of coaches' knowledge and expertise.

Firstly, this research has made the first attempt to capture the internal model of tennis coaches on the flat tennis serve technique which is the valuable contribution to the existing knowledge. In addition, the current expert internal model consisted of seven components which expands the existing research where less components have been demonstrated.

Previous attempts to investigate the coaches' internal models successfully identified the cue technical characteristics that coaches associated with effective technique (Leas & Chi, 1993; Thompson et al., 2009). By contrast, the current investigation

reported a wider range of attributes of the internal model which coaches associate with the flat tennis serve. Importantly, it introduced the “functionality” component that has not been demonstrated previously. It was concluded that the main attribute of the coaching expertise is not pure technical knowledge but rather the perception of technique as a whole movement and the ability to understand the connection between technical elements. Therefore, the present investigation highlights the importance for novice coaches to develop the knowledge of motor skills from two perspectives: technical and functional. Thus, the emergence of “functionality” component has a potential to open a new avenue of research on coaches’ internal model in tennis and other sports. The application of expert-novice paradigm revealed that novice coaches need to learn to observe a motion as whole and understand how one technical element affects another. More research is needed to investigate and substantiate “functionality” component.

Thirdly, no previous study in tennis have presented and compared the internal model of expert and novice coaches. Previous research in sprinting and golf focused on experts’ knowledge only (R. Jones, Bezodis, et al., 2009; A. Smith et al., 2012; A. Smith et al., 2015; Thompson et al., 2009). Although these studies have successfully identified the key technical parameters that expert coaches associated with technique, no comparison between levels has been made. By contrast, the current investigation applied an expert-novice paradigm which allowed deeper understanding of coaches’ knowledge and expertise. The application of mixed methodology provided the researcher with the opportunity to look at the data from two different perspectives. The results of quantitative analyses aligned with and complemented the results of qualitative analysis and revealed that the key distinguishing characteristics between levels is the experts’ greater ability to understand the functionality of the tennis serve rather than just recognise separate technical biomechanical components. Expert coaches were able to perceive the serve as a whole movement compared to novices who saw the serve as set of separate technical components. Experts understood how the serve works and were able to link the technique to other aspects of the game. Expert coaches were also more expressive, knowledgeable and confident in describing the technique and its aspects. Therefore, it was concluded that the key attribute of tennis coaching expertise is the understanding of technique and the ability to see a “bigger picture”. This finding enriches the knowledge on coaching tennis

expertise and can be applied to improve the novice coaches' development as it shows what needs to be learnt by novices to become experts. Finally, the internal models and its subsequent analytical methods may be applied to other technical elements in tennis, and in other sports.

The current study examined coaches' declarative knowledge of the flat tennis serve technique and identified the key distinguishing characteristics between expert and novice tennis coaches. The next study will focus on coaches' practical knowledge and diagnostic ability of the tennis serve technique and will also examine the difference between expert and novice tennis coaches.

Chapter 5 Study 2: Diagnostic ability

5.1. Introduction

Tennis coaches play many roles. One of them is performance analysis where coaches need to provide an effective intervention based on the correct evaluation of a player's performance. When analysing a player's performance, tennis coaches are required to assess critical variables of a player by identifying weaknesses and strengths of the skill (Chamberlain & Coelho, 1993; ITF, 2016). A coach's feedback to the player is directly affected by what the coach can, or cannot see in the player's technique (Giblin, 2014).

Previous studies in tennis, volleyball, swimming, and gymnastics have attempted to examine coaches' diagnostic abilities by applying the expert-novice paradigm where the performance of experts and novice coaches was compared. In these studies, it has been reported that experts outperformed novices in diagnostic accuracy (Franks, 1993; Imwold & Hoffman, 1983) and demonstrated deeper and more extensive procedural knowledge on the technique (Bian, 2003; Leas & Chi, 1993). Experts also possessed greater ability to identify technical errors (Armstrong & Hoffman, 1979; Giblin, 2014) and focused more on relevant information in comparison with novices (Mitchell et al., 2020). Despite this research, no previous studies have been conducted in tennis to capture and analyse coaches' diagnostic ability of the tennis serve technique. It is especially important to study tennis serve as it is considered the most important stroke in tennis and it can significantly determine the outcome of matches (Antunez et al., 2012).

Therefore, the current study aimed to examine the diagnostic ability and practical knowledge of expert and novice tennis coaches of the flat tennis serve technique and to identify the key distinguishing characteristics between the expert and novice coaches. The findings of this study provides a valuable contribution to the knowledge of expertise in tennis coaching, may improve tennis coach development and assist future researchers to gain a deeper understanding of expertise in coaching and its underlying mechanisms (Antunez et al., 2012; Giblin, 2014; V.E.D. Pinheiro, 1990).

5.2. General methods

This study consisted of two phases: 1) an interview; and 2) an online questionnaire. In both phases, coaches were shown three videos of the different tennis player performing the flat tennis serve. They were asked to assess the players' technique by

providing technical strengths, weaknesses and recommendations for corrections. In the first phase the videos were shown to participants during the interview. In the second phase - via online questionnaire. The construction process of these three test videos is presented in the next section.

5.2.1. Construction of the test video

Video analysis has been used in previous research to investigate the expert-novice difference in anticipation and visual ability of athletes and coaches (Abernethy, 2007; Abernethy & Woolstein, 1988; Boyd, 2004; Giblin, 2014; A. M. Williams, 2000; Woorons, 2001). A video-based diagnostic test is an objective method of performance evaluation as it provides a high level of consistency and the sequence of action does not change from trial to trial (A. M. Williams & Ericsson, 2005). This method included developing video material as the stimulus condition for diagnostic tasks. In this investigation all coaches observed the same three videos to ensure consistency in data analysis.

5.2.1.1. Equipment and camera position

Videos were recorded on an indoor tennis court using four video cameras: two Panasonic HC-V770M and two Canon Legria HFG 630, 1080P. The videos were filmed at a frame rate of 50 frames per second. The cameras were positioned in accordance with International Tennis Federation recommendations (ITF, 2016). For the front view, camera four was positioned behind the net looking towards the server. For the side views, cameras one and two were positioned in line with the base line. For the rear view, camera three was positioned about three metres directly behind the server. *Figure 7 demonstrated the position of the cameras during the recording sessions and the direction of the serve.*

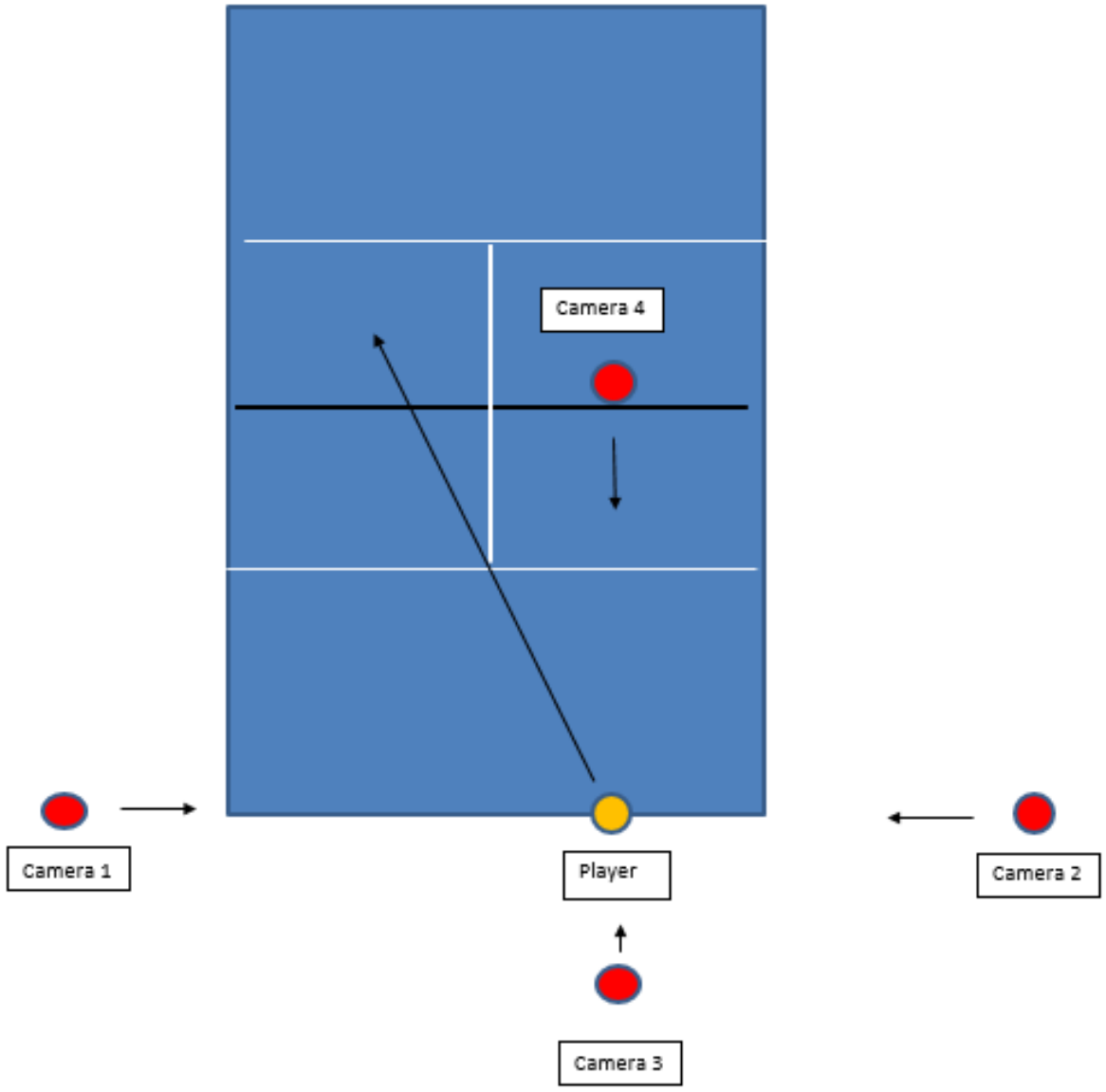


Figure 7 Position of the cameras (tennis court top view)

5.2.1.2. Participants

Three male tennis players, beginner, intermediate and high performance, were invited to participate for the tennis serve video recording. The participants were aged between 18 and 26 years old and all were free from injuries. The criteria for a player's level of identification was based on coach development technical fundamentals (Tennis Australia, 2013) and the International Tennis Federation number manual (ITF, 2004) and is presented in Table 11. The International Tennis Number (ITN) (ITF, 2004, p. 13) description is provided in appendix F International Tennis Number.

Table 11 The criteria for player's level identification

Criteria	Level of the player		
	Beginner (ITN 8-10)	Intermediate (ITN 5-7)	High Performance (ITN 4-1)
National ranking	No	No	Yes
Has decided to specialise in tennis	No	No	Yes
Total number of years in the coaching program	Up to 1	1 to 3	4+
Source (ITF, 2004; Tennis Australia, 2013)			

5.2.1.3. Procedure

Initially, information for participants was sent via email to all potential participants (Appendix G Information to Participants - Video Recording). Once a participant contacted the researcher, the time for the video recording session was finalised. The time was chosen according to each participant's availability.

Each session begun with a detailed explanation of the process followed by signing the consent form (Appendix H Consent Form - Video Recording). A ten-minute warm-up was then conducted to prepare the player for the serve and reduce the risk of injury. The warm-up consisted of general (physical) exercises and tennis specific (technical) exercises (e.g., shadow imitations of the serve action and practice serves) (Crespo & Reid, 2009). The generic warm-up included 4x10m sidesteps from the base line towards the net, 4 times 10 meters, jogging butt kicks, 4 times 10 meters high knee jogging, 4 times 10 meters cross steps, shoulder stretching for 10 seconds each arm, forearm stretching for 10 seconds each arm, and wrist stretching for 10 seconds each arm (Special Olympics, 2006). The tennis-specific warm-up included a continuous 30-second dynamic serve shadow imitations with their own racket followed by 10 warm-up serves at increasing velocity (5 serves at 60% of velocity, 2 x 70%, 1 x 80%, 1 x 90%, and one serve 100% of the maximum value) from the respective testing position (Ferrauti & Bastiaens, 2007). When the warm-up was completed, the player was positioned on a base line and instructed to perform a flat tennis serve with 100% velocity to the deuce court.

The videos from all four cameras were collated into one screen using the Adobe Premier Pro software program (AdobePremierePro, 2018). To ensure the anonymity for participants, faces were hidden by applying a blurring effect. The outcome of the serve was hidden from the participants as it could influence their analysis of technique. Figure 8 demonstrates the test video for the intermediate player.

Figure 8 Example of the test video

All three test videos were used for both phases of this investigation: during the interviews and online questionnaire. During the interview, videos were shown on the interviewer's computer screen. In the online questionnaire videos were inserted in the online questionnaire.

5.2.1.4. Coaches' consensus

Coaches' consensus was determined to ensure validity of the tennis players' level. The Delphi method (Fink, Kosecoff, Chassin, & Brook, 1984) was applied to obtain the coaches' opinions about the level of the serve.

The Delphi method has been widely used in sport, health, medicine and other fields of research when expert opinion was sought (Fink et al., 1984). It was also a recognized method for reaching consensus of participants' opinion on various topics. It usually involves three or four rounds of questioning until consensus between participants is reached (Hsu & Sandford, 2007).

In the current investigation six coaches (three Club Professional coaches; three High Performance coaches) were asked to complete the online questionnaire where they

confirmed the level of the player. All coaches familiarised themselves with the ITN player level description (Appendix F International Tennis Number) prior to the selection process.

The responses were collected via an online questionnaire using Victoria University's Qualtrics account (Qualtrics, 2005). The questionnaire included three videos. Coaches were asked to agree or disagree with the suggested level of the player when watching the video. An example of the question is presented in Figure 9. Coaches were able to repeat video as many times as they wanted before answering the question.

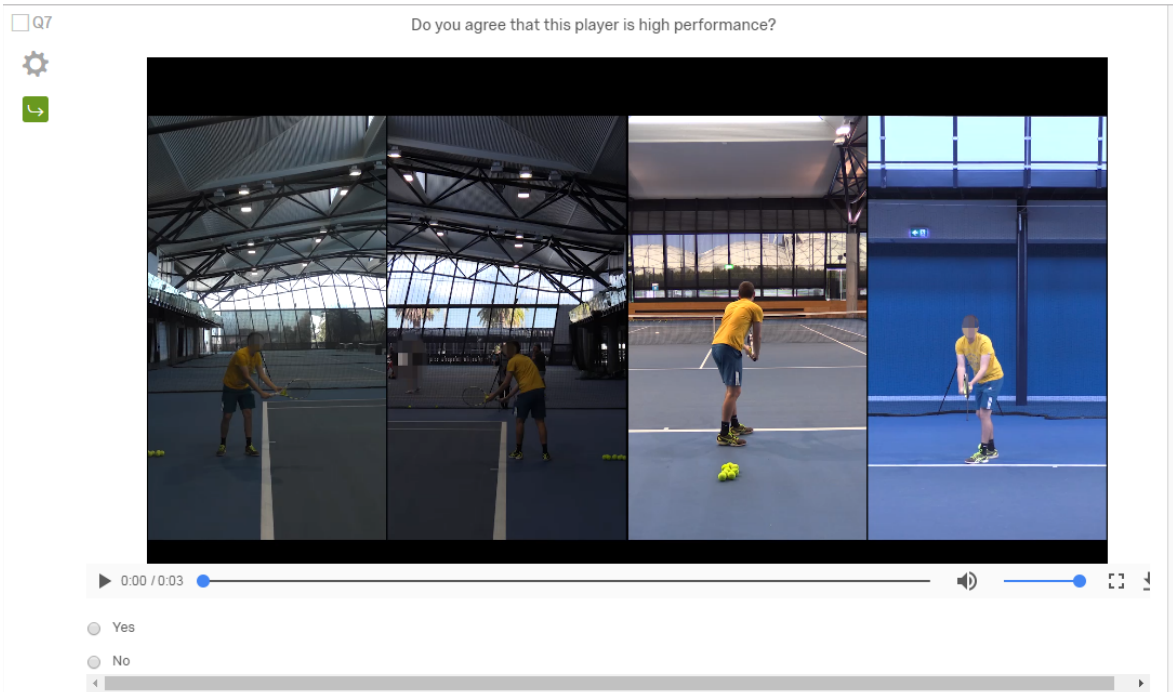


Figure 9 Example of the question from coaches' consensus online questionnaire

If coaches agreed with the level, the next player appeared on the screen. If they disagreed, coaches were asked to identify the level of the player by making a choice from the options: beginner, intermediate and high performance. As a result, 100% consensus level was reached.

5.3. Phase one – Interview

5.3.1. Methods

A one-on-one semi-structured interview was conducted with each participant to examine expert and novice tennis coaches' diagnostic ability and practical knowledge

of the flat tennis serve technique. During the interview, participants verbally analysed the tennis serve technique performed by three players of different levels. This interview method was considered to be valid for this study as the diagnosis of technique by coaches was normally based on a verbal interchange directly between coach and player (Leas & Chi, 1993).

5.3.1.1. Participants

In the current study eight male coaches aged between 18 and 49 years old (M=33 years ± 13.2) representing two different levels of expertise (novices n=4 & experts n=4) were chosen to participate in a one-on-one semi-structured interview. The sample size for this study was considered to be appropriate as the main goal was to gain insight into the coaches' knowledge rather than to estimate a population value (Bian, 2003). The sampling methods for participants was described in Section 3.1.

Expert coaches were involved in coaching activities for an average of 25.5 ± 4.5 years, and novice coaches for an average of 1.5 ± 0.6 years. Expert coaches have played tennis for an average of 13.5 ± 1.3 years, and novices for an average of 9.3 ± 3.3 years.

5.3.1.2. Procedure

An invitation email with the information to participants (Appendix I Information to Participants - Diagnostic Ability) along with Consent forms (Appendix C Consent Form for Participants Involved in Research - Interview) and questionnaire (Appendix E Pre-interview Questionnaire) were sent to coaches via the Tennis Australia coaching database. Once the coach contacted the researcher, the interview times and venues were finalised. The location and the time of the interview was chosen according to each participant's availability. Three pilot interviews with three different tennis coaches were conducted to determine the appropriateness of the interview questions, estimate the timing of this task, and to increase the general robustness of the data collection stage for this study.

Each interview began with general information about the project, an explanation of the procedure, answering participant's questions, and signing the consent form in accordance with Victoria University research ethics guidelines (Appendix C Consent Form for Participants Involved in Research - Interview). After that, the coach was shown a series of three videos. The order of players in the videos was the following:

intermediate, high performance and beginner. The level of the players was not disclosed to the participants. It was possible that some coaches were familiar with the athletes on the video which could affect their response, although the faces were hidden on the videos. To address this potential bias, every coach was asked if he recognised the player prior to the conducting of the diagnostic task. The response from all coaches was negative.

The participant was then asked to assess every serve and provide technical strengths, weaknesses and recommendations for corrections. An interview guide was developed for this task and presented in Appendix B Interview Guides - Study Two. The participants had an opportunity to spend as much time as they liked on each player and repeat the video as many times as they needed. The interviews lasted between 20 to 30 minutes. The think-aloud protocol was implemented during the interviews (De Groot, 1978). Tennis coaches were instructed to express their thoughts during the interview which was the key factor when applying this method (K.A. Ericsson & Simon, 1993).

5.3.1.2. Data analysis

All eight interviews were transcribed verbatim. Minor editing was performed on the transcribed data such as changing coach's names to numbers such as "Jason" to "Coach 1" to ensure anonymity. Member checking was applied in order to assure the credibility and reliability of the study: all interviews transcripts were sent to the participants to review and verify the interpretive accuracy (Braun & Clarke, 2006). If the script was returned with a correction from the participant, it was edited and sent again to the participant until the final confirmation was received.

A mixed methods research design (Johnson et al., 2007) was used to gain a deeper understanding of coaches' diagnostic ability and practical knowledge on the flat tennis serve technique. The data was analysed by applying the Grounded Theory Approach (B. G. Glaser & Strauss, 1967) in combination with the Comparison Method (S. M. Kolb, 2012). Quantification of the qualitative data and one-way MANOVA was used for quantitative analysis.

The transcribed verbal reports were analysed using NVIVO 11 Pro qualitative software (NVIVO, 2018). The schematic algorithm of the data analysis process and its description are presented in Figure 4 in Section 3.4.

The data coding process started from familiarisation with the data. Line-by-line coding was performed to analyse the diagnostic ability of expert and novice coaches. This has been done by identifying strengths, weaknesses and recommendations for corrections that coaches provided during the analysis. After that, the second round of line-by-line coding was performed. An analysis of coaches' practical knowledge of the tennis serve was performed by identifying meaning units related to the tennis serve technique. The meaning unit categories and sub-categories were created, their properties and dimensions analysed and relationships between them established. During this process the Constant Comparison Method of data analysis was applied in order to relate sub-categories to a higher category and achieve data saturation (S. M. Kolb, 2012). The identification of causal relationships between findings has been applied to allow deeper analysis of the coaches' practical knowledge and described in Section 3.4.1.

The quantitative analysis was then performed to identify differences between experts and novices in their diagnostic ability and practical knowledge. The analysis consisted of two steps: quantification of the qualitative data and then differentiation of the data (Vergeer & Lyle, 2013). Quantification of the qualitative data was performed first to transform qualitative data into numerical data. Specifically, the number of strengths, weaknesses, recommendations, concepts, technical elements, body elements, phases, reasoning chains parameters were calculated for every coach. Secondly, this numerical data was inserted into SPSS (27.0.0.0) to conduct a one-way Multivariate Analysis of Variance (MANOVA) test. Eight dependent variables were used: strengths, weaknesses, recommendations, concepts, technical elements, body elements, phases, and reasoning chains. The independent variable was level of coaching expertise: expert or novice.

5.3.2. Results

This study examined the diagnostic ability and practical knowledge of expert and novice tennis coaches and identified the distinguishing characteristics between them.

The results are presented in two sections: qualitative analysis and quantitative analysis.

5.3.2.1. Qualitative analysis

The schematic representation of expert and novice coaches' practical knowledge were developed as demonstrated in Figure 10 and Figure 11. Examples of meaning units were included in figures to illustrate the type of data from which sub-categories were formed. The design was based on a previous study in golf where sub-categories and meaning units were presented (A. Smith et al., 2015). The extraction from the interview is presented below to better illustrate the data.

> "I like he has a weight holding on the back leg, and then he got some sort of step up and then his ball toss is in front of his body which is good (in terms of distance between him and the ball). I would work on his position – he is standing too far behind base line and then he is stepping up timing and hitting timing is not quite right, he steps up too early. His left arm is coming up later than his right leg. His ball toss in the front but it's too low so it doesn't give him enough time which I think leads to that step-in position. He is not really balancing and holding the weight therefore hi left feet moves in as he steps up and I think it's because he has not enough time because of his ball toss and swing. There is rotation going on when he hits his weight transfer basically like a forehand, there is not much going in. His arm, right elbow is too straight when he is coming down and when he swings. So I think the sequence of getting the wrist down and the elbow down and the shoulder down was not quite there. It's more like shoulder action. The grip is forehand, and I do think his right leg is coming over when he finish" (Novice coach 4).

> "There are some good things there. First of all, there is nice weight transfer through the action, he is coming back and then rocking forward. He does going into knee bend, however, it's not quite enough of the knee bend which affects his leg drive and in turn, it affects his contact point which is quite low and not that reached. Because of the knee bend it doesn't look quite stable, and I guess that foot more to do with stability of the knee drive. It wasn't really in the course but…you can see that leg drive is not in balance and it was not deep enough, it was not stable enough. There is nice shoulder-over-shoulder. Left arm is going up nice and straight, there is shoulder rotation which is really nice. There

> is pronation in that action which is good. However, it does look like elbow is bent on contact which has probably to do with kinetic chain not having enough leg drive coming up to the ball. We never really addressed toss but if it was a higher toss, would have more leg drive…but there is not much…It does look like he has correct grip as he is getting pronation on the action. He is stepping in, the left arm is tucked in which is great on contact and in the follow through. However, he is landing on his left foot but not quite in arabesque finish. It's quite instable finish with the right leg kicking out to the side so that is the stability concern and that does have to do with knee drive" (Expert coach 3).

The expert model consisted of six components: "technical elements", "body elements", "phases", "key flexion points", "concepts" and "reasoning chains". These components formed two categories: "biomechanical factors" and "functionality" as shown in Figure 10.

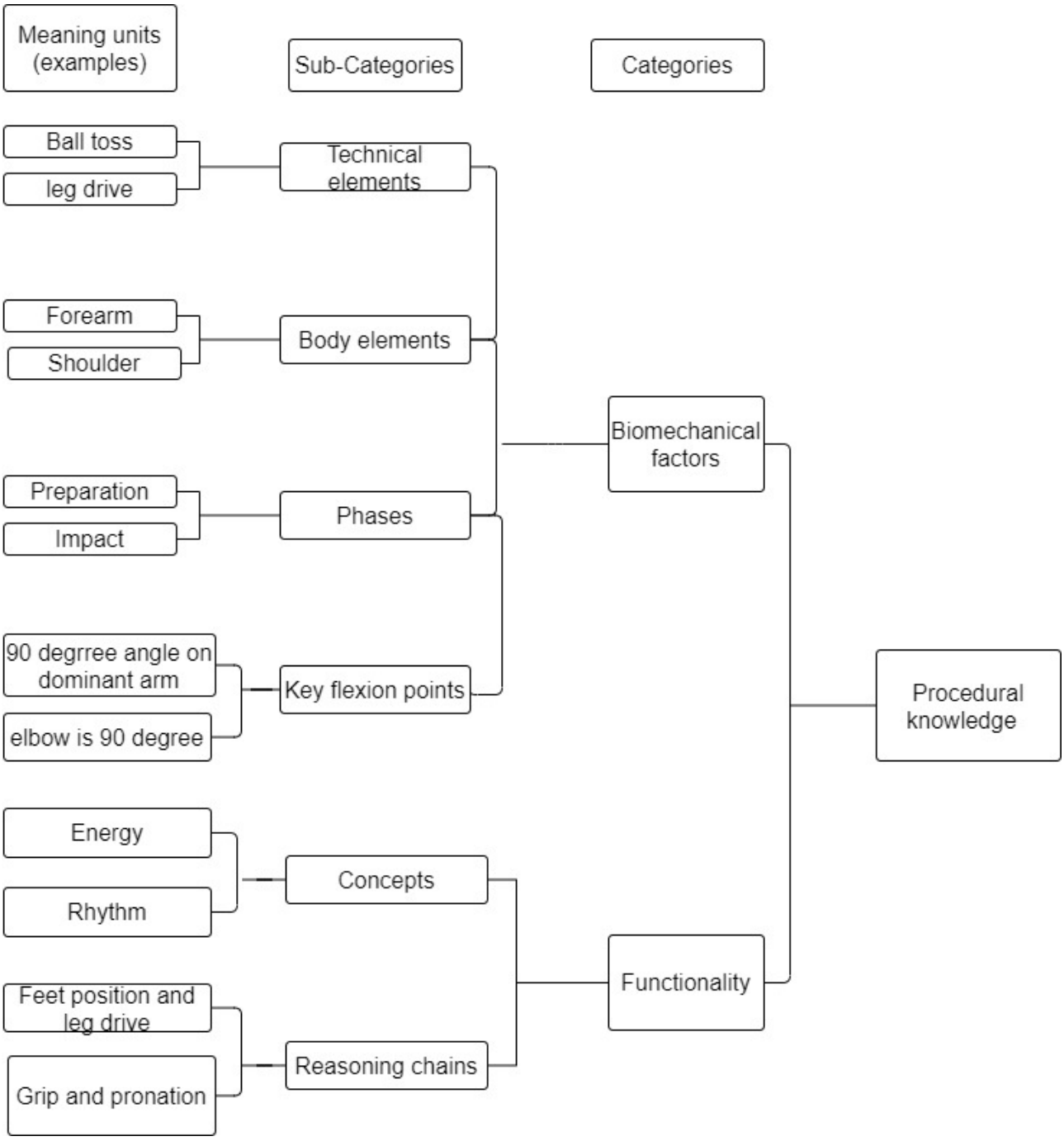


Figure 10 Expert model – practical knowledge phase one

The novice model consisted of five components: “technical elements”, “body elements”, “phases”, “key flexion points”, “concepts” and “reasoning chains”. These components formed two categories: “biomechanical factors” and “functionality” as shown in Figure 11.

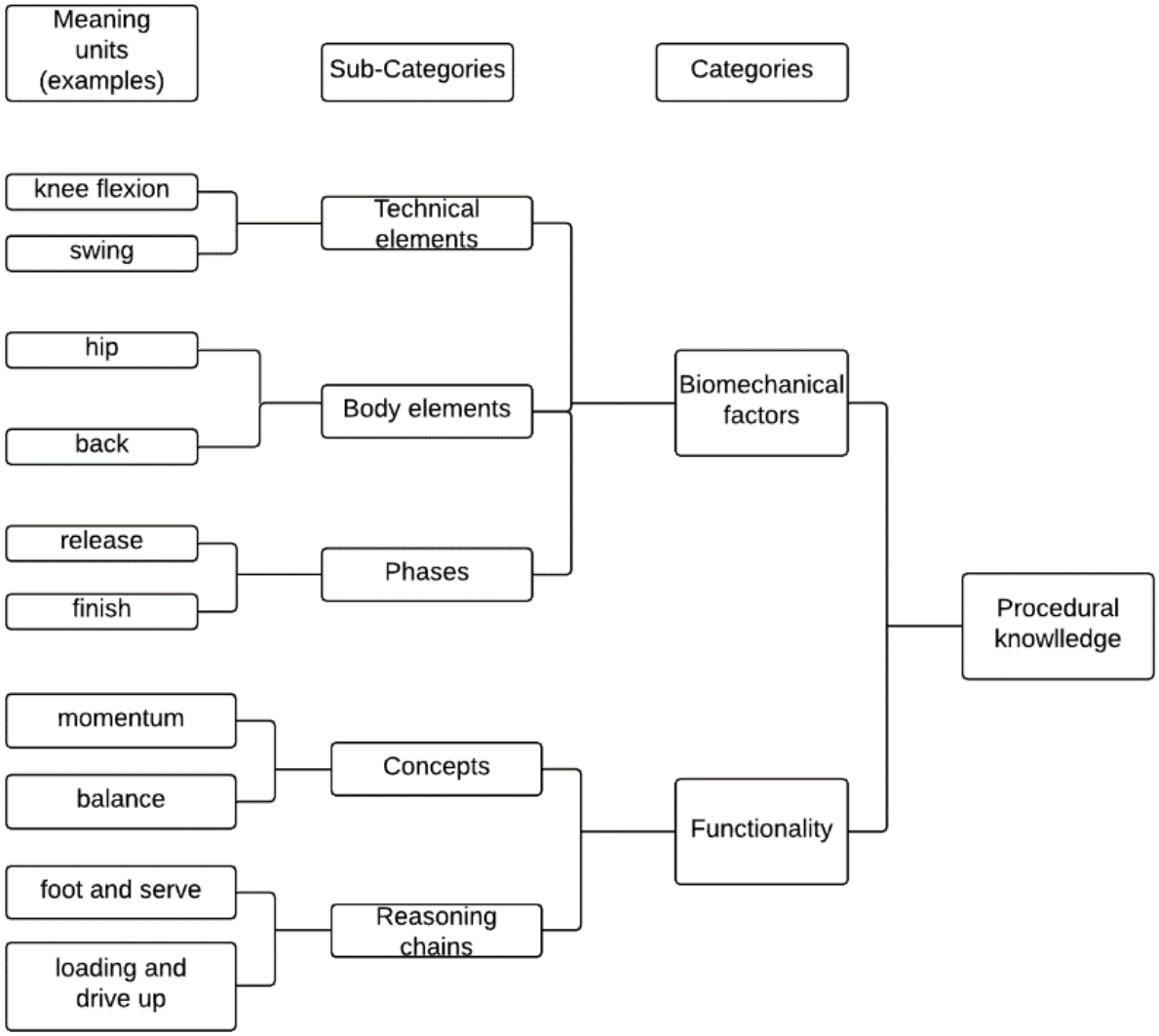


Figure 11 Novice model – practical knowledge: phase one

The “biomechanical factors” category represented coaches’ knowledge of technical cues from biomechanics perspective that they applied during the technique analysis, and included “technical elements”, “body elements” “phases” and “key flexion point” (for experts only) components. The detail analysis of these components is presented in the following paragraphs.

The “technical elements” component represented coaches’ knowledge on the technical terminology of the tennis serve. Table 12 compared the existing in the

scientific tennis literature technical elements (Elliott, 2006; Elliott et al., 2003; ITF, 2007; Kovacs & Ellenbecker, 2011; Tennis Australia, 2013) and those technical elements identified by experts and novices during the interview. The "☑" in the tables indicated that the element was identified and "☐" that it was not mentioned by coaches: certain technical elements were mentioned by experts only such as "loading", "landing in arabesque position", or by novices only such as "type of swing" and "eye focus". Some elements were identified by both groups such as "grip" and "stance". Certain technical elements were not identified neither by experts nor by novices such as "co-ordination of two arms" and "hip rotation".

Table 12 Technical elements of the flat serve: phase one

Technical elements	Novices	Experts
Grip	☑	☑
Stance	☑	☑
Ball toss	☑	☑
Co-ordination of 2 arms	☐	☐
Trophy position	☑	☑
Knee flexion	☑	☑
Hip rotation	☐	☐
Trunk rotation	☐	☐
Swing	☑	☑
Type of swing	☑	☐
Position of the non-racket arm	☑	☑
Loading	☐	☑
Leg drive	☑	☑
Shoulder-over-shoulder	☐	☑
Twist	☐	☐
External/internal rotation of the shoulder	☐	☑
Shoulder angle at maximum external rotation	☐	☐
Shoulder and arm alignment	☐	☐
Non-racket arm movement	☐	☐
Upper arm elevation	☐	☐
Elbow extension	☐	☐
Elbow flexion	☐	☐
Weight transfer	☐	☑
Wrist flexion/extension	☐	☐
Shoulder angle between arms and trunk	☐	☐
Pronation (as a general concept)	☐	☑
Forearm pronation	☐	☐
Hip extension	☐	☐
Contact point	☑	☑
Landing in arabesque position	☐	☑
Follow through	☑	☐
Eye focus	☑	☐
Separation angles	☑	☑
Type of serve (step-up/platform)	☑	☑

The “body elements” component included the body parts that coaches mentioned during the analysis of the tennis serve motion. Table 13 demonstrates body elements that expert and novices identified during the analysis and compares the identified body elements with existing in the tennis scientific literature body elements (Elliott, 2006; Elliott et al., 2003; ITF, 2007; Kovacs & Ellenbecker, 2011; Tennis Australia, 2013). Similarities and differences between experts and novices were identified. Some elements were mentioned by both experts and novices such as “knee” and “hip”. Some elements were identified by novices only such as “back” and “eyes”, or by experts only such as “elbow”, “wrist”. The “palm” and “toe” body element not mentioned neither by experts nor novices.

Table 13 Body elements of the flat serve: phase one

Body elements	Novices	Experts
Knee	☑	☑
Hip	☑	☑
Shoulder	☑	☑
Elbow	☐	☑
Wrist	☐	☑
Leg(s)	☑	☑
Arm(s)	☑	☑
Chest	☑	☑
Feet (foot)	☑	☑
Hand(s)	☑	☑
Back	☑	☐
Eyes	☑	☐
Upper body	☐	☑
Body	☑	☑
Head	☑	☐
Trunk/torso	☐	☑
Toe	☐	☐
Fingertips	☐	☑
Forearm	☐	☑
Palm	☐	☐

The “phases” component referred to the phases of the tennis serve that coaches identified in their diagnostic process. Table 14 demonstrates the phases existing in the tennis scientific literature and those identified by novices and experts. The difference and similarity in the “phases” component were identified: both experts and novices mentioned “loading”, “contact” and “finish”. “Cocking” phase was not mentioned

neither by experts nor novices. “Start” and “acceleration” phases were identified only by experts and “release” phase – only by novices.

Table 14 Phases of the flat serve: phase one

Phases	Novices	Experts
Start	☐	☑
Release	☑	☐
Loading	☑	☑
Cocking	☐	☐
Acceleration	☐	☑
Contact	☑	☑
Deceleration	☐	☐
Finish	☑	☑

The “key flexion point” referred to quantitative biomechanics that coaches mentioned during the interview: the emphasis on measurements and quantification when analysing movements of the human body (Jennett, 2008). Only experts applied quantitative biomechanical characteristics during the analysis such as “90 degrees elbow in trophy position”, “knee bend should be approximately 110 degrees” and “the magnitude of external rotation 185 degrees”. Overall, noticeable difference and similarities between expert and novices were detected in all components of “biomechanical factors” category.

The second category “functionality” demonstrated the coaches’ understanding of tennis serve technique: the ability to apply concepts when analysing the technique and ability to see how one element affects another in the kinetic chain. It included “concepts” and “reasoning chains” components.

The “concepts” component was formed by biomechanical and physics concepts that coaches applied when analysing the technique. Table 15 demonstrates the concepts that coaches applied during the diagnostic task by expert and novice coaches. The difference and similarities between experts and novices existed in the “concepts” component: experts applied wider range of concepts compared to novices. The “energy” and “timing” were identified by novices only and all other concepts – by experts only. The similarities were also identified: the “kinetic chain”, “balance” and “momentum” were mentioned by both experts and novice.

Table 15 Concepts applied during the diagnostic process: phase one

Concept	Novices	Experts
Kinetic chain	☑	☑
Balance	☑	☑
Ground up	☐	☑
Ground reaction force	☐	☑
Energy	☑	☐
Elastic reaction	☐	☑
Rhythm	☐	☑
Linear drive	☐	☑
Momentum	☑	☑
Timing	☑	☐
Power	☐	☑
Magnitude of intensity	☐	☑
Angular torsion	☐	☑
Leverage	☐	☑
Hyper angulation	☐	☑
Accuracy	☐	☑
Stability	☐	☑

The “reasoning chains” component represented the connectedness of the coaches' knowledge and understanding of the tennis serve technique. The examples of reasoning chains were: “extra pace AND good rhythm AND co-ordination in the upper body”, “foot action AND serve”, “the grip AND separation angles both horizontal and vertical.” The “AND” means that one part of reasoning chain ends, and another starts. It was found that experts demonstrated a wider range of reasoning chains compared to novices.

In addition to the analysis of coaches’ practical knowledge presented above, their diagnostic ability was also examined by analysing strengths, weaknesses and recommendations provided by coaches. Table 16 demonstrated strengths identified by novices and experts. The “☑” in the table indicates that strength was identified by coaches and “☐” that it was not. It was revealed that the difference in the ability to identified technical strengths existed: certain strengths were identified by both groups such as “ball toss” and “balance”, others – by experts only such as “rhythm”, “leg drive”, or by novices only such as “eye contact” and “grip”.

Table 16 Strengths identified by coaches during the diagnostic process: phase one

Strengths	Novices	Experts
Ball toss	☑	☑
Contact point	☑	☑
Balance	☑	☑
Body weight transfer forward	☑	☑
Trophy position	☑	☑
Knee flexion	☑	☑
Jumping into the court	☑	☑
Step-up technique	☑	☑
Eye contact	☑	☐
Left arm is up for right amount of time	☑	☐
Left arm is straight	☑	☐
Grip	☑	☐
Back swing	☑	☐
Rhythm	☐	☑
Slight wrist tilt	☐	☑
Leg drive	☐	☑
Horizontal separation angle	☐	☑
Shoulder-over-shoulder	☐	☑
Throwing mechanics	☐	☑
Flat back foot	☐	☑
Kinetic chain	☐	☑

Table 17 demonstrated weaknesses identified by novices and experts. Noticeable variations were observed in weaknesses. For example, “landing”, “grip”, “not enough knee flexion” were identified by both experts and novices. “Trophy position” and “does not jump” were identified by novices only and “not enough external rotation”, “racket does not drop down very far” – was by experts only.

Table 17 Weaknesses identified by coaches during the diagnostic process: phase one

Weaknesses	Novices	Experts
The player does not bring feet together when loading	☑	☑
Landing	☑	☑
Grip	☑	☑
Not enough leg drive	☑	☑
Not enough knee flexion	☑	☑
Left arm is not coming straight	☑	☑
Not enough loading on the back foot	☑	☑
No extension up	☑	☑
Not enough driving into the court	☑	☑
Left arm drops too quickly	☑	☑
Trophy position	☑	☐
Not enough arch in the back	☑	☐
Does not jump	☑	☐
Lack of body weight transfer from the back to the front foot	☑	☐
Contact point	☑	☐
head drops too quickly	☑	☐
Not enough external rotation	☐	☑
Racket does not drop down very far	☐	☑
Not great racket speed	☐	☑
Lack of elastic energy	☐	☑
Poor magnitude of intensity	☐	☑
the way the player is holding the ball at the start	☐	☑
Loading too much on the right	☐	☑
Limited external rotation of the shoulder	☐	☑
Racket drops too close to the trunk	☐	☑
Vertical separation angle	☐	☑
Hyper angulation with right arm	☐	☑
Balance	☐	☑
External rotation	☐	☑
Internal rotation	☐	☑
Elbow is to the side	☐	☑
Little separation angle between shoulder and hip	☐	☑
Lack of energy transfer through the body	☐	☑
Throwing mechanics	☐	☑
Rhythm	☐	☑
Co-ordination	☐	☑
Knees and toes are not aligned	☐	☑

The analysis of recommendations revealed that experts provided a wider range of recommendations. The examples of recommendations were: “transfer weight back to the right foot”, “keep the left arm up longer”, and “finishing in better arabesque position”.

Overall, the qualitative analysis demonstrated that the difference and similarities between experts and novices existed in their practical knowledge and diagnostic ability of the tennis serve technique.

5.3.2.2. Quantitative analysis

The quantitative analysis was performed to identify statistically significant difference between expert and novice tennis coaches in their practical knowledge and diagnostic ability (Pallant, 2016). The quantification of the qualitative data was performed first to transform qualitative data into numerical data. This was done by identifying the numeric information for every coach for every component of coaches' model. In addition, the number of strengths, weaknesses and recommendations were also identified. This numerical data was then inserted into SPSS software and MANOVA analysis was performed (Pallant, 2016). The inspection of the mean scores revealed that expert coaches outperformed novices on all variables which is shown in Table 18.

Table 18 Descriptive statistics: phase one

Descriptive Statistics					
	Level of coach	Mean	Standard Deviation	N	Significance
Technical elements	Expert	18.25	1.258	4	*.001*
	Novice	12.25	1.258	4	
	Total	15.25	3.412	8	
Body elements	Expert	22.25	1.258	4	*.000*
	Novice	15.50	.577	4	
	Total	18.88	3.720	8	
Reasoning chains	Expert	9.00	.816	4	*.000*
	Novice	2.75	.957	4	
	Total	5.88	3.441	8	
Concepts	Expert	7.75	.957	4	*.000*
	Novice	2.25	.500	4	
	Total	5.00	3.024	8	
Weaknesses	Expert	15.25	1.258	4	*.031*
	Novice	12.75	1.258	4	
	Total	14.00	1.773	8	
Recommendations	Expert	9.00	.816	4	*.002*
	Novice	6.00	.816	4	
	Total	7.50	1.773	8	
Strengths	Expert	9.00	.816	4	*.356*
	Novice	8.25	1.258	4	
	Total	8.63	1.061	8	
Phases	Expert	1.75	.500	4	*.030*
	Novice	2.75	.500	4	
	Total	2.25	.707	8	

Eight dependent variables were used: technical elements, body elements, phases, reasoning chains, concepts, strengths, weaknesses and recommendations. The independent variable was the level of coaches (expert & novice) and α=*0.05*. Initial assumption testing was performed (Box's Test of Equality of Covariance Matrices, Pillai's Trace, Levene's Test of Equality of Error Variances) (Tabachnick & Fidell, 2013), and no violation of assumptions was detected.

Table 18 demonstrates that the statistically significant difference of $p<0.05$ was achieved for the following variables: technical elements ($p= .001$), body elements ($p= .000$), reasoning chains ($p= .000$), concepts ($p= .000$), weaknesses ($p= .031$), recommendations ($p= .002$) and phases ($p= .030$). Strengths was the only parameter where no significant difference was identified ($p= 0.356$).

Overall, during the qualitative and quantitative analysis, two models representing coaches' practical knowledge were developed and compared. The noticeable differences as well as similarities between expert and novice coaches on their practical knowledge and diagnostic ability were then identified.

The main method of the data collection in this phase was in-depth interview. The next phase will apply online questionnaire to examine and compare practical knowledge and diagnostic ability of expert and novice tennis coaches.

5.4. Phase two – Online questionnaire

5.4.1. Methods

Phase one of the current investigation used an interview method for data collection, which allowed deeper examination of coaches' practical knowledge and diagnostic ability. Phase two complemented phase one and employed an online questionnaire method as it provided the advantages such as time and cost efficiency (Petrov, 2018). The online questionnaire method has been successfully applied in the previous research on coaches' knowledge on drills in track and field (Whelan et al., 2016).

5.4.1.1. Construction of the online questionnaire

The online questionnaire in this study is qualitative in nature which allowed the researcher to get a better understanding of coaches' diagnostic ability and practical knowledge (I. Jones, 2014). In addition, participants had an opportunity to complete the questionnaire at a convenient time and place that make the process of

investigation more efficient and allowed the researcher to examine a larger population of coaches (Whelan et al., 2016).

The online questionnaire was developed by using the Qualtrics online survey software (Qualtrics, 2005) and consisted of two parts. The first part collected demographic data about the participants' educational level, and their current coaching certification, playing and coaching experience, age and gender. Part two of the questionnaire contained three videos of players performing a flat serve in which three questions were asked for every player: 1) What are technical strengths? 2) What are technical weaknesses? 3) What would you recommend correcting?

The participants watched the videos as many times as they needed and typed strengths, weaknesses and recommendations into the text boxes provided on the screen. The structure of the online questionnaire is presented in Appendix J Online Questionnaire Structure. The videos for the questionnaire were previously developed in phase one of the current investigation where a beginner, intermediate and high-performance player performed the flat serve. The detailed description of the video recording process and participant selection was presented in Section 5.2. The order of players was consistent with phase one of this study which were intermediate, high performance and beginner players. The level of the player was not disclosed in the questionnaire. Three pilot surveys with two tennis coaches which were Junior Development and High-Performance levels were conducted to ensure a clear and easy understanding for participants.

5.4.1.2. Participants

Sixteen coaches across Australia (females=5, males=11, aged between 18 and 69 years old, M=43.4 ± 15.5 years), representing two different levels of expertise (novices n=8 and experts n=8) completed the questionnaire.

Expert coaches were involved in coaching activities for an average of 33.2 ± 9.8 years and novices for an average of 9.4 ± 6.6 years. Expert coaches had played tennis for an average of 31.2 ± 12.9 years, and novices for an average of 9.9 ± 5.5 years. The sampling method for participants was presented in Section 3.1.

5.4.1.3. Procedure

Initially, an invitation email with the information to participants (Appendix K Information to Participant - Online survey) and Consent Form (Appendix L Consent form - Online

Questionnaire) were sent to participants via the Tennis Australia coaching database. Once the participant contacted the researcher, the Consent Form was signed and the link to the questionnaire provided. Participants had an opportunity to complete the questionnaire at a time convenient for them.

5.4.1.4. Data analysis

A mixed method research design (Johnson et al., 2007) was used to get deeper understanding of coaches' diagnostic ability and practical knowledge on the flat tennis serve technique. The data was analysed by applying the Grounded Theory Approach in the combination with the Constant Comparison Method (B. G. Glaser & Strauss, 1967). Quantification of the qualitative data and one-way MANOVA was used for quantitative analysis. The data analysis process was identical to phase one as of the current investigation and can be found in Section 5.3.1.2.

5.4.2. Results

This this study examined the diagnostic ability and practical knowledge of expert and novice tennis coaches and identified the distinguishing characteristics between them. The results are presented in two sections: qualitative analysis and quantitative analysis.

5.4.2.1. Qualitative analysis

The schematic representation of expert and novice coaches' practical knowledge were developed as shown in Figure 12 and Figure 13. Examples of meaning units were included in Figures to illustrate the type of data from which sub-categories were formed. The design was based on the previous study in golf where key technical parameters including sub-categories and meaning units were presented (A. Smith et al., 2015).

The expert knowledge consisted of six components: "technical elements", "body elements", "phases", "key flexion points", "concepts" and "reasoning chains". These components formed two categories: "biomechanical factors" and "functionality" as shown in Figure 12.

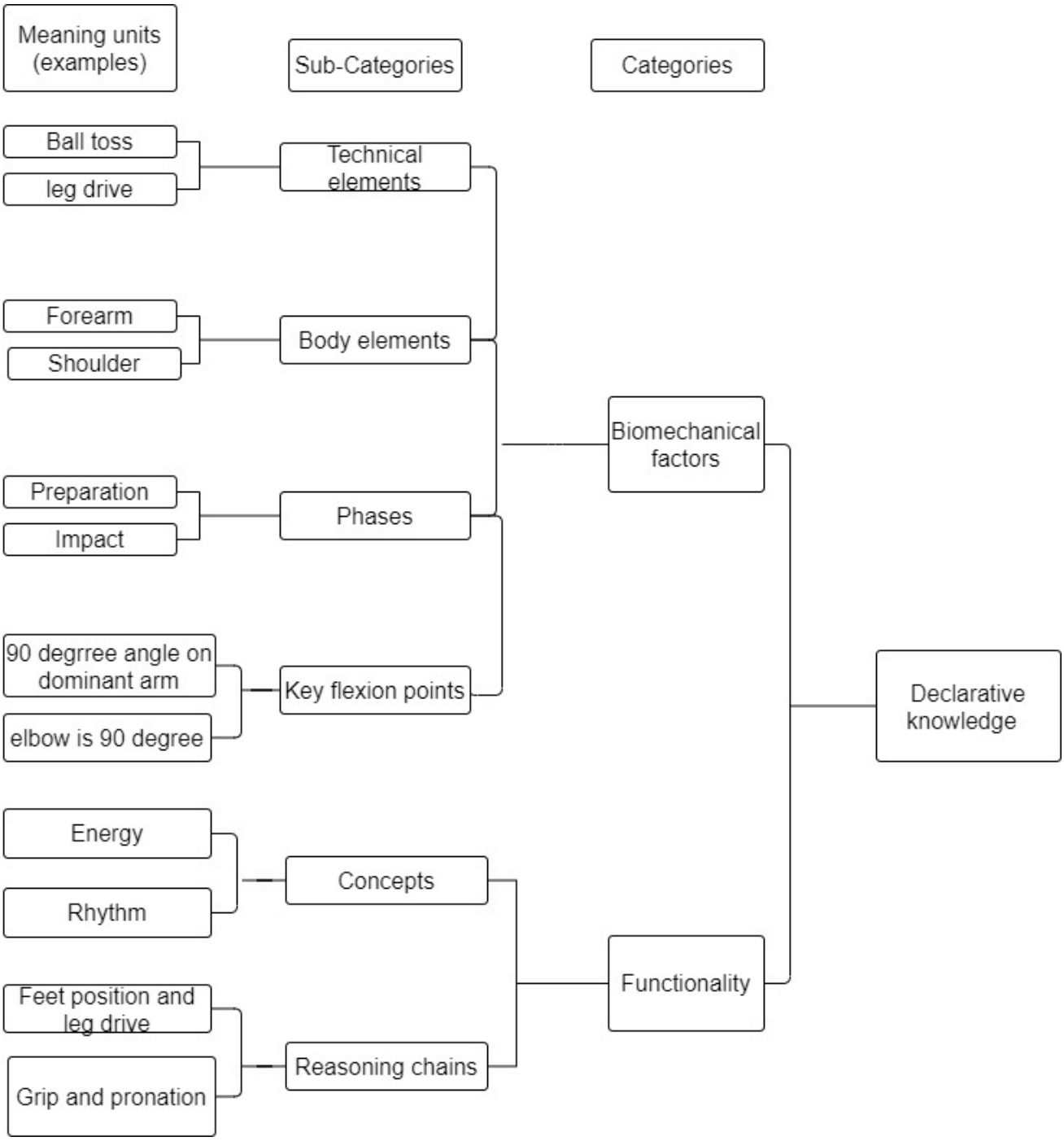


Figure 12 Expert model practical knowledge phase two

The novice model consisted of five components: “technical elements”, “body elements”, “phases”, “concepts” and “reasoning chains”. These components formed two categories: “biomechanical factors” and “functionality” as shown in Figure 13.

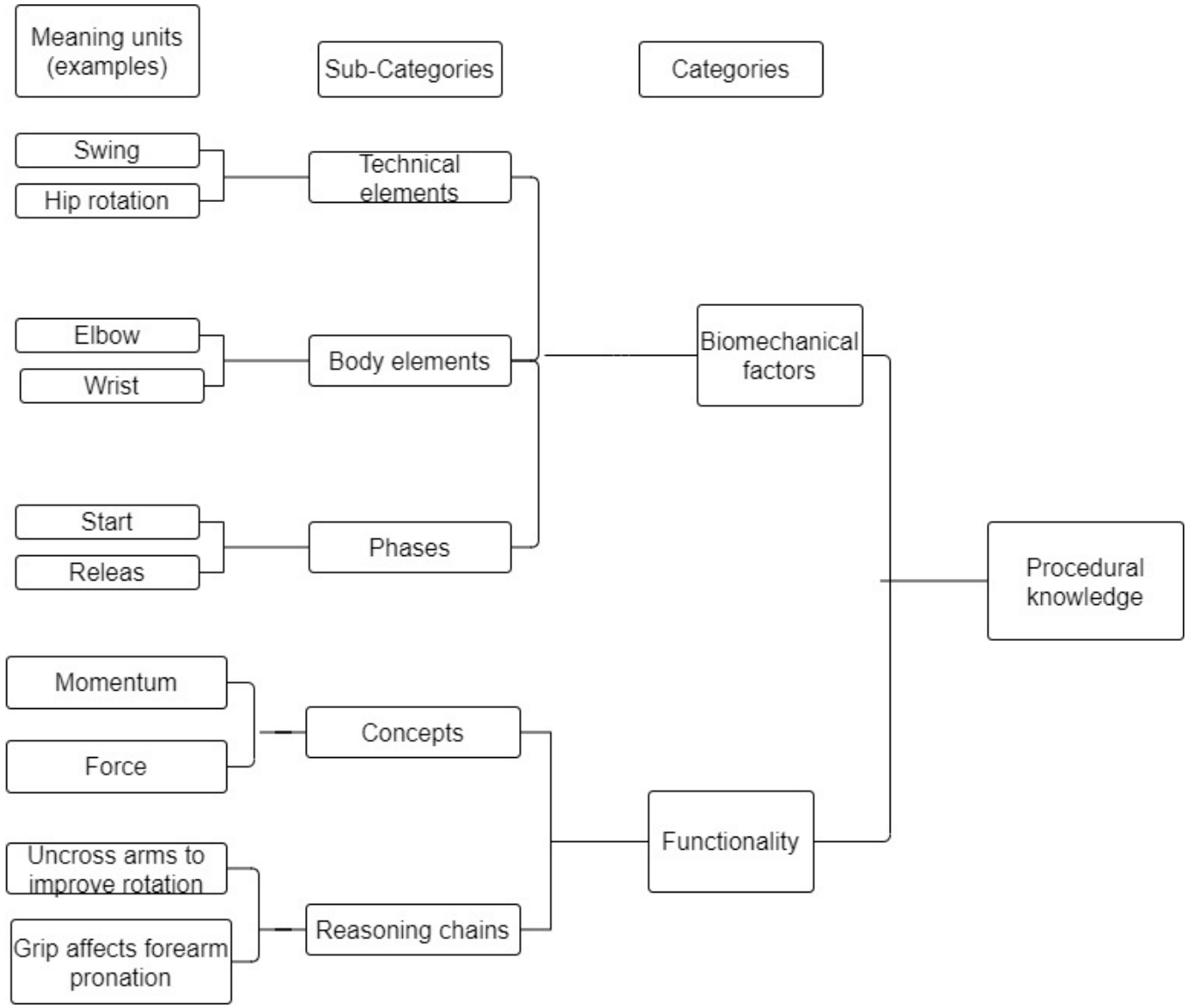


Figure 13 Novice model practical knowledge phase two

The “biomechanical factors” category represented coaches’ knowledge of technical cues from biomechanics perspective that they applied during the technique analysis, and included “technical elements”, “body elements” “phases” and “key flexion point” (for experts only) components. The detailed analysis of these components is presented in Tables 19 to 24. The “☑” in the table indicated that the element was identified by coaches and “☐” that it was not mentioned.

The “technical elements” component represented coaches’ knowledge on the tennis serve technical terminology. Table 19 compared the existing in the scientific tennis literature technical elements (Elliott, 2006; Elliott et al., 2003; ITF, 2007; Kovacs & Ellenbecker, 2011; Tennis Australia, 2013) and those technical elements identified by expert and novice coaches. It also demonstrated the differences and similarities between expert and novice coaches. Certain technical elements were mentioned by experts only such as “co-ordination of 2 arms” and “upper arm elevation”), or by novices only such as “trunk rotation” and “forearm pronation”). Some elements were identified by both groups such as “grip” and “stance”. Some technical elements were not identified either by experts or by novices such as “position of the non-racket arm” and “shoulder angle at maximum external rotation”.

Table 19 Technical elements of the flat serve: phase two

Technical element	Novices	Experts
Grip	☑	☑
Stance	☑	☑
Ball toss	☑	☑
Co-ordination of 2 arms	☐	☑
Trophy position	☑	☑
Knee flexion	☑	☑
Hip rotation	☑	☑
Trunk rotation	☑	☐
Swing	☑	☑
Type of swing	☑	☑
Position of the non-racket arm	☐	☐
Loading	☐	☑
Leg drive	☑	☑
Shoulder-over-shoulder	☑	☑
Twist	☐	☐
External/internal rotation of the shoulder	☑	☑
Shoulder angle at maximum external rotation	☐	☐
Shoulder and arm alignment	☐	☐
Non-racket arm movement	☑	☑
Upper arm elevation	☐	☑
Elbow extension	☐	☐
Elbow flexion	☐	☐
Weight transfer	☑	☑
Wrist flexion/extension	☐	☐
Shoulder angle between arms and trunk	☐	☐
Pronation (as a general concept)	☑	☑
Forearm pronation	☑	☐
Hip extension	☐	☐
Contact point	☑	☑
Landing in arabesque position	☑	☑
Follow through	☑	☑
Eye focus	☐	☐
Separation angles	☑	☑
Type of serve (step-up/platform)	☐	☑

The “body elements” component included the body parts that coaches mentioned during the analysis of the tennis serve motion. Table 20 represents body elements that experts and novices identified during the interview task. It also compares the identified elements with existing body elements in the tennis scientific literature (Elliott, 2006; Elliott et al., 2003; ITF, 2007; Kovacs & Ellenbecker, 2011; Tennis Australia, 2013). Similarities and differences between expert and novice coaches were identified. Some elements were mentioned by both experts and novices such as “knee” and “hip”, some elements were identified by experts only such as “upper body” and “head”, or by novice

coaches only such as “fingertips” and “forearm”. Some elements were not mentioned either by experts or by novices such as “toe” and “back”.

Table 20 Body elements of the flat serve: phase two

Body element	Novices	Experts
Knee	☑	☑
Hip	☑	☑
Shoulder	☑	☑
Elbow	☑	☑
Wrist	☑	☑
Leg(s)	☑	☑
Arm(s)	☑	☑
Chest	☑	☑
Feet(foot)	☑	☑
Hand(s)	☐	☐
Back	☐	☐
Eyes	☐	☐
Upper body	☐	☑
Body	☐	☐
Head	☐	☑
Trunk/torso	☑	☑
Toe	☐	☐
Fingertips	☑	☐
Forearm	☑	☐
Palm	☑	☑

The “phases” component referred to the phases of the tennis serve that coaches identified in their diagnostic process. Table 21 demonstrates the phases existing in the tennis scientific literature and those identified by novices and experts. Noticeable differences and similarities between experts and novices were observed: “start, “release”, “acceleration” and “contact” phases were identified by both experts and novices. “Loading” was mentioned by experts only. “Cocking”, “deceleration” and ‘finish” were not identified either by experts or by novices.

Table 21 Phases of the flat serve: phase two

Phases	Novices	Experts
Start	☑	☑
Release	☑	☑
Loading	☐	☑
Cocking	☐	☐
Acceleration	☑	☑
Contact	☑	☑
Deceleration	☐	☐
Finish	☐	☐

The “key flexion point” component referred to quantitative biomechanics that coaches mentioned during the interview: the emphasis on measurements and quantification when analysing movements of the human body) (Jennett, 2008). Only expert coaches applied quantitative biomechanical characteristics during the analysis: “elbow at the back of the serve is not quite 90 degree”, “90 degree angle on dominant arm”, “racket arm gets to 90 degree” and “elbow higher to achieve a “90-90” position”.

The second category “functionality” demonstrated coaches’ understanding of tennis serve technique indicating their ability to apply concepts when analysing the technique and their ability to see how one element affected another in the kinetic chain. It was formed by the “concepts” and “reasoning chains” components.

The “concepts” component was formed based on biomechanical and physics concepts that coaches applied when analysing the flat serve technique. Table 22 demonstrates the concepts that coaches applied during the diagnostic task. The differences and similarities between experts and novices were observed. “Power”, “kinetic chain”, “balance” and “momentum” were identified by both groups. “Force” and “kinetic energy” were mentioned by novices only and “rhythm”, “energy” and “ground reaction force” – by experts only.

Table 22 Concepts applied by coaches during the diagnostic process: phase two

Concept	Novices	Experts
Power	☑	☑
Kinetic chain	☑	☑
Balance	☑	☑
Momentum	☑	☑
Force	☑	☐
Kinetic energy	☑	☐
Rhythm	☐	☑
Energy	☐	☑
Ground reaction force	☐	☑

The “reasoning chains” component represented the connectedness of the coaches' knowledge and their ability to understand the connection between technical elements. The examples of reasoning chains were: “kick leg backwards AND balance”, “grip AND pronate forearm”, and “uncross arms AND rotation”. The “AND” means that one part of reasoning chain ends, and another starts. It was noticed that experts demonstrated wider range of reasoning chains compared to novices. The numerical characteristics for this component will be presented in Section 5.4.2.2.

After all components of expert and novice models were identified and analysed, the data from the interview then was grouped and coded to identify strengths, weaknesses and recommendations for the corrections. Table 23 demonstrates strengths identified by experts and novices during the analysis. The “☑” in the tables indicated that the element was mentioned by coaches and the “☐” that element was not identified. Some strengths were identified by both groups such as “grip” and “ball toss”), some – by novices only such as “release” and “momentum”), and some – by experts only such as “racket path” and “internal rotation”.

Table 23 Strengths identified by coaches during the diagnostic process: phase two

Strengths	Novices	Experts
Grip	☑	☑
Ball toss	☑	☑
Stance	☑	☑
Trophy position	☑	☑
Leg drive	☑	☑
Balance	☑	☑
Body weight transfer into the court	☑	☑
Back swing	☑	☑
Contact point	☑	☑
Throwing mechanics	☑	☑
Knee flexion	☑	☑
Release	☑	☐
Momentum	☑	☐
Separation angle	☑	☐
acceleration	☑	☐
Trunk rotation	☑	☐
Racket path	☐	☑
Palm down (pre-throw position)	☐	☑
Internal rotation	☐	☑
External rotation	☐	☑
Right arm motion	☐	☑
Tossing arm	☐	☑
Back foot and shoulder are aligned	☐	☑
Rhythmical synchronization two arms	☐	☑
Routine	☐	☑
Racket points towards target	☐	☑
Left arm tucked in at contact point	☐	☑
Shoulder rotation	☐	☑
Timing	☐	☑
Hands together at the start	☐	☑

Table 24 demonstrated weaknesses identified by expert and novice coaches during the analysis. Noticeable differences and similarities between experts and novices were observed. For example, “ball toss”, “stance” were identified by both groups. The “rotation”, “slow start motion” were mentioned by novices only and “loading” and “hip drive” by experts only.

Table 24 Weaknesses identified by coaches during the analysis: phase two

Weaknesses	**Novices**	**Experts**
Ball toss	☑	☑
Palm up in trophy position	☑	☑
Stance	☑	☑
Knee flexion	☑	☑
Follow through	☑	☑
Grip	☑	☑
Back swing	☑	☑
Left arm	☑	☑
Contact point	☑	☑
Balance	☑	☑
Landing	☑	☑
Extension up	☑	☑
Leg drive	☑	☑
Not enough shoulder tilt	☑	☑
Elbow is too high in trophy position	☑	☑
Not enough power	☑	☑
Not enough forward movement	☑	☑
Rotation	☑	☐
Slow start motion	☑	☐
Stop at the start motion	☑	☐
Too quick swing	☑	☐
Trunk rotation	☑	☐
Pause is too long at the trophy position	☑	☐
Feet position	☑	☐
Muscle tightness in the right shoulder	☐	☑
Stiff throwing action	☐	☑
Forward swing	☐	☑
Hip drive	☐	☑
Separation angle	☐	☑
Kinetic chain	☐	☑
Left foot moves at the contact	☐	☑
Arabesque position	☐	☑
Loading	☐	☑
Wrist pronation	☐	☑
Left arm is not tucked in enough	☐	☑
No jump into the court	☐	☑
Left hand not holding the throat of the racket	☐	☑
Head dips	☐	☑
Right arm bends in contact	☐	☑

The analysis of recommendations revealed that experts provided a wider range of recommendations compared to novices. The numerical characteristics for recommendations will be presented in Section 5.4.2.2. The examples of recommendations were: “a ball toss more forward”, “shoulder should be more side on” and “push up more”.

5.4.2.2. Quantitative analysis

The quantitative analysis was performed to identify statistically significant differences between experts and novices in their practical knowledge and diagnostic ability. The quantification of the qualitative data was performed to transform the qualitative data into numerical data. Firstly, the number of strengths, weaknesses, recommendations, concepts, technical elements, body elements, phases, reasoning chains were calculated for every coach. This data was then inserted to SPSS software (Pallant, 2016) and MANOVA analysis was performed to identify differences between expert and novice coaches. The results below revealed that expert coaches outperformed novices on all variables.

Eight dependent variables were used: technical elements, body elements, phases, reasoning chains, concepts, strengths, weaknesses and recommendations. The independent variable was level of coaches (expert & novice) and $\alpha=0.05$.

Table 25 demonstrated that the mean for expert coaches was greater compared to novice coaches in all variables.

Table 25 Descriptive statistics: phase two

Descriptive Statistics					
	Level of coach	Mean	Std. Deviation	N	Significance
Technical elements	Expert	15.75	2.252	8	.000
	Novice	9.50	1.195	8	
	Total	12.63	3.667	16	
Body elements	Expert	11.13	1.553	8	.000
	Novice	5.50	.926	8	
	Total	8.31	3.156	16	
Reasoning chains	Expert	4.25	1.035	8	.000
	Novice	1.75	.707	8	
	Total	3.00	1.549	16	
Phases	Expert	2.13	.835	8	.021
	Novice	1.25	.463	8	
	Total	1.69	.793	16	
Concepts	Expert	3.25	.463	8	.000
	Novice	1.13	.354	8	
	Total	2.19	1.167	16	
Strengths	Expert	7.25	1.389	8	.001
	Novice	4.63	.916	8	
	Total	5.94	1.769	16	
Weaknesses	Expert	8.63	1.302	8	.001
	Novice	5.50	1.604	8	
	Total	7.06	2.144	16	
Recommendations	Expert	8.00	1.512	8	.001
	Novice	5.00	1.414	8	
	Total	6.50	2.098	16	

Initial assumption testing was then performed (Box's Test of Equality of Covariance matrices, Pillai's Trace, Levene's Test of Equality of Error Variances) (Tabachnick & Fidell, 2013) and no violation was detected. The statistically significant difference was also detected on all variables: technical elements (p= .000), body elements (p= .000), reasoning chains (p= .000), concepts (p= .000), weaknesses (p= .001), recommendations (p= .001), phases (p= .021) and strengths (p= .001).

While it was considered that the online questionnaire offered the appropriate research method for this study to deepen data collection, two limitations should be mentioned. Firstly, there was no opportunity to clarify information provided by the respondents. This limited the data collection process of the online questionnaire compared to the interview method where data saturation was reached by clarification questions to the

interviewees. Secondly, the results from the interview and the online questionnaire cannot be generalised to a larger population of coaches or to coaches of other sports as the current investigation was more qualitative in nature, and aimed to get deeper understanding of the knowledge rather than to estimate a population value.

Overall, during the qualitative and quantitative analysis, the schematic representation of expert and novice coaches' practical knowledge were developed and compared, and qualitative and quantitative differences and similarities between expert and novice tennis coaches were identified. The results from phase one of the current investigation were consistent with results of phase two. In both phases the expert model consisted of six components and the novice model contained five components. These components formed two categories: the "biomechanical factors" and "functionality". The qualitative similarities and differences between expert and novice coaches were identified in all components of the models during the qualitative analysis on phase one and two. The quantitative analysis supported these results as statistically significant difference between expert and novice coaches were identified for all components of the models in both phases. Qualitative differences between experts and novices in their diagnostic ability were identified during qualitative analysis. Statistically significant differences were identified for "weaknesses", "strengths" and "recommendations" in phase one, and for "weaknesses" and "recommendations" in phase two which was depicted in Table 18 and

Table 25. These results will be discussed in Chapter 7.

5.5. Summary of key findings

The aim of the current study was to examine the diagnostic ability and practical knowledge of expert and novice tennis coaches of the flat tennis serve technique, and to identify the key distinguishing characteristics between expert and novice coaches. As a result, the following findings have emerged from this investigation.

Two models representing coaches' practical knowledge have been developed. This provided an original contribution to the knowledge on tennis coach expertise as visual representation of coaches' practical knowledge had not been previously presented. In addition, no previous study has performed such a detailed analysis of practical knowledge by combining two methods of data collection which were interview and online questionnaire.

The online questionnaire developed in this study brought a unique contribution to the knowledge of tennis coaching expertise and could be used in coach development to examine coaches' knowledge on other technical elements. It may also inspire new research to examine coaches' diagnostic ability in other sports as online questionnaire could be replicated.

Secondly, the application of the expert-novice paradigm revealed that the main distinguishing characteristics between experts and novices were experts' greater ability to apply quantitative biomechanics in the diagnostic process, and to understand the cause-and-effect relationships between technical elements. These findings suggested that novice coaches needed to develop their knowledge in all components of their practical knowledge to become experts. This could be applied in coach development as the research demonstrated specific areas that novices needed to improve.

Thirdly, expert coaches significantly outperformed novices in the number of identified strengths, weaknesses and recommendations. Experts were more expressive and demonstrated more detailed analysis compared to novices. They also applied more advanced biomechanical principles in their analysis.

Surprisingly, contradictions between novices and experts were detected on certain technical elements that were identified as weakness by one group and strengths by another. This finding demonstrated the difference in diagnostic ability between experts and novices. A possible explanation for this difference was due to the experts' greater declarative, procedural knowledge base, and coaching experience. To achieve the higher level of the expertise novice tennis coaches should improve their knowledge of the serve technique and learn how to recognise the key weaknesses and strengths. This could be done by developing a training program to improve knowledge of novice coaches and their diagnostic ability. The correctness of the analysis was not assessed in the current investigation. More research is needed to identify the correctness of coaches' analysis and to understand the expert-novice difference at a deeper level.

In addition to contradictions identified between experts and novices, coaches from the same group had exactly the opposite diagnosis on certain features of the serve. Several technical elements were identified as strength by one coach and as weakness by another within the same expertise group. This can be explained by the unique characteristics of the coaches' internal model, different coaching or playing experience and additional education or self-education. These factors would create a different and unique internal model for every coach even at the same certification level. These contradictions amongst coaches demonstrated that diagnostic ability and procedural and declarative knowledge of coaches are different along the expertise continuum. It is important to ensure that coaches are provided with the correct and complete internal model of the tennis serve technique during coach education programs from the beginning of the coaching pathway as it subsequently affects their practical knowledge and diagnostic skills. The next study will apply the findings from previous two studies to develop education tool for novice coaches that aimed to improve their declarative, practical knowledge and diagnostic skills of the tennis serve technique.

Chapter 6 Study 3: Online training course

6.1. Introduction

Coach education plays an essential role in sports training as coaches' knowledge and skills subsequently affect their athletes' performance (Mallet, Trude, Lyle, & Rynne, 2009). Previous research in coach knowledge and decision making has highlighted the need for coaches to develop background knowledge to interpret patterns and to apply their knowledge into problem solving. It is recommendation that the development of skills should be explicitly incorporated into coach education and development (J. Lyle, 2010).

The process of direct knowledge transition from experts to novices has been considered as a successful method for knowledge development (Nash & Collins, 2006). Previous research on coaches' decision making has emphasised that training programs for coaches may adopt an approach of teaching novice coaches the strategies that expert coaches apply in the same domain (Lipshitz & Strauss, 1997). Then the fundamental question arises: "What knowledge should be included in coach training programs?" The answer to this question could potentially reduce the current time required for novice coaches to attain expertise (Abraham & Collins, 1998). In order to understand the type of knowledge or skills novice coaches should develop, differences between expert coaches and novice coaches could be explored (A. M. Williams & Davids, 1988).

The first two studies of this thesis successfully identified the key distinguishing characteristics between novice and expert coaches in their declarative and practical knowledge and diagnostic ability. These distinguishing characteristics were then used in the present study to develop a training course aimed to improve the knowledge and diagnostic skill of novice coaches such as understanding of the causal connections between technical elements.

As discussed in Section 2.4 of this thesis, a considerable number of studies have focused on training athletes' perceptual-cognitive skills, however, no online training courses have been developed for tennis coaches. In addition, despite the fact that many online training programs are available and offer e-learning modules for coaches (National-Coaching-Certification-Program, 2020), the effectiveness of these programs remain uncertain, as coaches are certified upon the completion of the program without

assessment of their competency, knowledge and understanding (C. Cushion & Nelson, 2013; Trudel, Culver, & Werthner, 2013). Therefore, the aim of this study was to develop and demonstrate the effectiveness of an online coach training course which aimed to improve coaches' practical knowledge, and diagnostic ability and understanding of the flat tennis serve technique.

This study makes an original contribution to the field of tennis coach education as it introduces the online training course for tennis coaches that has not been presented previously. It is anticipated that coaches' analysis of performance subsequently affects a training program recommended to the athlete (Morante, 2008). Therefore, the development of coaches' ability to understand the functionality of the tennis serve technique should improve their diagnostic ability, the quality of coaching and, as a result, the athlete's performance. Thus, the understanding of the cause-and-effect relationships between technical elements should allow tennis coaches to prescribe a more effective training intervention (Giblin, 2013). By knowing how one element may affect another, coaches may be able to fix issues more effectively by addressing the cause of the problem instead of focusing on many separate components of the tennis serve. This course can also be adjusted to other technical elements in tennis, and can be applied for other sports to improve coaches' knowledge and their diagnostic abilities of sport technique.

6.2. Methods

6.2.1. The research design

One-group pre-test-post-test design (Farrow & Abernethy, 2001; Reichardt, 2009) was utilised where the practical knowledge and diagnostic skills were measured in one group of novice coaches before and after the 4-weeks online training course. This design has been successfully applied in a tennis study which examined the effectiveness of video-based perceptual training of athletes (Farrow & Abernethy, 2001).

Figure 14 demonstrates the design of the current study in which the knowledge of coaches before (pre-test) and after (post-test) the online training was compared to evaluate the effectiveness of the course.

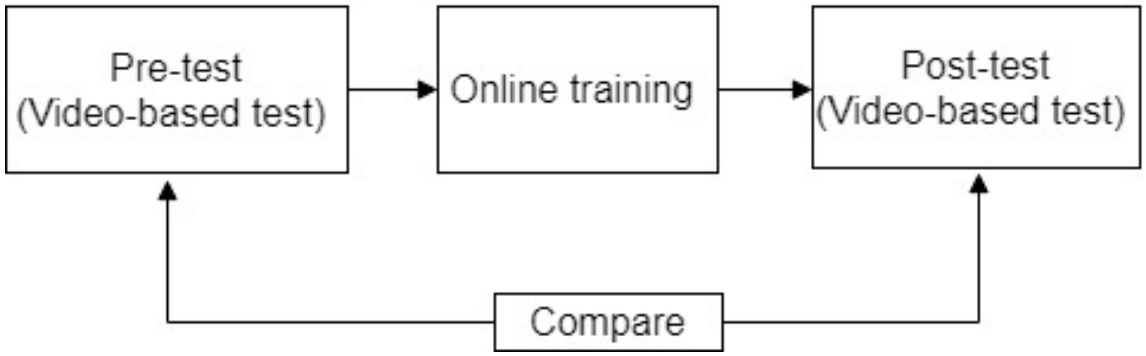


Figure 14 The research design

6.2.2. The Whole-Part-Whole learning model

The Whole-Part-Whole (WPW) learning model is a framework for developing training and learning experience (R. A. Swanson & Law, 1993). In addition to new knowledge and skills, this approach allows learners to obtain understanding of the information presented. The aim of this study was to improve coaches' knowledge and understanding of the tennis serve technique. Therefore, the WPW model was considered as appropriate for the online training course. WPW model consists of three aspects: the "first whole", the "part" and the "second whole" (R. A. Swanson & Law, 1993).

The "first whole" prepares learners for new information by aligning their existing knowledge with new content by providing "the big picture" (R. A. Swanson & Law, 1993). In the current investigation the "first whole" was presented by demonstrating the whole movement and learning outcomes of the course. This part aimed to align coaches' existing knowledge with new material and motivate them by demonstrating the "connectedness" of the material (R. A. Swanson & Law, 1993).

The "part" aspect provides learners with a strong understanding of the individual components of the "first whole" as it is crucial for the understanding of the "whole" aspect (R. A. Swanson & Law, 1993). In this part, the phases and key technical elements of the tennis serve were presented.

The "second whole" links the individual parts together as understanding the relationship between the "parts" leads to a strong understanding of the learning

material (R. A. Swanson & Law, 1993). Thus, the connection between technical elements of the serve were presented in the final part of the online training course to demonstrate how technical elements are connected and affect each other in the kinetic chain. Video-based training programs highlighting the link between important information on the screen and outcome of the sport action have been successfully implemented in earlier studies in sport (Singer et al., 1994; Tayler et al., 1994; A. M. Williams & Burwitz, 1993).

6.2.3. Orienting visual attention

The present investigation employed orienting visual attention and voice instructions methods. These methods were recognised as an effective approach to improving anticipation and visual perception skills in sport (Hagemann et al., 2006; Janelle, J.D., Coombes, & Mousseau, 2003; Larkin et al., 2015; Ryu et al., 2013; A. M. Williams, 2000).

In video-based training, the orienting visual attention method refers to directing attention towards the key information on the screen. It has been previously applied in soccer and badminton by using a transparent red patch, semi-transparent red lines, directional arrows and circles (Hagemann et al., 2006; Janelle et al., 2003; Ryu et al., 2013). These studies reported that orienting visual attention improved athletes' anticipatory skill. Therefore, the present investigation used directional arrows (Figure 15), circles (Figure 16) and other visual tools (Figure 17) to direct coaches' attention to the technical elements of the tennis serve.

Error! Reference source not found.

Figure 15 Circle highlighting the ball toss and release phase during the video

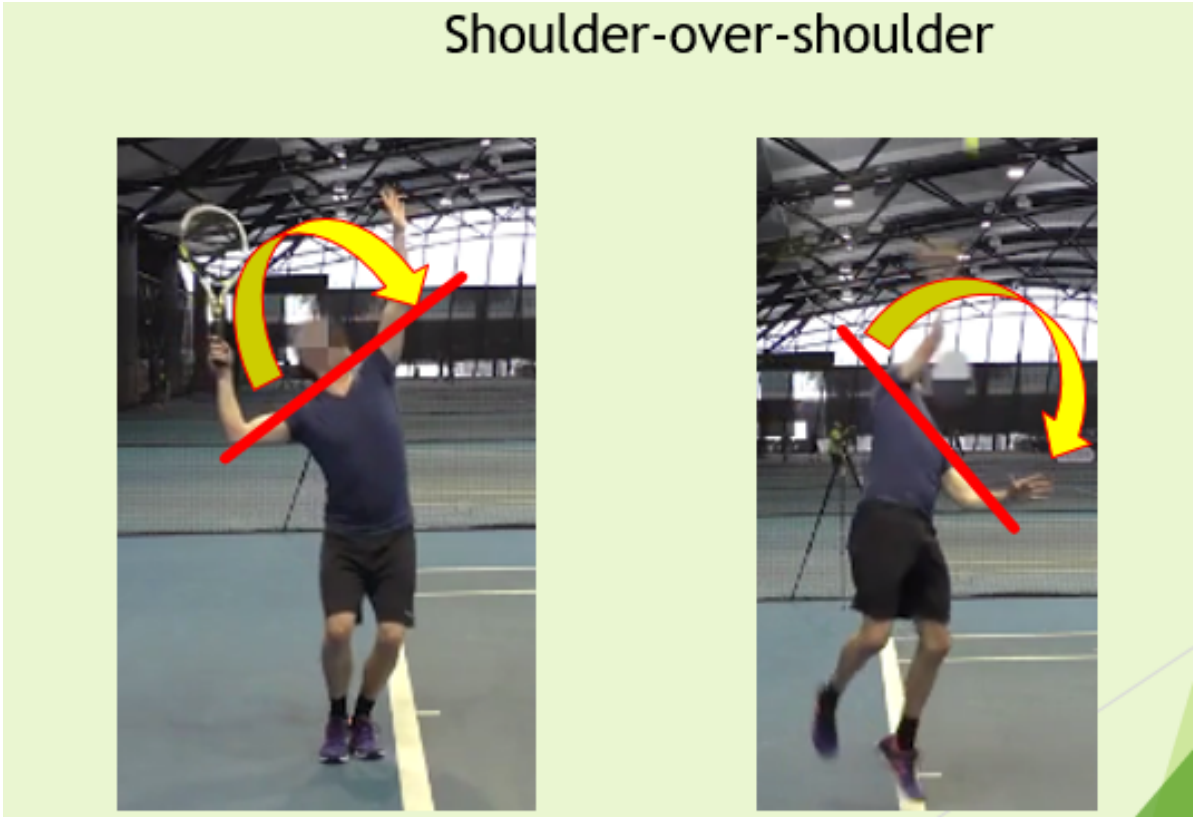


Figure 16 Red line and yellow arrow highlighting shoulder-over-shoulder element of the serve on the slide

In addition, it has been previously reported in soccer that verbal information in combination with visual cues in video-based training enhanced motor skill acquisition (Janelle et al., 2003). The current study applied imaginary guidance in the form of the explicit instruction which aimed to develop a causal relationship between specific cues and pattern of movement (R.C. Jackson & Farrow, 2005). In addition to slides and visual information such as videos, narrated slides were included to reinforce coaches' learning.

6.2.4. The construction of the online training course

The online coaching course was built in the internal Victoria University Learning Management System. The content of the course was based on the existing tennis scientific literature about the flat tennis serve technique, knowledge of expert coaches captured in Study one and two of this investigation, and the recommendations from coach education research (Elliott et al., 2003; Knudson, 2007; V.E.D. Pinheiro & Simon, 1992; Pluim & Safran, 2004; Reid, Elliott, & Crespo, 2015; Roetert et al., 2009). The course consisted of a "welcome" message, the introduction, eight learning sessions, eight quizzes, and an evaluation questionnaire at the end. The number of training sessions was guided by similar research on athletes: eight sessions over four weeks (Farrow et al., 1998; Tayler et al., 1994). Coaches were suggested to complete two sessions per week. The structure of the course was as follow:

Week 1:

- Introduction + Session one (phases overview, the preparation phase) + Quiz.
- Session two (the swing phase, the backswing) + Quiz.

Week 2:

- Session three (the forward swing) + Quiz.
- Session four (the impact phase) + Quiz.

Week 3:

- Session five (the follow-through phase) + Quiz.
- Session six (kinetic chain) + Quiz.

Week 4:

- Session seven (connections part one) + Quiz.
- Session eight (connections part two) + Quiz.
- Evaluation of the course.

In the “welcome” message, coaches were provided with overview of the course, importance of the knowledge provided, duration, technical requirements, schedule, and researcher’s contact details if technical support is required. Guidance to navigate through the Victoria University learning management system was developed and provided to participants to ensure effectiveness of the process.

Figure 18 demonstrates one of the pages from the guide. The introduction session explained the structure of the course in detail and the learning outcomes: 1) Identify four phases of the serve; 2) Identify the key biomechanical features of every phase; 3) Identify the connection between biomechanical features; 4) Learn the correct kinetic chain occurrence; 5) Identify biomechanical strengths and weaknesses in the technique for various levels of the players.

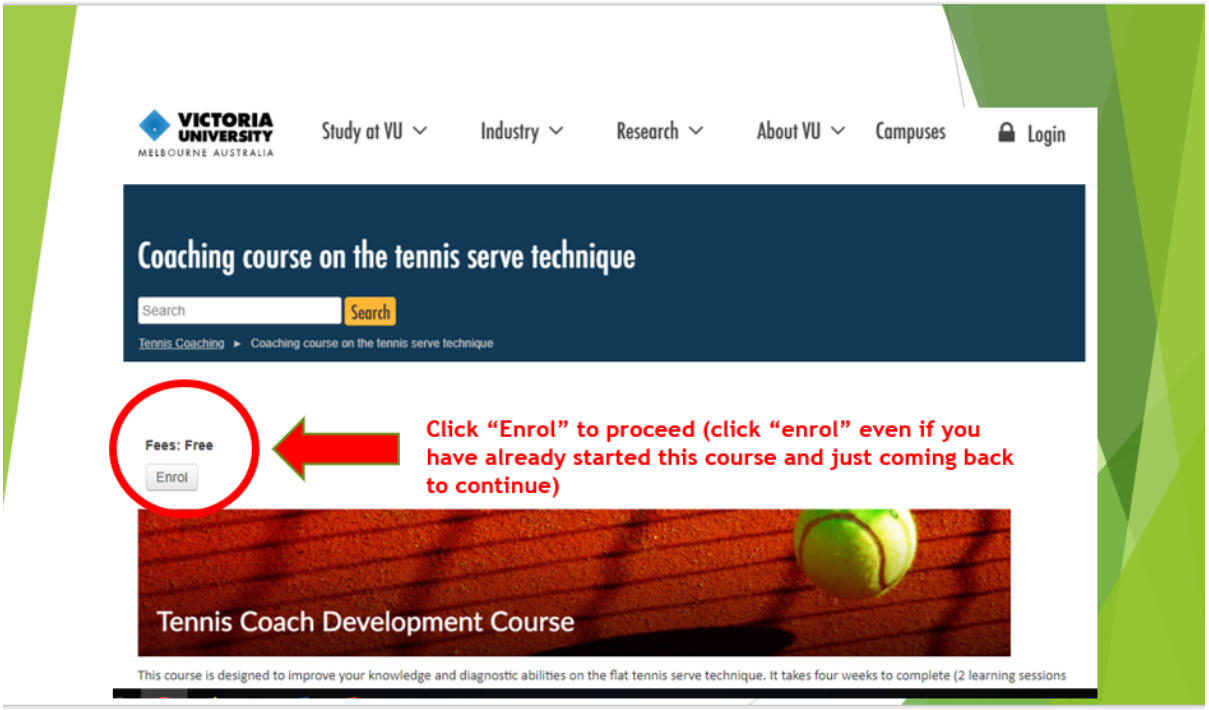


Figure 17 Guidance to navigate through Victoria University learning management system - example

Every session included narrated presentation slides and a Quiz at the end. Narrated presentations were constructed using Microsoft PowerPoint Presentation software (Microsoft10, 2015). Where necessary, the videos of the flat tennis serve analysed by coaches in Study two were included to reinforce coaches' learning and understanding of the presented material. The video was constructed using the Adobe Premier Pro software program (AdobePremierePro, 2018). The process of video recording was explained in detail in Section 5.2 of this thesis. The video and imaginary examples of the diagnostic of the serve technique were based on expert coaches' practical knowledge and their diagnostic analysis provided in Study two that represent the direct knowledge transfer from expert coaches to novice coaches. The guiding visual attention method was implemented in the training course where key cues for information were highlighted on the screen (Farrow et al., 1998; Grant & Williams, 1996; A. M. Williams & Burwitz, 1993) and presented in detail in Section 6.2.3 earlier.

The Quizzes were developed according to the learning outcomes for each session. The participants were required to achieve 100% on each Quiz to proceed to the next session. If coaches received less than 100%, they had an opportunity to repeat the Session and the Quiz. The Quizzes consisted of multiple-choice questions and

included text multiple choice questions (Figure 19) and the imagery questions (Figure 20).

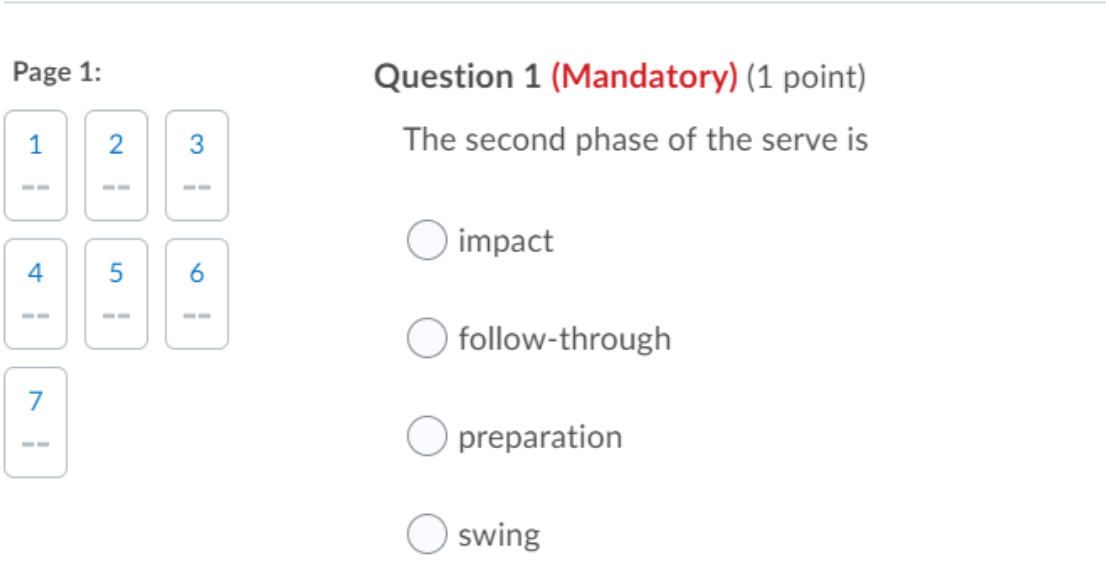


Figure 18 Example question from quiz for session three

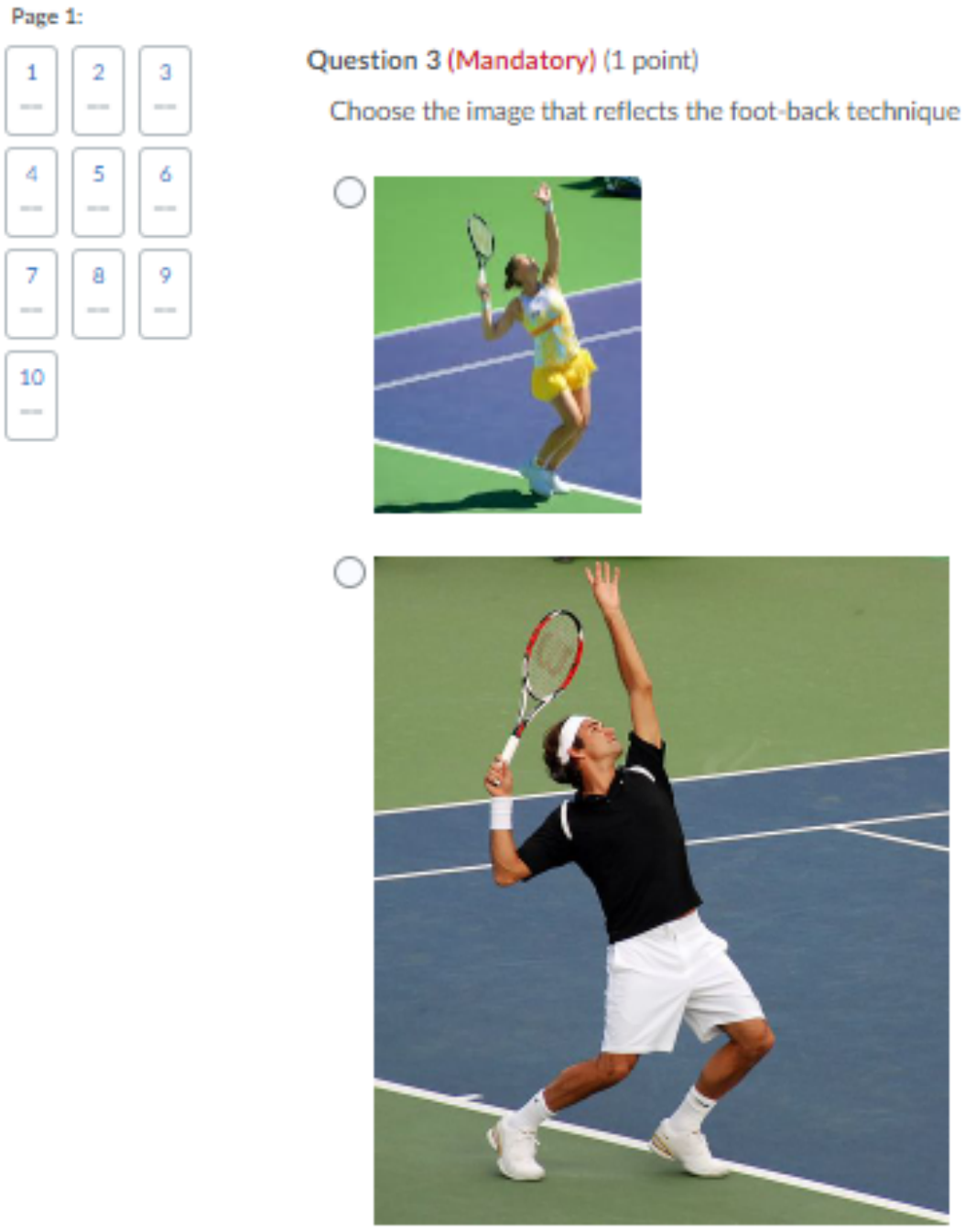


Figure 19 Imagery question - example

The first six Sessions of the course were based on the combination of experts' practical knowledge and existing tennis scientific literature about the flat tennis serve technique (Elliott et al., 2003; Knudson, 2007; V.E.D. Pinheiro & Simon, 1992; Pluim & Safran, 2004; Reid et al., 2015; Roetert et al., 2009). Sessions One to Five focused on the phases of the tennis serve, and corresponding to each phase, the technical elements,

and the diagnostic of strengths and weaknesses as it has been previously emphasised that novice coaches need to learn the common technical errors and recognise technical phases that are critical for performance (V.E.D. Pinheiro & Simon, 1992). Session Six explained the kinetic chain of the tennis serve technique. Session seven and eight focused on the connections between key technical elements.

The Evaluation Questionnaire was inserted at the end of the course to collect feedback from the participants about the course and their learning. It included questions such as: “How useful was this course for your understanding of the tennis serve technique?”; “How would you rate your knowledge about the connections between the biomechanical features before you took this course?”; and “How useful was the "connections” concept for your understanding of the tennis serve technique?” The full list of questions and suggested answers are presented in (Appendix M Evaluation Questionnaire Online Course). *Every session started from demonstrating the learning outcomes. Figure 21 provides an example of the slide that was at the beginning of every session.*

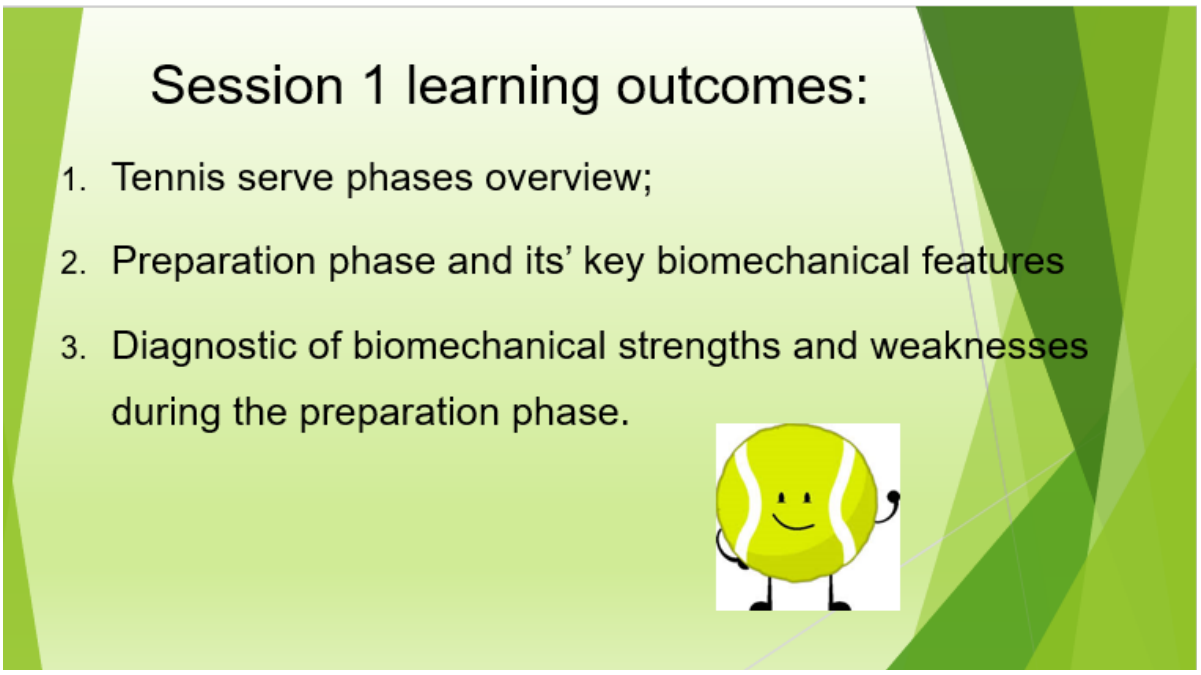


Figure 20 Learning Outcomes Session 1

After that the learning material was presented such as narrated slides including text, images and videos followed by the diagnostic of the material presented in the session and a quiz.

Figure 22 demonstrates one of the slides explaining diagnostic of the preparation phase. To better illustrate the structure of the online course, the example of session number three is presented in Appendix N Session Three Online Course. The comments inserted below every slide represents voice instructions for the narration process.

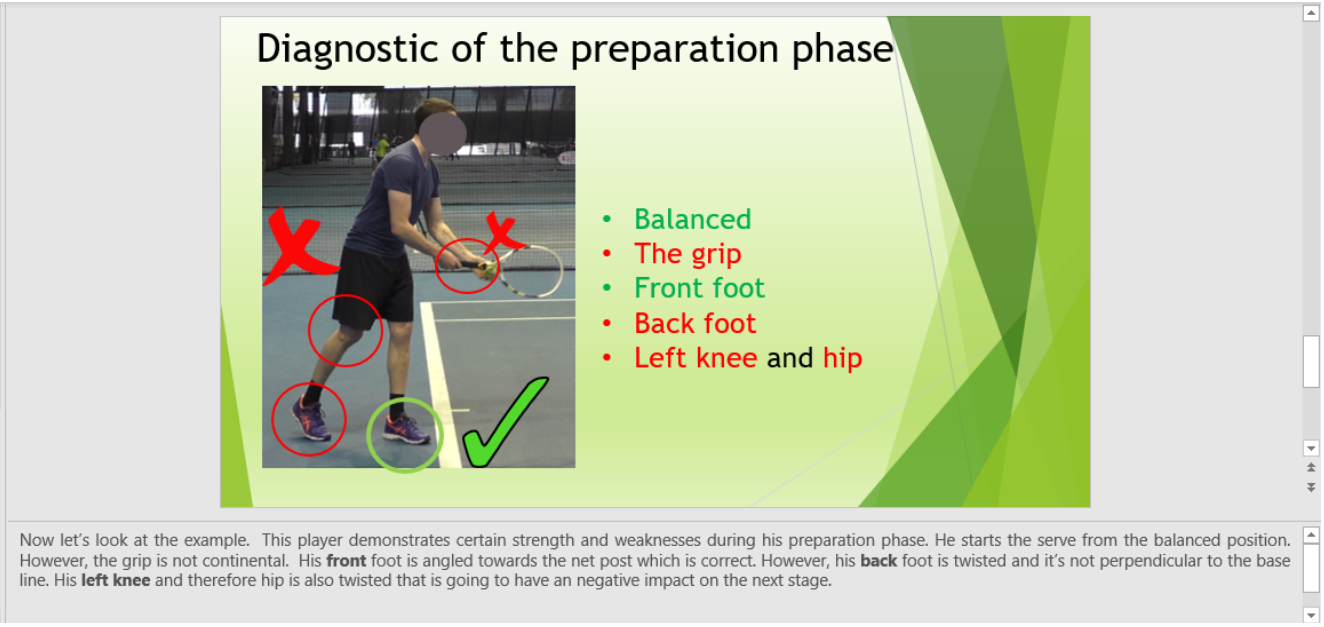


Figure 21 Diagnostic of the preparation phase – example with narration notes

6.2.5. Measure

Video-based test and an in-depth interview were performed to measure the effectiveness of the online training course.

6.2.5.1. Video-based test

A video-based test was used during the interview to collect coaches' practical knowledge and diagnostic skills before and after training. The test consisted of three separate videos in which beginner, intermediate and high-performance players performed the tennis flat tennis serve. The construction process and participants

selection were identical to the process described in Section 5.2. Figure 23 provides an example of the video.

Figure 22 Beginner player video for video-based test

6.2.5.2. Interviews

Two one-on-one semi-structured interviews were conducted with all participants and were similar to phase one of Study two. In both interviews, participants completed the video-based test by watching three videos and analysing verbally the technique of every player. The interview guide (Appendix B Interview Guides – Study Three) was designed and implemented to ensure comparability and consistency between interviews (A. Smith et al., 2015). It consisted of three parts: introduction, analysis and conclusion. During the introduction part, the procedure was explained, and participants asked any questions they had. The analysis part included questions about the strengths and weaknesses of every player: “What are the technical strengths of this serve?”, and “What are technical weaknesses of this serve?” The clarification questions were asked to reach full understanding of the coaches’ opinion. For example: “When you said “rocking motion”, what did you mean by that?”, “Can you explain for me what do you mean by “hooked toss” please?”

During the conclusion part of the interview, the next steps for the research were explained to the coaches such as member checking procedure, and the online training course. Each interview lasted between 15 to 20 minutes.Three pilot interviews with

three different tennis coaches were conducted to determine the appropriateness of the online training course, estimate timing of the task, and to increase the general robustness of the data collection stage.

6.2.6. Participants

Nine novice tennis coaches were recruited to complete the online coaching course (one female, eight males) who were aged between 19 to 55 years (M=40 ± 11 years). Coaches were involved in coaching activities for an average of 8 ± 5 years and have played tennis for an average of 7 ± 6 years. The multiple-standard participant sampling method was used for the recruitment and selection of participants (Bian, 2003; D. F. Jones et al., 1995; A. Smith et al., 2012; Solomon & Lee, 1991; Woorons, 2001). The criteria for participant recruitment and selection were:

- Professional certification: all coaches must have coaching professional certification at the beginner level (Graduate Professional Coach ATPCA);
- A minimum of one year of coaching experience; and
- All participants must be currently coaching.

Previous studies have successfully applied this method for selection of coaches to examine their diagnostic skills of technique in volleyball (Bian, 2003) and golf (A. Smith et al., 2012) and instructors' perceptual capacity in tennis (Woorons, 2001).

6.2.7. Procedure

The procedure consisted of the following steps: invitation, consent form and questionnaire, the first interview (pre-test), online training and the second interview (post-test) which is shown on Figure 24.

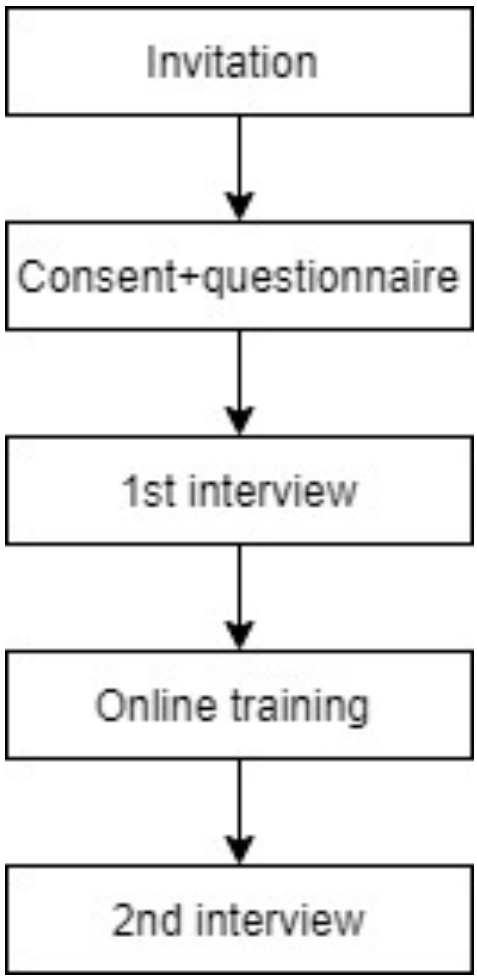


Figure 23 The procedure

Initially, an invitation to participate in this investigation was distributed via the Australian Tennis Professional Coach Associations such as ATPCA and Tennis Australia, the author's personal professional tennis network and the supervisors' professional network. Once a potential participant contacted the researcher, the information to participants (Appendix O Information to Participant - Online Course) was sent to the participant. As soon as the participant agreed to participate, the Consent Form (Appendix P Consent Form - Online Course) and a short Questionnaire (Appendix R Questionnaire Online Course) were provided via email. The

Questionnaire collected demographic data such as coaches' certification level, age, gender, playing and coaching experience.

After the participants signed the Consent Form and completed the Questionnaire, the time for the first interview was organised according to the participant's availability. Both interviews were performed via Zoom (Yuan, 2012), in which coaches were shown three videos (video-based test Section 6.2.5.1. and interviews Section 6.2.5.2.) and asked to identify the technical strengths and weaknesses for every player.

The think-aloud protocol (Section 3.6. of this thesis) was implemented during the interviews where tennis coaches were instructed to express their thoughts, which was the key factor when applying this method (De Groot, 1978; K.A. Ericsson & Simon, 1993). The order of players was the same as in Study two of this investigation: intermediate, high performance and beginner. The level of the players was not disclosed to the participants. It was possible that some coaches were familiar with players on the video that could affect their response, although the faces were hidden on the videos. To address this potential bias, every coach was asked whether they recognised the player in the video prior to conducting the diagnostic task. The response from all coaches was negative. The participants had an opportunity to spend as much time as they liked viewing the video of each player and repeat the video as many times as they needed.

After completing the interview, participants were provided the link to the online training course via email. Coaches were instructed to complete the course over four weeks (two sessions per week). Three days after a participant completed the course, the second interview was conducted.

6.2.8. Data analysis

All nine interviews were transcribed verbatim. Minor editing was performed on the transcribed data such as changing the participant's name from "Jason" to "Coach 1" to ensure anonymity. Member checking was applied to assure the credibility and reliability of the data: all interview transcripts were sent to the participants to review and verify the interpretive accuracy (Braun & Clarke, 2006). If the script returned with a correction from the participant, it was edited and sent again to the participant until final confirmation was received.

A mixed method research design (Johnson et al., 2007) was used to examine coaches' practical knowledge and diagnostic ability before and after the course. The data was analysed using the Grounded Theory Approach in the combination with the Constant Comparison Method (B. G. Glaser & Strauss, 1967) followed by quantitative analysis (Poisson Regression and Generalised Mixed Linear Model Analysis). The schematic algorithm of the data analysis process and its description was presented in Figure 4 in Section 3.4. of this thesis.

The transcribed verbal reports were analysed using NVIVO 12 qualitative software (NVIVO, 2018). The data coding process started from familiarisation with data. Line-by-line coding was performed first to analyse coaches' diagnostic ability by identifying strengths and weaknesses that they mentioned during the interview. After that, the second round of line-by-line coding was performed to examine coaches' practical knowledge by identifying meaning units related to the tennis serve technique. Following on; the meaning unit categories and sub-categories were created, their properties and dimensions were then analysed and relationships between them were established. During this process the Constant Comparison Method of data analysis was applied in order to relate sub-categories to a higher category and achieve data saturation (S. M. Kolb, 2012). The identification of causal relationships between findings has been applied to allow deeper analysis of the coaches' practical knowledge.

The quantitative analysis was performed to identify differences between coaches' practical knowledge and diagnostic ability before and after the intervention (Pallant, 2016). The quantification of the qualitative data was performed first to transform qualitative data into numerical data. This quantification was achieved by counting the number of different elements identified by the coach in each component of coaches' practical knowledge such as technical elements, body elements, phases, concepts, key flexion points, and reasoning chains. The number of identified strengths and weaknesses was also counted to analyse coaches' diagnostic ability. The numerical data were then imported into the Statistical Analysis System (SAS Studio, University Edition, Version 9.4, SAS Institute, Cary, NC) to conduct Poisson regression with the generalised mixed linear model procedure (Proc Glimmix).

The seven components were modelled as repeated measurements of a single dependent variable with the following mixed model. The fixed effects in the model were the component (seven levels) interacted with dummy variable representing the treatment effect (to estimate the treatment for each component) and the dummy variable interacted with the age of the coach (a linear numeric effect), to estimate the mean modifying effect of age on the seven components. A separate analysis was also performed with the fixed effect for age replaced by separate effects for playing years and coaching years. The modifying effects were estimated for two between-subjects deviations (W.G. Hopkins et al., 2009). The random effects were coach identity (nine levels), coach identity interacted with the treatment effect (to estimate individual differences in the treatment effect; coach identity and this effect were given an unstructured covariance matrix to allow them to be correlated), and the component interacted with coach identity (to account for the repeated measurements represented by the component). The residual error was specified to allow for over- or under-dispersion of the Poisson-distributed counts.

In the absence of a practically important threshold for an increase in coaching diagnostic skills and practical knowledge, magnitudes of effects were evaluated via standardisation using magnitude thresholds provided by the appropriate between subject SD, here the pre-test SD averaged across the seven measures using the random effects in the mixed model. The thresholds for small, moderate, large, very large and extremely large increases were 0.2, 0.6, 1.2, 2.0 and 4.0 times this SD (W. G. Hopkins, S. W. Marshall, A. M. Batterham, & J. Hanin, 2009).

Sampling uncertainty in the estimates of effects is presented as 90 per cent compatibility limits. Probabilistic decisions about true (large-sample) magnitudes accounting for the uncertainty were based on one-sided hypothesis tests of substantial magnitudes (Lakens, Scheel, & Isager, 2017). The p value for rejecting a hypothesis of a given magnitude was the area of the sampling z distribution of the effect statistic with values of that magnitude. Hypotheses of substantial decrease and increase were rejected if their respective p values were less than 0.05. If one hypothesis was rejected, the p value for the other hypothesis was interpreted as evidence for that hypothesis, since the p value corresponded to the posterior probability of the magnitude of the true effect in a reference Bayesian analysis with a minimally informative prior (W.G. Hopkins, 2019; W.G. Hopkins & Batterham, 2018). If neither

hypothesis was rejected, the magnitude of the effect was considered to be unclear, and the magnitude of the effect was shown without a probabilistic qualifier.

6.3. Results

This study developed and examined the effectiveness of an online coach training course which aimed to improve coaches' knowledge and understanding of the flat tennis serve technique. The results are presented in two sections: qualitative analysis and quantitative analysis.

6.3.1. Qualitative analysis

The schematic representation of coaches' practical knowledge before and after the intervention was developed as demonstrated in Figure 25 and Figure 26. Examples of meaning units were included in figures to illustrate the type of data from which sub-categories were formed such as "low ball toss does not give him enough time to step in", and "angle 10 degrees off". The design was based on a previous study in golf where sub-categories and meaning units were presented (A. Smith et al., 2015).

The pre-test practical knowledge model is demonstrated on Figure 25 and consisted of five components: "technical elements", "body elements", "phases", "concepts" and "reasoning chains". These components formed two categories: "biomechanical factors" and "functionality".

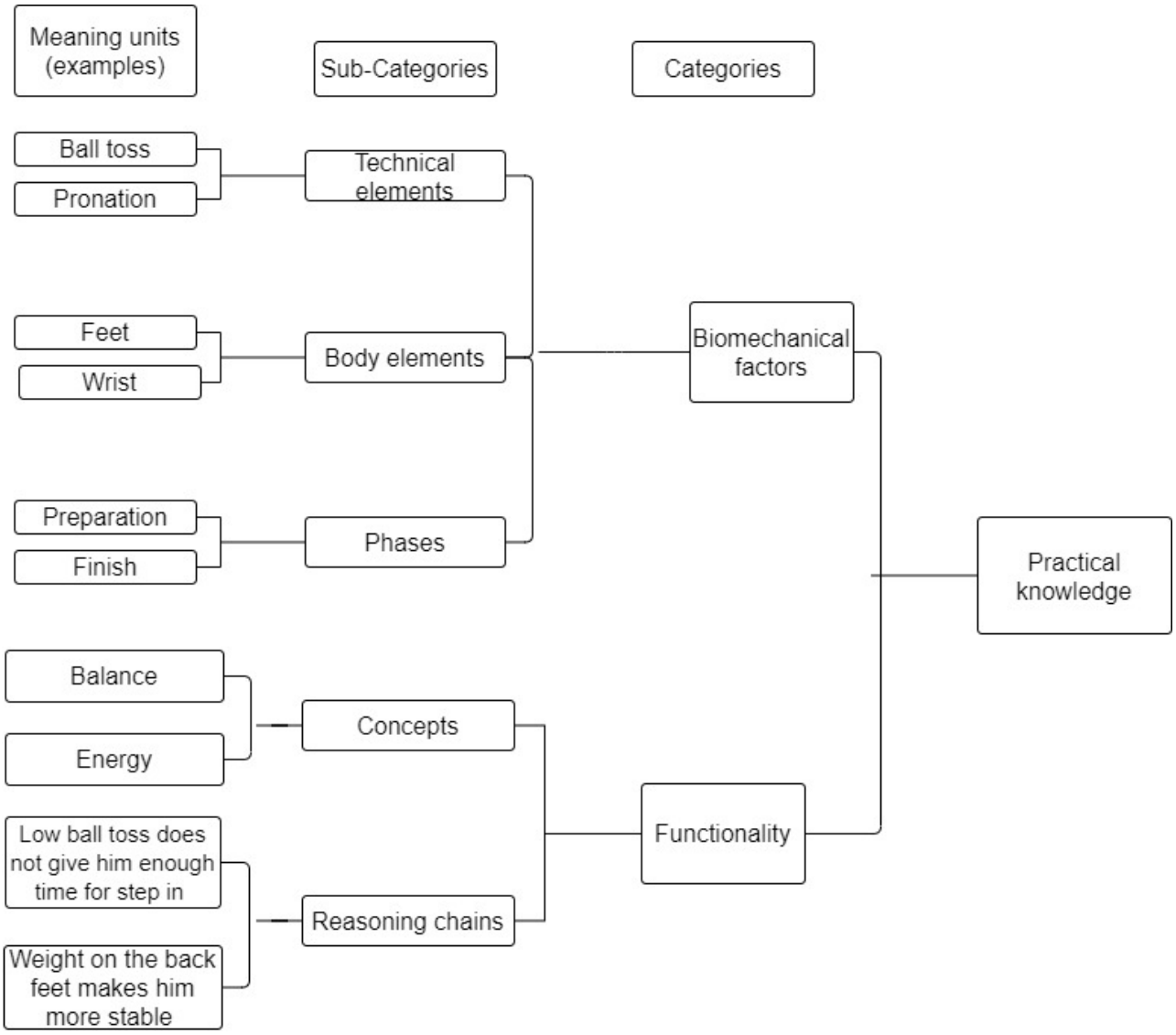


Figure 24 Coaches' practical knowledge model - pre-test

The post-test practical knowledge model included six components: "technical elements", "body elements", "phases", "key flexion points", "concepts" and "reasoning chains" as show on Figure 26. These components formed two categories: "biomechanical factors" and "functionality".

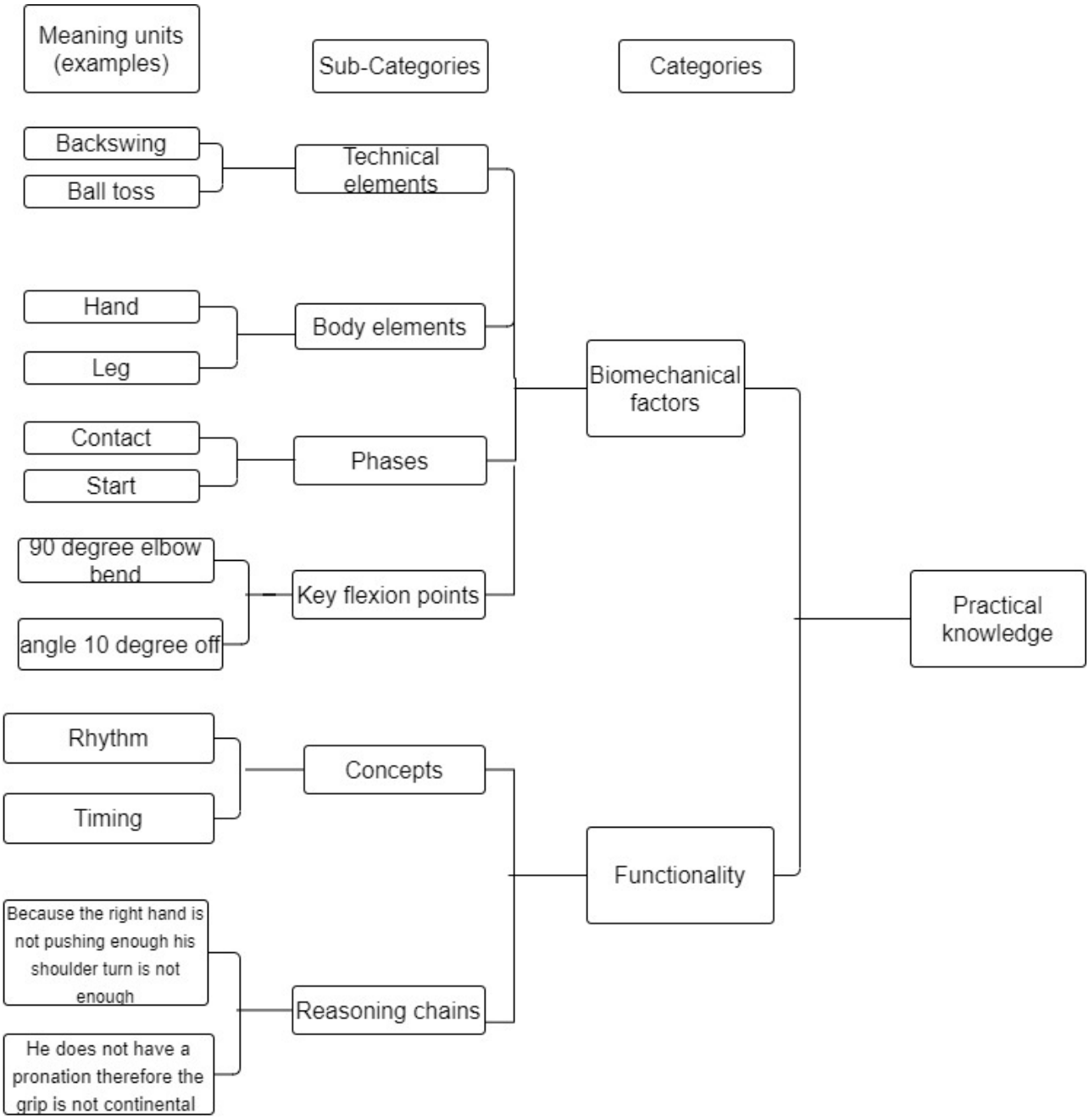


Figure 25 Coaches' practical knowledge model - post-test

The "biomechanical factors" category represented coaches' practical knowledge of technical cues from biomechanics perspective that they applied during the technique analysis, and included "technical elements", "body elements" "phases" and "key flexion point" (for post-test model only) components. The detail analysis of these components is presented in Tables 26-29. The "☑" in the tables indicates that the element was identified and "☐" that it was not mentioned by coaches.

The “technical elements” component represented coaches’ practical knowledge on tennis serve technical terminology. Table 26 compares the existing in the scientific tennis literature technical elements (Elliott, 2006; Elliott et al., 2003; ITF, 2007; Kovacs & Ellenbecker, 2011; Tennis Australia, 2013) and those technical elements identified by coaches during pre-test and post-test interviews. The differences and similarities between coaches’ knowledge before and after the intervention were identified. For example, some technical elements were mentioned during both the pre-test and post-test such as “grip”, “stance”, and “ball toss”. Some technical elements such as “co-ordination of 2 arms”, “shoulder and arm alignment”, and “led drive” were identified during the post-test only.

Table 26 Technical elements of the flat serve: online course

Technical element	Pre-test	Post-test
Grip	☑	☑
Stance	☑	☑
Ball toss	☑	☑
Co-ordination of 2 arms	☐	☑
Trophy position	☑	☑
Knee flexion	☑	☑
Hip rotation	☑	☑
Trunk rotation	☐	☐
Swing	☑	☑
Type of swing	☑	☑
Position of the non-racket arm	☐	☑
Loading	☑	☑
Leg drive	☐	☑
Shoulder-over-shoulder	☑	☑
Twist	☐	☐
External/internal rotation of the shoulder	☑	☑
Shoulder angle at maximum external rotation	☐	☐
Shoulder and arm alignment	☐	☑
Non-racket arm movement	☐	☑
Upper arm elevation	☑	☑
Elbow extension	☐	☐
Elbow flexion	☐	☑
Weight transfer	☑	☑
Wrist flexion/extension	☐	☐
Shoulder angle between arms and trunk	☐	☑
Pronation (as a general concept)	☑	☑
Forearm pronation	☐	☑
Hip extension	☐	☐
Contact point	☑	☑
Landing in arabesque position	☐	☑
Follow through	☐	☑
Eye focus	☐	☑
Separation angles	☐	☑
Type of serve (step-up/platform)	☑	☑

The “body elements” component included the body parts that coaches mentioned during the analysis. Table 27 demonstrates body elements that were or were not identified during the analysis of the tennis serve. The left column demonstrates body elements involved in the tennis serve motion identified in the tennis scientific literature (Elliott, 2006; Elliott et al., 2003; ITF, 2007; Kovacs & Ellenbecker, 2011; Tennis Australia, 2013). Similarities and differences between pre-test and post-test were identified. Some body elements were mentioned during both pre-test and post-test

such as “knee”, “hip”, and “shoulder”, some elements were identified during post-test only such as “head”, “toe”, and “forearm”.

Table 27 Body elements of the tennis serve: online course

Body element	Pre-test	Post-test
Knee	☑	☑
Hip	☑	☑
Shoulder	☑	☑
Elbow	☑	☑
Wrist	☑	☑
Leg(s)	☑	☑
Arm(s)	☑	☑
Chest	☑	☑
Feet (foot)	☑	☑
Hand(s)	☑	☑
Back	☐	☑
Eyes	☐	☑
Upper body	☐	☐
Body	☑	☑
Head	☐	☑
Trunk/torso	☐	☑
Toe	☐	☑
Fingertips	☐	☐
Forearm	☐	☑
Palm	☑	☑

The “phases” component refers to the phases of the tennis serve that coaches identified during the diagnostic process. Table 28 demonstrates the phases existing in the tennis scientific literature and those identified by coaches during pre-test and post-test interviews. The differences and similarities in the “phases” component were identified. The “start”, “release”, “cocking”, “acceleration” and “contact” were mentioned by coaches during both pre-test and post-test interviews. The “loading” and “deceleration” phases were identified by coaches during post-test only.

Table 28 Phases of the tennis serve: online course

Phase	Pre-test	Post-test
Start	☑	☑
Release	☑	☑
Loading	☐	☑
Cocking	☑	☑
Acceleration	☑	☑
Contact	☑	☑
Deceleration	☐	☑
Finish	☑	☑

The “key flexion point” referred to quantitative biomechanics that coaches mentioned during the analysis: the emphasis on measurements and quantification when analysing movements of the human body (Jennett, 2008). Quantitative biomechanics of the flat tennis serve was identified by coaches during post-test only: “90 degrees with elbow and bicep”, “45 degrees start”, “angle 10 degrees off”, “45 degrees tilted forward”, right hand 90 degrees” and “90-degrees elbow bend”.

Overall, differences in coaches’ knowledge were identified in all components of the “biomechanical factors” between the pre-test and post-test where new elements, phases and key flexion points were mentioned during the post-test. The second category “functionality” demonstrated the coaches’ understanding of tennis serve technique: the ability to apply concepts when analysing the technique and ability to see how one element affects another in the kinetic chain. It included “concepts” and “reasoning chains” components.

The “concepts” component was formed by biomechanical and physics concepts that coaches applied when analysing the technique. Table 29 demonstrates the concepts that coaches applied when analysing technique. The differences and similarities between the pre-test and post-test existed. For example, the “balance”, “rhythm”, “timing” and “power” were mentioned by coaches during both the pre-test and post-test. The “kinetic chain”, “consistency”, “dynamics”, “accuracy” were mentioned during the post-test interview only.

Table 29 Concepts identified by coaches: online course

Concept	Pre-test	Post-test
Kinetic chain	☐	☑
Balance	☑	☑
Consistency	☐	☑
Energy	☑	☑
Rhythm	☑	☑
Dynamics	☐	☑
Timing	☑	☑
Power	☑	☑
Accuracy	☐	☑
Stability	☐	☑
Gravity	☐	☑
Speed	☑	☑
Angular momentum	☐	☑

The “reasoning chains” component represented coaches' understanding of the tennis serve technique and the connectedness of their practical knowledge. The examples of reasoning chains were: “ball toss AND time AND position”, “wrist angle AND grip”, and “energy AND stability”. The “AND” means that one part of reasoning chain ends, and another starts. It was found that wider range of reasoning chains were demonstrated by coaches during post-test interview compared to the pre-test. The numerical characteristics of this component will be presented in Section 6.3.2.

To better illustrate reasoning chains, the extractions from two interviews (before and after the online program) are presented below. The information related to reasoning chains is highlighted with Italic.

Basically, starting form the ground and work my way up when analysing the serve. So some good things that I can see on the action is that there is a weight transfer going back and then coming forward - the little rock which is good. Toss can be a little bit higher. It looks he’s got quite shortened sort of action so I guess for the short action it is probably ok. Things to work on it is in a feet basically. From what I can see that right foot is stepping too early in the action. *It’s coming up before the toss is going up so his hips are already sort of squared* as he goes into the action which is obviously influencing everything. So basically I would start looking at that. The other thing is he is coming a little be out of his knee bend and moving forward. With his *left foot as well*

which is obviously taking away from his leg drive as he gets into the action. But then he also got a lower toss so I think the toss I would not focus too much on because the *moment you work on legs the toss, you know, fix as well*, so I would start definitely with the legs there. To be honest it doesn't look as natural step up as well so I think it could be good to look at both a platform and a step up and to see which one is more comfortable for him. So it did not look to be comfortable to be honest. It's not very explosive and that just a legs, I would say, all legs. It's exactly where I would start. You know, the action is too quick and toss is a second…so as I said before, connecting with that starting with *legs would address the toss and getting him into the court* a little bit especially with the first serve. He is also not getting anything from his front leg - there is nothing coming out, it's all back leg drive" (Pre-test interview, player one, Coach four).

"So for player number 1 most of the things are not there. Starting at the beginning there is *not enough weight transfer forward which is thereby affecting the leg drive so that's why he falls out of his stance half through* as he is about to make a contact in the forward motion of the action. As he is going through the forward swing *his feet come out because he hasn't had enough weight transfer forward and knee not getting ready for leg drive.* There are other thigs as well. *There is no shoulder-over-shoulder…probably because of the legs* I would mostly *focus on the legs cause it's the beginning of the initial phase of the kinetic chain and because of that it's affecting everything* I guess. It also looks like the grip is not right, there is no separation between the forearm and the racket on contact - it's just straight line except the *elbow is a little bit bent which potentially tells that the grip is wrong*. He does lend on the front leg which is good. I guess the toss is good, it's a nice forward toss and there is a weight transfer backwards, but he is not coming back (Post-test interview, player one, Coach four).

In addition to the results presented above, other qualitative observations have been made. For instance, some coaches expressed confusion during the pre-test interview when analysing the high-performance player as they "never worked with this level before" (Coach 3). Or "In my opinion it's a perfect serve" (Coach 6). Thus, they could not identify any technical weaknesses. Also, four coaches acknowledged that usually they use a slow-motion video recording when analysing the player's technique and "it was hard to see certain technical elements such as pronation in a standard motion"

(Coach 4). Finally, it was noticed that coaches analysed the serve differently: every coach had unique diagnostic approach. Examples of the approaches were: start from the feet and moved up, look at certain body parts, and checking phases of the serve only.

Coaches' diagnostic ability was also examined by analysing the strengths and weaknesses provided by coaches. The qualitative analysis revealed that coaches provided a wider range of strengths and weaknesses during the post-test interview. The examples of strengths included: "timing for his backswing", "pronation", and "ball toss is in front". The examples of the weaknesses were: "too much rotation", "left hand is not straight when tossing the ball", and "not driving upwards and forward". It was also noticed that coaches analysed players quite differently during interviews. For instance, "stance" and "leg drive" were identified as strengths by one coach and as weaknesses by another.

Overall, differences were detected in all components of coaches' practical knowledge in which coaches demonstrated a wider range of technical and body elements, concepts and reasoning chains during the post-test compared to pre-test. The key difference between the pre-test and post-test models were the "key flexion points" component that appeared only in the post-test model.

6.3.2. Quantitative analysis

The quantitative analysis was performed to identify difference between coaches' practical knowledge and diagnostic ability before and after the intervention (Pallant, 2016). Mean values for pre-test measures are presented in Table 30.

Table 30 Mean and standard deviation for pre-test measures representing practical knowledge and diagnostic skills of the nine coaches

Measure	Mean ± SD
Practical knowledge	
Body elements	9.2 ± 3.2
Concepts	3.0 ± 2.1
Phases	3.9 ± 2.9
Reasoning chains	4.2 ± 2.5
Technical elements	15.9 ± 5.2
Diagnostic skill	
Strengths	16.3 ± 7.2
Weaknesses	13.8 ± 6.7

The effects on each component and the mean all the components were expressed in percent units and are presented in Table 31. Moderate, large and very large treatment effects on components of coaches' practical knowledge and diagnostic skills were found. All effects were clearly substantial with sufficient precision for the true magnitudes to be very likely or most likely. The largest effect was found in the reasoning chain component which was very large. The modifying effects were trivial but unclear.

Table 31 Effects on each component of coaches' practical knowledge and diagnostic ability. Data are mean, ±90% CL (%)

	Effect (%)	Decision[a]
Treatment effects	.	
Body elements	65, ±37	Large**
Concepts	93, ±71	Large**
Phases	52, ±52	Large*
Reasoning chains	98, ±62	Very large**
Strengths	72, ±31	Large**
Technical elements	75, ±32	Large**
Weaknesses	50, ±29	Moderate**
Mean of the above	71, ±23	Moderate**
Modifying effects	.	
2SD playing years	4, ±27	Trivial
2SD coaching years	-3, ±26	Trivial

90%CL, approximate 90% compatibility limits.
[a]Observed magnitude with magnitude-based decision. Clear effects are shown with the probability of a true substantial magnitude (*very likely, **most likely).

The quantitative analysis demonstrated that the online coaching course was an effective tool for improving coaches' practical knowledge and diagnostic ability of the tennis serve technique. The largest increase was detected for the reasoning chains component, demonstrating that the course was especially effective in improving coaches' understanding of the tennis serve technique and the connections between the technical elements.

The results from the evaluation questionnaire are presented in tables 32 to 36. Table 32 demonstrated that for one coach the course was "moderately useful", five coaches

assessed it being “very useful” and three coaches considered it to be “extremely useful”.

Table 32 Question 1: How useful was this training course for your understanding of the tennis serve technique?

Answer	%	Count
Extremely useful	33.33%	3
Very useful	55.56%	5
Moderately useful	11.11%	1
Slightly useful	0.00%	0
Not at all useful	0.00%	0
Total	100%	9

Table 33 showed that all coaches heard about the connection between biomechanical features of the serve before the online course. Only one coach clearly understood the connection, four coaches indicated that they understood it, and four others selected the “somewhat understood it” option.

Table 33: How would you rate your knowledge about the connections between the biomechanical features before you took this course?

Answer	%	Count
Clearly understood it	11.11%	1
Understood it	44.44%	4
Somewhat understood it	44.44%	4
Had heard about it but didn’t understand it	0.00%	0
Never heard of it	0.00%	0
Total	100%	9

Table 34 demonstrated that the module about the connection between elements was considered extremely useful for understanding of the tennis serve technique for six coaches and very useful for other three coaches.

Table 34: Question 3 How useful was the "connections" concept for your understanding of the tennis serve technique?

Answer	%	Count
Extremely useful	66.67%	6
Very useful	33.33%	3
Moderately useful	0.00%	0
Slightly useful	0.00%	0
Not at all useful	0.00%	0
Total	100%	9

Table 35 demonstrated coaches' perception of the complexity of the course. Four coaches assessed the course as "not very complex", three considered it as "somewhat complex" and two coaches perceived it as "very complex".

Table 35 Question 4: Rate the level of complexity of the course

Answer	%	Count
Extremely complex	0.00%	0
Very complex	22.22%	2
Somewhat complex	33.33%	3
Not very complex	44.44%	4
Not complex at all	0.00%	0
Total	100%	9

Table 36 showed the degree to which coaches were going to apply the knowledge on the connection between the biomechanical features of the serve in their coaching practise. The feedback demonstrated that six coaches estimated the likelihood as "extremely likely" and three coaches answered "moderately likely".

Table 36: Question 5 How likely you are going to apply the knowledge about the connections between the biomechanical features in your coaching?

Answer	%	Count
Extremely likely	66.67%	6
Moderately likely	33.33%	3
Slightly likely	0.00%	0
Not very likely	0.00%	0
Not likely at all	0.00%	0
Total	100%	9

When answering the question “What did you like most about this course?”, the coaches expressed the following: “clear and precise presentation”; “diagrams and videos”; “clear, concise information, very organised and helpful for participants”; “the breakdown of different phrase, really break the technique up which made identify issues much easier”; “connections - a hundred coaches will see a hundred different things, but seeing the connection between them all will connect the hundred things. It allows coaches to have a similar voice”; “with very clear explanation, going step by step and very easy to understand”; “sections where connecting the biomechanical features sum up the contents nicely”; “the use of images and the links to YouTube were quite useful” and “simple and easy”.

When answering the question “What are some ways this course could be improved?”, the coaches provided the following recommendations: “It will be great if the video quality can be improved”, “More videos of each part as you go through the questions and quizzes as well as final video showing everything done perfectly and stopped and labelled!”, “Start an intervention and what drills /activities could be used to improve things. I think this would be a valuable extension”, “Should consider doing forehand and backhand too in the future”, “Moving videos as we are watching movements rather than stationary snaps. More foot-up actions. A second level to this would be correct physiological names for movements and use of anatomy. There is a connection between biomechanics and physiological history of individuals e.g. injuries or musculoskeletal inadequacies, which for individuals is often prior knowledge. A

version for junior (hot shot) age would be helpful too", "Very good to me....", "Videos explaining the contents would be useful", "The wording in a couple of terms was a bit different than what I am used to but in general is a very good tool for an intermediate coach" and "More videos of different players".

6.4. Limitations

The researcher took all necessary measures to present information as accurately as possible, in order to decrease the influence of the researcher's biases. This was done by applying various methodologies to assure the validity and reliability of the research that was described in Section 3.8. of this thesis. However, some unavoidable limitations were still present.

Firstly, it should be noted that the correctness of the analysis was not assessed in the current investigation. Thus, more research is needed to identify the correctness of coaches' analysis and to understand the expert-novice difference at a deeper level. Secondly, the researcher did not have control over factors relating to coaches' knowledge such as coaching experience, playing experience, self-education, as coaches could obtain more information between the pre-test and post-test interviews. Undoubtedly, the improvements in coaches' knowledge and diagnostic ability could be partially due to these factors as well as familiarisation with the video presented during the interview. However, the results demonstrated large improvements for all participants. Therefore, it was concluded that the course itself was the major reason for the findings that revealed enhanced coaches' knowledge and diagnostic ability. Finally, it should be acknowledged that due to the ethics requirements, players' faces on the test videos were blacked out which could affect their diagnostic skill as coaches did not have access to the full movements such as head position and gaze of the player.

6.5. Summary of key findings

The aim of the current study was to develop and demonstrate the effectiveness of an online training course which aimed to improve coaches' practical knowledge and diagnostic ability and understanding of the flat tennis serve technique. As a result, the following important findings have emerged.

Firstly, this study developed a unique online coach education course that brought an original contribution to tennis coach development. The course combined the video-

based training and orienting visual attention methods, the whole-part-whole learning model, problem-based learning approach with videos, slides and quizzes to enhance the effect of the course on coaches' knowledge, and diagnostic skills.

Secondly, the following components of coaches' practical knowledge were identified: "technical elements", "body elements", "phases", "key flexion points", "concepts" and "reasoning chains". The analysis of every component demonstrated the specificity of knowledge for every component before and after the online course. These results can be applied by a coach education provider to evaluate the effectiveness of their coach courses.

Importantly, evidence supporting the effectiveness of the course has been provided in this study. The qualitative and quantitative analysis demonstrated that the online coach education course significantly improved coaches' practical knowledge and diagnostic ability of the tennis serve technique. The strongest effect of the course was found on coaches' understanding of the technique and their knowledge of the tennis serve biomechanics. Therefore, the course may be applied in tennis coach development to improve coaches' practical knowledge, understanding and diagnostic skill of the flat tennis serve technique.

A few unexpected observations have been made. It was concluded that novice coaches should be allowed to coach not only beginner and intermediate players, but also high-performance players to become experts more quickly. Moreover, every coach had a unique approach for the diagnosis of the serve although they completed the same coaching certification. The coaches also provided the opposite diagnosis when analysing the same player. These findings highlight the need for more research to gain a deeper understanding of expert tennis coaches' diagnostic strategies and approaches.

Finally, the feedback provided by the coaches revealed that the online course was perceived as an effective tool for improving their understanding of the technique. Recommendations provided by coaches can be used in the future to improve the quality of the course.

Chapter 7 Discussion

This thesis has set out to explore the differences which exist in the technical knowledge of novice tennis coaches compared to their expert counterparts with a particular focus on the flat serve technique. The author was interested to know what novice and expert coaches know, how they diagnose the technical deficiencies in tennis players, and whether the complex technical knowledge required to coach the flat serve could be effectively learnt by novices using an online training program.

Despite current research on coaches' expertise, there has been little investigation into the declarative and practical knowledge of tennis coaches. Furthermore, limited research has been done in online coach education in tennis although online learning provided additional opportunity to support and benefit the development of coaches (Oakley & Twitchen, 2018). This thesis aimed to overcome this gap in knowledge by examining coaches' knowledge and diagnostic skills, and then to provide practical application of the findings by using mixed method research design. This chapter will review and discuss the findings in the light of scientific literature followed by the integration and a discussion of the results as one coherent story.

7.1. Study 1: Internal Model

The aim of the first study of this thesis was to investigate the internal models of expert and novice tennis coaches and to identify the key distinguishing characteristics between each level. The discussion of the qualitative findings will be followed by the discussion of the quantitative findings.

7.1.1. The Qualitative Findings

When investigating the internal model of the flat serve, the results revealed that expert and novice tennis coaches' internal models of the flat tennis serve technique consisted of the following components: "technical elements", "body elements", "phases", "key flexion points" (which formed "biomechanical factors" category) and "concepts", "important elements" and "reasoning chains" (which formed "functionality" category). This finding demonstrated the specificity, depth and complexity of coaches' knowledge on the tennis serve technique. By identifying components of coaches' internal model, the present investigation brings a valuable contribution to the research on tennis coaches' knowledge as no similar research has been demonstrated previously. These findings may be applied in coach development as it was established that the internal

model played a critical role in the diagnosis of technical errors in sport skills (V.E.D. Pinheiro & Simon, 1992).

The “biomechanical factors” of the flat serve identified by the participants in this study included “technical elements”, “phases”, “body elements” and “key flexion points”. These components will be discussed individually in the following paragraphs. The analysis of the “technical elements” component revealed that there were both noticeable differences and similarities between experts and novices. Table 5 demonstrated the existing expert-novice difference in coaches’ knowledge on technical elements of the flat serve. In addition, novice coaches made errors in tennis technique terminology such as “wrist and elbow pronation” instead of “forearm pronation”, and “not step-up serve” instead of “platform serve”. This indicated that the knowledge of novice coaches on many technical components was limited compared to the experts. There are two possible explanations for this difference.

Firstly, the difference in certification level and, consequently, in the amount of knowledge that coaches possessed, as expressed by, the technical terminology in the interviews. It is possible that during the coach education course, novice coaches were not provided with all technical elements that exist in the current scientific literature, and, therefore, did not have them in their internal model. This assumption may be validated in future research by accessing coach education curriculum and content and comparing the information that has or has not been provided to novice coaches.

The second potential explanation could be the level of athletes that expert and novice coaches usually work with. In this study expert coaches worked only with high performance athletes at the time of their interview. Before reaching the high-performance level, certain technical skills should be mastered by a tennis player to perform the flat serve to a high standard such as eye focus and coordination of two arms. Thus, it’s possible that expert coaches focused only on the technical parameters relevant to the high-performance player. By contrast, novice coaches worked with beginner and intermediate players and, therefore, emphasised the technical elements relevant to these levels such as “eye focus” and “weight transfer”. Thus, it can be concluded that the level of the athletes that the coach usually works with affects a coaches’ internal model. This conclusion is supported by previous research in golf that reported that coaches’ practical knowledge was influenced by the level of the athletes they observed (Sherman et al., 2001).

These findings can be applied in tennis coaching to facilitate novice coaches' learning and development. Novice coaches should be included in coaching high-performance tennis players in addition to beginners and intermediates. This will allow them to acquire the necessary knowledge and experience to become experts more quickly. In this scenario, the training of high-performance players can be done via mentoring where the expert coach works with the novice coach during the training session to ensure the quality of learning. The findings can also be applied in tennis coach education as this investigation demonstrated which technical elements need to be added to the novice's internal model to increase their level of expertise.

Similarly to the technical elements discussed above, similarities and differences between experts and novices were identified: some of the body elements were mentioned by both groups (e.g. "knee", "hip", "shoulder") and some were identified by experts (e.g. "head", "toe", "fingertips") or novices only ("eyes"). Interestingly, neither experts nor novices identified "torso" and "palm" body elements which could be due to the content of the coach education program and can be validated only via an examination of the coach education curriculum and content. Thus, it may be concluded that the knowledge difference between expert and novice coaches existed in the "body elements" component as well. In addition to the difference mentioned, the noticeable link between technical elements and body elements were noticed. For example, novice coaches did not identify the "trunk rotation" technical elements. As a result, body element "trunk" was not mentioned as all. The technical element "eye focus" was identified by novice coaches only and, as a result, the body element "eyes" was also named only by novices. This finding demonstrated that coaches' knowledge of technical and body elements was interconnected. This knowledge can be applied in coach education to improve coaches' internal model on technique.

The "phases" component demonstrated coaches' knowledge of the phases of the tennis serve technique. It was found that coaches identified eight phases of the tennis serve ("start", "release", "loading", "cocking", "acceleration", "contact", "deceleration" and "finish") (Elliott, 2006; Elliott et al., 2003; ITF, 2007; Kovacs & Ellenbecker, 2011; Tennis Australia, 2013). This finding aligned with a previous study in sprint running that revealed that coaches divided sprinting technique into three distinct phases: "start", "pick-up/drive" and "maintenance" (Thompson et al., 2009). However, this study examined the knowledge of expert coaches only. By contrast, the present investigation

made a comparison between novices and experts which extends the current knowledge on coaches' expertise. It was found that both experts and novices identified all eight phases of the serve. This led to the conclusion that novices' knowledge was similar to the knowledge of experts in the "phases" component of the internal model. In the same way as the "technical elements" component discussed above, this similarity could also be related to the content of coach education courses. It is possible that novice coaches learnt all the phases of the serve during the course, and, therefore, demonstrated similar knowledge to experts.

The "key flexion point" components demonstrated coaches' knowledge of quantitative biomechanics. Interestingly, only experts mentioned the quantitative biomechanics parameters which demonstrated that expert coaches were much more knowledgeable in biomechanics compared to novices. This lead us to conclude that one of the important distinguishing characteristics between expert and novice coaches is the knowledge of biomechanics and the ability to apply this knowledge to the tennis serve technique. This finding can be utilised in coach education as it indicates that in order to become an expert, novice coaches should learn biomechanics fundamentals and how to apply them to the technique.

Overall, the "biomechanical factors" category partially supported the previous research in golf, tennis, swimming and sprint running (Giblin, 2014; Leas & Chi, 1993; Sherman et al., 2001; A. Smith et al., 2012; A. Smith et al., 2015; Thompson et al., 2009). For example, categories "club motion" and "body motion" categories were reported in a study that examined coaches' internal model of golf swing. These categories consisted of different key technical parameters such as "wrist joint" (A. Smith et al., 2015). Another study determined three characteristics of a successful golf swing: "ball flight", "club motion" and "body motion" (A. Smith et al., 2012). Four characteristics of good technique were found in sprint running: "posture", "hip position", "ground contact" and "arm action" (Thompson et al., 2009). The study in swimming demonstrated four components that coaches associated with ideal freestyle stroke: "body position", "arm stroke", "kick" and "breathing" (Leas & Chi, 1993). Thus, identified in the present study the "biomechanical factors" category aligned with previous research and provided answers as to what coaches knew about the tennis serve technique from the biomechanics perspective. However, it extended previous research by introducing additional parameter which has not been previously identified such as the "key flexion

points". This finding may inspire future research on coaches' internal model of other technical skills in tennis such as slice, or other sports. The identified expert-novice difference in "biotechnical factors" component can be applied in coach education to improve knowledge of novice tennis coaches.

The second category of the internal model was "functionality" and included "concepts", "important elements" and "reasoning chains" components. This category referred to the coaches' understanding of the tennis serve technique, the ability to recognise the connections and relationships between technical cues and apply various biomechanical and physics principles to the technique.

The "concept" component demonstrated that coaches' internal model included the knowledge of biomechanical and physics concepts. It was found that expert coaches demonstrated greater knowledge in physics and biomechanics compared to novices who mentioned only "kinetic chain" and "energy". Therefore, one of the key distinguishing characteristics between levels was the experts' extensive knowledge of biomechanical and physics concepts. This finding can be applied in coach education as it demonstrated that novice coaches should learn various biomechanical concepts and be able to apply them to the tennis serve technique.

The "important elements" component demonstrated coaches' knowledge of important for tennis serve technique elements. The elements that were mentioned by expert coaches as important such as "leg drive", "driving up and forward", "body weight transfer", and "knee bend" are also emphasised as important in the tennis serve biomechanical literature (Kovacs & Ellenbecker, 2011).

This finding confirmed the result of the previous study in tennis that revealed elements of the tennis serve that coaches considered important: "ball toss positioning", "trunk rotation", "leg drive" and "pronation" (Giblin, 2014). In the current investigation "ball toss", "leg drive" and "pronation" were also emphasised as important. However, the aforementioned study identified four important elements compared with 18 in the present study. Therefore, this finding extends current knowledge in tennis by demonstrating a greater number of important for tennis serve elements.

Interestingly, expert coaches did not consider the "ball toss" to be an important element, although it was established that the position of the ball toss impacted the location and variability of the serve (Hervas, 2014). This finding can be explained by

the level of athletes that coaches usually work with. Experts worked with high performance athletes only at the time of their interview, and it was possible that they emphasised the technical parameters relevant to the high-performance level. Ball toss is one of the pre-requisites of the higher standard serve. Thus, expert coaches did not identify the “ball toss” as important. It can be concluded that the level of the athletes that coaches usually work with affected coaches’ internal model. More research is needed to understand the “important elements” component at a deeper level and to examine technical elements that are important for different level of athletes.

In addition, it was reported that expert coaches outperformed novices by identifying a wider range of important elements compared to novices who mentioned only “ball toss”, “good trophy position” and “grip”. This finding led to the conclusion that expert coaches possessed a deeper understanding of the key elements that affect the quality of the tennis serve technique. Therefore, one of the key distinguishing characteristics between experts and novices was the knowledge of aspects of the serve that play an important role in the serve technique development. This finding emphasised that, in addition to technical knowledge, novice coaches needed to understand the technique and be able to recognise the most important cues. This knowledge can be applied in coach education by teaching novice coaches to understand which aspects of the serve they should emphasise during coaching practise.

The “reasoning chains” component represented the connectedness of the coaches' knowledge, the ability to understand the connection between the technical elements, and how one element may affect another. This component demonstrated that coaches possessed a good understanding of how the tennis serve was performed. Expert coaches emphasised a wider range of reasoning chains compared to novices. This led to the conclusion that another key distinguishing characteristic was experts’ greater understanding of the serve. Therefore, to become experts, novice coaches needed to learn how the technical elements were connected and affected each other as it may improve the quality of coaching and, as a result, the athletes’ performance.

In addition to the components discussed above, interesting observations have been made during the qualitative analysis. Firstly, when describing the technique, expert coaches moved from more general concepts such as “rhythm”, “kinetic chain”, and “linear drive” to specific technical elements or movement. By contrast, novices focused on separate elements from the beginning such as “grip”, “ball toss”, and “racket

position". This observation led to the conclusion that the expert coaches possessed greater understating of the technique and perceived it as a whole movement rather than separate technical parts. This finding provided us with a new insight into coaches' declarative knowledge as previous studies have not identified this element of expert coaches' knowledge.

Another noticeable observation was that expert coaches provided various "coaching hints" and discussed the technical elements in connection with injury prevention, stress resistance, the individual characteristics of the player and strategy. For example, they discussed the ball toss and the strategic intention after the serve: serve and volley or serve and stay back. Novice coaches did not demonstrate such an ability. This demonstrated that in addition to deeper understanding of the tennis serve technique, experts could see the tennis serve as part of the entire game, rather than an isolated technical component. This also showed a deep and more extensive knowledge of expert coaches in relation to the tennis serve technique and its relationship with other parts of the game.

Finally, the expert coaches mentioned throwing biomechanics when explaining the serve technique. For example: "I train a lot with getting them on the medicine ball to keep that good throwing action into the shot" (Expert Coach 3); "I believe that if you've got a good grip, and you got good throwing mechanics, the rest will look after itself" (Expert Coach 4); and "I have a few non-negotiables…. Do they have a good throwing motion, a good throwing action?" (Expert Coach 1). Interestingly, novice coaches did not mention the throwing mechanics. This finding supports the previous conclusion that in addition to pure technical knowledge the expert internal model included understanding how the serve works, and their ability to apply other concepts to the coaching of the flat serve technique.

Overall, it was reported that a coaches' internal model of the serve included not only knowledge of the technical components, but also the knowledge of how it worked which has not been revealed in previous studies on the internal model. Therefore, this finding expanded the current knowledge by demonstrating that coaches' internal model included the "what is known" component in addition to how the knowledge has interacted in a functional way. These findings provided a valuable contribution to the knowledge on coach expertise and may inspire more research on the coaches' internal model in tennis and other sports. The key distinguishing characteristics between

experts and novices were identified in the experts' superior knowledge of the tennis serve technical elements, body elements, quantitative biomechanics, biomechanical and physics concepts, important elements and the understanding of the connection between technical elements. Therefore, these findings extended the existing knowledge on the internal model by identifying the key distinguishing parameters and providing the detailed analysis of the model that has not been demonstrated previously in tennis. The practical implication of these findings could be applied to coach development as it has demonstrated the knowledge that novice tennis coaches should develop to become experts.

7.1.2. The quantitative findings

These findings from the quantitative analysis of the results supported this conclusion that the significant difference in "concepts", "key flexion points" and "reasoning chains" parameters demonstrated that the key difference between expert and novices included expert coaches' greater knowledge in concepts and biomechanics and their greater understanding of the connection between the elements. This conclusion was in alignment with the previous research in tennis in which visual observational patterns of expert and novice coaches were examined (Reid et al., 2015). It was reported previously that while assessing the technique of the tennis serve, expert coaches focused on the centre of the trunk, whereas novices observed many random attributes such as the ball, elbow, torso. Potentially, expert coaches focused on the centre of the body in order to see the whole movement when novices focused on separate parts. This conclusion was supported by previous research in climbing where expert and novice coaches' observed a climber and their visual search behaviour was examined (Mitchell et al., 2020). It was reported that expert coaches focused on the proximal regions whereas novices concentrated more on distal regions. Hence, the present study supported this finding by revealing the expert coaches' superior ability to perceive the movement as a whole, and to understating the connection between technical elements of the tennis serve.

The results of the current investigation also confirmed previous work in swimming where experts significantly outperformed novices in the number of reasoning chains ($p = .026$) (Leas & Chi, 1993). Similar result was also reported in research on expertise of radiologists, where more experienced radiologists demonstrated a significant increase in the number of reasoning chains compared to less experts ($p = .05$) (Lesgold

et al., 1998). The experts' greater understanding was supported by previous research on situational awareness where the expert-novice paradigm has been applied on warfare technicians (Randel, Pugh, & Reed, 1996). It was reported that experts spent more time than novices on understanding the situation rather than providing the best solution possible. Experts were able to integrate cues and knowledge rather than concentrate on individual elements of the skill.

This finding led me to an interesting conclusion that the primary attributes of tennis coaching expertise is the ability to understand the relationships between technical elements, and how this operates for an individual player when applied to the physics and biomechanical principles. Two possible explanations can be suggested for this unexpected outcome.

Firstly, the content of coaching development courses should be taken into consideration as all participants completed the Tennis Australia Coaching Certification (Junior Development for novice coaches and High Performance for experts). Courses for expert coaches may include detailed learning content on the physics, complex biomechanics and its application to the serve technique. It is also possible that in High Performance courses, coaches are taught to recognise the connection between technical elements and how one element affects another in the kinetic chain. To validate this assumption the detailed analysis of the novices and experts' coaching courses such as content, structure, duration, assessments should be performed, which was outside of the scope of this study. It can be still concluded that tennis coaching expertise was determined by the ability to understand the functionality of the serve: application of biomechanical principles to technique, understanding the connection between technical elements and its relationships, the ability to see the movement as a whole rather than separate parts. This conclusion aligns with the constraints-led approach (Renshaw, Chow, Davids, & Hammond, 2010).

The emerged "functionality" component of the expert tennis coaches' internal model in this study supported the constraints-led approach as "functionality" implied the understating of the relationships between technical elements of the tennis serve. In addition, motor skills are often "self-organized" by the individual, meaning that variation in the tennis serve technique of the elite tennis players can be easily observed, although it is built using the technical fundamentals they have been taught by their coach. Therefore, there is a need for novice coaches to understand how the serve

works as every player is different. Undoubtedly, novices need to develop the knowledge of "what to assess" in the technique such as technical elements and phases. However, to reach expert's level they need to gain an understanding of how the tennis serve works to be able to recognise variations in individuals' performance and provide effective feedbacks. This includes knowledge of the technical elements that play an important role in understanding each element of the serve and how they are connected to each other. By acquiring this knowledge, novice coaches will be able to see the serve as a whole and apply their "reasoning chain" components to their coaching. As a result, the feedback that novice coaches provide to athletes may be improved.

The small sample size (n=8) can be potentially seen as the limitation of the current research. However, this study is more qualitative in nature, as the quantitative method was applied to reach a deeper understanding of the data. A small sample size was appropriate for qualitative research as the primary goal was to gain insight into the coaches' knowledge rather than to estimate a population value (Bian, 2003; Leas & Chi, 1993). In addition, this sample size was previously used in previous studies that successfully identified the expert-novice difference (Bian, 2003; Giblin, 2014; Mitchell et al., 2020). The results cannot be generalised beyond the flat tennis serve technique. Generalisations also should not be made to the entire tennis coach population due to the small sample size. The internal models developed in this thesis represented the knowledge of eight Australian tennis coaches holding the Tennis Australia certification. The internal models were a general representation of the knowledge of participants in this particular group of coaches. Every coach has their own unique internal model. This generalisation was necessary to build the most detailed tennis coaches' internal model and to compare internal models between expert and novice tennis coaches who participated in this investigation.

It should be acknowledged that the nature of "think aloud" protocol can potentially influence the quantity of the data collected. From the interviewer's observation, experts felt more comfortable and confident when thinking aloud compared to novices. For example, beginner Coach 2 expressed the challenge of this technique: "…it's hard to talk and analyse…" which may reduce the amount of data collected.

It also should be noted that this study did not assess the correctness of the knowledge as the focus was on the expert-novice difference. It remains unknown what tennis coaches exactly know about the various phases of the flat serve and the technical concepts therein. For example, both groups mentioned all eight phases. However, their understanding about every phase was not examined. Thus, future research may be conducted on components of the internal model individually to get an even deeper understanding of coaches' declarative knowledge.

7.2. Study 2: Diagnostic Ability

The ability of coaches to observe the sport technique and identify strengths, weaknesses and recommendations for corrections is an essential skill in tennis coaching (ITF, 2016). The aim of this investigation was to examine the diagnostic ability and practical knowledge of expert and novice tennis coaches of the flat tennis serve technique and to identify the key distinguishing characteristics between levels of expertise. As a result, several important findings have been found.

Firstly, a new online questionnaire was developed and applied to examine coaches' practical knowledge and diagnostic ability on technique. Although the online questionnaire did not allow the researcher to clarify terminology and reach data saturation compared to the interview method, it still can be considered an effective tool to examine coaches' practical knowledge and diagnostic ability as the results of phase two (Online Questionnaire) aligned with the results of phase one (Interview). Online survey have begun to be used as a method to assess coaches' effectiveness at the level of the individual as well as at a larger population scale (Tooth, Nielsen, & Armstrong, 2013). For example, the Coaching Effectiveness Survey developed by the Institute of Executive Coaching and Leadership has been recognised as a reliable tool to evaluate coach effectiveness (Tooth et al., 2013). Another study successfully used an online questionnaire to examine the perception of coachees on their goals (Gallant & Gilham, 2014). An online questionnaire was also used in a study examining Canadian coaches' decision to obtain coaching certification (Gurgis, Kerr, & Stirling). In addition, an online questionnaire was also used to examine coaches' knowledge of drills in track and field (Whelan et al., 2016). Despite this research, no studies have examined online questionnaires to assess coaches' knowledge and diagnostic ability on technique in tennis. Therefore, this study makes a unique and original contribution to the tennis coaching expertise knowledge and tennis coach development, and has

the potential to stimulate further research to extend the validity of the questionnaire used in this investigation and to apply it to another sports.

Secondly, the expert and novice models representing coaches' practical knowledge is unique. Previous studies have examined the diagnostic ability of expert and novice coaches in volleyball, tennis and swimming (Bian, 2003; Giblin, 2014; Grgantov et al., 2013; Leas & Chi, 1993; Woorons, 2001; Yanofsky, 1998). However, no models of coaches' practical knowledge have been developed in these studies. Therefore, the current investigation makes an important contribution to the field of coaches' knowledge. In addition, the models allow the researcher to systematise coaches' practical knowledge and analyse it from a unique perspective.

Thirdly, interesting observations have been made when applying the expert-novice paradigm to compare practical knowledge of expert and novice coaches. It was found that both experts and novices demonstrated their knowledge of technical elements, body elements, and phases of the tennis serve. They also applied biomechanical and physics concepts as well as cause and effect relationships in the analysis (reasoning chains) that illustrated their understanding of the technique. The main distinguishing characteristic between experts and novices was their ability to apply quantitative biomechanics in analysis: the "key flexion point" parameter was identified for experts only. Thus, it was concluded that expert tennis coaches possessed superior knowledge of advanced biomechanical principles and the ability to apply it during the diagnostic process. This conclusion confirmed results from previous studies in swimming (Leas & Chi, 1993) and climbing (Mitchell et al., 2020). The study in swimming examined the diagnostic ability of expert and novice swimming coaches and reported that only expert coaches were able to apply biomechanical and hydrodynamic parameters during the analysis of freestyle swimming stroke technique (Leas & Chi, 1993). The experts' more complex knowledge of the principles of movement compared to novices was also demonstrated in climbing where cognitive-perceptual process of expert and novice climbing coaches (Mitchell et al., 2020).

Another interesting observation was that novice coaches focused more on the basic technical elements such as "ball toss" and "contact point" whereas experts operated with more complex technical terminology during the analysis such as "horizontal separation angle" and "kinetic chain". In addition, experts mentioned advanced

biomechanical concepts such as “magnitude of intensity”, whereas novices only applied basic concepts such as “timing”. This finding demonstrated that expert coaches possessed more extensive practical knowledge and advanced understanding of the tennis serve technique compared with novice coaches. This conclusion supported previous research in swimming in which diagnosis of the freestyle stroke was compared between novice and expert coaches (Leas & Chi, 1993). It was reported that experts demonstrated the ability to apply biomechanical and hydrodynamic parameters in their analysis while novices focused only on basic parameters. This observation led to the conclusion that expert coaches possessed advanced knowledge of biomechanics in comparison with novices. This difference can potentially be explained by the certification level and the depth of coaches’ knowledge. It is likely that during the coaching courses, novice tennis coaches did not receive information about complex biomechanical principles or advanced technical elements of the serve while expert coaches’ courses may encompass this information. As a result, novice coaches were able to apply only basic biomechanical concepts in their diagnostic process. This finding demonstrated that to reach expert levels, novice coaches need to develop advanced knowledge on the biomechanical principles to apply them during the diagnostic analysis of the serve technique.

Three important conclusions have been determined. Firstly, coaches’ practical knowledge included not only pure technical knowledge but also the understanding of how the tennis serve works: the “functionality” component. This finding extends our current understanding of coaches’ practical knowledge. It also provides an exciting opportunity to advance our knowledge on coach expertise by encouraging more research on coaches’ practical knowledge as this field is currently under investigated.

Secondly, the key distinguishing characteristic between expert and novice coaches in this study was their practical knowledge of advanced biomechanical principles and the ability to apply them when analysing technique. Thus, to become experts, novice coaches need to improve their knowledge in tennis serve biomechanics and learn how to apply it during analysis. In addition to knowledge development, novice coaches need to understand the tennis serve as it is an essential component of coaches’ expertise. These findings can be applied in tennis coach education to improve novice coach development. Further research is required in other sports to confirm these results.

Another important observation to arise from the quantitative analysis was that expert coaches significantly outperformed novice coaches in the number of technical elements, body elements, reasoning chains, concepts and phases in both parts of this investigation. The significant difference was identified in all parameters in both phases of the current study. The exception was “strengths” in phase two. This finding demonstrated that expert coaches possessed more extensive and deeper practical knowledge compared to novices as well as a greater understanding of technique, and they perceived the tennis serve motion more as a whole picture rather than separate fragments.

This finding is supported by several previous studies in different sports. For instance, in a comparison of diagnostic knowledge of expert and novice swimming coaches, it was reported that only experts provided cause and effect statements in their diagnostic analysis (Leas & Chi, 1993). Similarly, in volleyball, expert coaches used deeper cause and effect relationships when analysing the players’ performance (Yanofsky, 1998). A study in volleyball revealed that experts identified more components of volleyball spiking (experts=18, novices=7), body parts (experts=21, novices=11), more crucial issues, demonstrated deeper knowledge and a richer vocabulary during the analysis (Bian, 2003). Volleyball expert coaches exhibited longer reasoning chains in their diagnostic analysis (the mean length =3.1) when compared with novices (the mean lengths=2.04). For expert and novice radiologists, experts identified more findings related to the lung disease than novices (mean=9.09 for experts, mean=6.63 for novices) and more clusters (reasoning chains) (mean=2.47 for experts, mean=1.48 for novices) (Lesgold et al., 1998). Similarly, expert gymnastics judges demonstrated greater ability to understand the biomechanics of the motion than novices when predicting accuracy (error identification) was examined (Ste-Marie, 1999). Experts outperformed novices in anticipation of the upcoming events and error identification. It was proposed that expert gymnastics judges possessed better understanding of the biomechanics compared to novice judges (Ste-Marie, 1999). Hence, novice coaches need to develop the knowledge about technical cues and the connection between them which can improve their understanding of the technique, diagnostic ability, and practical knowledge.

The analysis of diagnostic ability also revealed interesting results. It was found that experts outperformed novices in the number of identified strengths, weaknesses and

recommendations for corrections in both phases of the current investigation. The significant difference was identified for weaknesses and recommendations in phase one, and for weaknesses, recommendations and strengths in Phase two. Based on this observation it was concluded that the analysis of expert coaches was more detailed and informative compared to novices.

This finding is supported by the previous research in volleyball where coaches' diagnostic ability of volleyball spiking technique was compared between two levels of expertise. It was shown that experts were more critical and evaluative in their analysis and identified more information cues compared to novices (experts = 56.2%, novices = 28.6%) (Bian, 2003). The significant difference in the number of identified technical weaknesses has also been previously reported in a study in tennis comparing visual search behaviour of expert and novice tennis coaches (Giblin, 2014). Experts and novices were asked to view the video recording of the tennis serve and to identify technical weaknesses. It was reported that expert coaches significantly outperformed novices in the number of weaknesses identified ($p=0.012$). Another study in tennis examined the difference between expert and novice tennis instructors in their analytical perception (Woorons, 2001). The participants were shown a video of tennis instruction and asked to describe what they observed. It was reported that the perception of expert instructors was more selective as they provided more details, evaluations and interpretations when watching the lesson. The experts' ability to identify more technical weaknesses was also demonstrated previously in gymnastics where recognition accuracy of experienced and inexperienced gymnastic instructors was examined (Imwold & Hoffman, 1983). The research demonstrated that experienced instructors were significantly more accurate in identifying the correct components than novices (54% accuracy for experts and 46% for novices). It should be noted that the correctness of the identified strengths, weaknesses and recommendations were not assessed in the current investigation. Thus, the greater number of strengths, weaknesses and recommendations can only indicate the depth of coaches' knowledge rather than the correctness of the feedback.

Despite all the studies discussed above, no research has attempted to provide a detailed analysis of the diagnostic ability of expert and novice tennis coaches on the tennis serve technique. Although the ability to identify technical errors in the technique have been examined previously in tennis (Armstrong & Hoffman, 1979; DiCicco,

1990), no studies have included strengths and recommendations for correction in the analysis which is an essential part of the diagnostic process. The current investigation provides an original contribution to the knowledge of coaches' diagnostic ability and has demonstrated that novices need to develop this skill.

The experts' ability to identify more technical weaknesses and strengths can be explained by two factors. Firstly, the greater playing and coaching experience can influence the diagnostic skill. It has been previously established in tennis that playing and teaching experience affects the ability to identify errors in the tennis serve technique (DiCicco, 1990). Participants with high levels of playing and teaching experience identified significantly more errors in the tennis serve compared to participants with less experience (DiCicco, 1990). In the current investigation, expert coaches possessed greater coaching and playing experience compared to novices. Another study in tennis also supported this conclusion in which the difference between experienced and inexperienced tennis teachers on their ability to identify common performance errors of the tennis forehand was examined (Armstrong & Hoffman, 1979). It was demonstrated that experienced teachers outperformed novices in the number of identified errors. An 85.5% accuracy was reported for experienced teachers and 83.7% accuracy for inexperienced teachers. Another research study examined the difference between expert and novice coaches' diagnostic ability of the shot-put technique (V.E.D. Pinheiro, 1990). It was concluded that experts possessed a superior knowledge base compared to novices. Expert's analyses were more extensive, diagnostic accuracy was better and they identified more errors (V.E.D. Pinheiro, 1990). It can be concluded that greater playing and coaching experience contributes to superior diagnostic skills.

Another explanation of experts' superior performance can be more effective visual search behaviour. It was previously reported in climbing that expert coaches demonstrated fewer eye fixations but of greater duration than novices, and they focused on the most relevant to the task information (Mitchell et al., 2020). It is possible that expert tennis coaches in the current investigation outperformed novices in the number of strengths, weaknesses and recommendations due to the more developed and efficient visual search behaviour.

An unexpected observation was made during the analysis of coaches' diagnostic ability in both phases of the investigation. It was detected that contradictions existed on identified strengths and weaknesses. For instance, novice coaches considered "leg drive" as a strength, but experts identified it as weakness for the beginner player. The "balance" was identified as a strength by the novice coaches and a weakness by the expert coaches. This finding demonstrated the difference in expert and novice coaches' practical knowledge and diagnostic ability. This finding was consistent with previous research in swimming where contradictions were reported on the identified features of the freestyle stroke (Leas & Chi, 1993). It was noticed that novice and expert swimming coaches assessed technique differently: on some features such as "body roll" experts and novices had exactly the opposite diagnosis. Contradictions in diagnostic skills were also observed in volleyball: novice coaches perceived cues of the technique as non-problematic whereas experts recognised the same cues as problematic (Bian, 2003).

These contradictions may be potentially explained by the difference in the knowledge base as there is connection between error identification skill and coaches' knowledge (J. Cote et al., 1995). Specifically, the difference in the internal model (the schematic representation of the ideal technique) affects coaches' perception of the motor skill and, as a result, feedback provided by them.

A motor skill diagnostic model has previously been suggested by Pinherio and Simon (1992) where they described the motor skill diagnostic process (V.E.D. Pinheiro & Simon, 1992). The process consisted of the following three steps. Initially, information cue acquisition initiates the recognition process: when observing the motor skill, a coach compares the actual performance with the ideal internal model of the skill. The second step is the cue interpretation. During this process, the interpretation accuracy depends on a coach's knowledge as it determines which errors can be identified or missed. The final step is based on the information collected during the first two steps, the feedback is formulated, and a coach provides a recommendation for error correction. Thus, accuracy of the motor skill diagnostic depends on the cues that a coach is able to recognise (V.E.D. Pinheiro & Simon, 1992). Therefore, when the internal model of a novice coach is incomplete or incorrect, it brings distortion to the entire motor skill diagnostic process from the beginning. The initial information cue acquisition (when a coach is observing the motor skill) will be followed by the

subconscious comparison of the actual performance with an incorrect internal model. As a result, this will affect the cue interpretation stage (error identification and selection) and, consequently, a coach will formulate incorrect feedback. The contradictions identified in the current investigation emphasised the importance for novice coaches in developing a correct and complete internal model from the beginning of the coaching pathway as it may reduce the errors in their diagnosis of technique and help them improve players' performance.

On the other hand, these variations could be considered from constraint-led approach where the motor skill is self-organised (Spittle, 2021). Under constraint-led approach methodology, the learner is seen as complex system that includes many components (degrees of freedom), and is able to develop functional movement solutions (Spittle, 2021). The correct and complete internal model is essential for coaches and provides them the opportunity to see the variations between what they see and what they know. However, some variations should be allowed by coaches as soon as the movement remains functional.

In addition to the contradictions identified between groups, they were also detected within the same group of coaches in both phases. For example, for the intermediate player novice coaches identified "grip" and "back swing" as a weakness and as a strength at the same time. Expert coaches recognised "leg drive", "rhythm" and "shoulder-over-shoulder" as strengths and weaknesses for beginner player. These findings clearly demonstrated that variations in the diagnostic process exist not only between different levels of expertise but also within the same level of expertise. It led to the conclusion that coaches' practical knowledge was different even at the same level of expertise. The identified variations within the same group can be explained by the linear model of the expertise continuum (Figure 3 Tennis Australia coach expertise continuum): some coaches can be closer to the next expertise level than others due to factors such as quantity and quality of coaching experience. As mentioned above, the declarative knowledge (the internal model) can also influence the diagnostic ability. Although coaches completed the same coaching certification, every coach has a unique internal model due to learning experience outside of the completed coaching course. Therefore, the difference within the same group of expertise can be expected. More research is required to examine the diagnostic ability within the same level of expertise.

The identified difference between experts and novices in their diagnostic ability and practical knowledge of the tennis serve technique can relate to the software hypothesis which explain the difference between level of expertise by experts' superior knowledge base and decision-making abilities (Chamberlain & Coelho, 1993). For example, the correlation between the level of expertise and coaches' visual search behaviour has been identified in swimming (Moreno et al., 2006). The study compared the visual search strategies of expert and novice coaches. It was suggested that identified differences between experts and novices were due to the difference in coaching experience and knowledge base (Moreno et al., 2006). Another study examined the effect of experience on the recognition accuracy of gymnastic coaches and reported a unique visual profile of experienced coaches. It was concluded that superior performance was due to expert coaches' higher experience and familiarity with the motor skill (Imwold & Hoffman, 1983). The current investigation was in alignment with the software hypothesis (Chamberlain & Coelho, 1993). It was found that experts possessed greater practical knowledge compared to novices, and they identified more strengths, weaknesses, and recommendation for corrections. Thus, it can be concluded that the difference in diagnostic skills can be explained by expert's extensive knowledge and their greater experience.

7.3. Study 3: Online training course

It has been previously found that the main attributes of coach expertise are experts' greater knowledge, better ability to interpret and understand the kinematics of action and to recognise connections between technical elements compared to non-experts (Giblin, 2013; J. Lyle, 2010). Therefore, these skills can be purposefully developed during formal coach education programs to speed-up the process of novice coach development (J. Lyle, 2010). Interestingly, recent evidence suggested that informal learning of sport coaches can provide a greater contribution to their knowledge compared to formal education courses because formal coach education programs often do not consider the reality of coaching practice and "what works" for coaches (C. Cushion & Townsend, 2019). Therefore, the present study applied the results of studies one and two of this thesis where experts' knowledge, skills, and experience in combination with theoretical fundamentals were used to develop a unique and novel online coach education course.

The literature review of this thesis demonstrated that a considerable amount of literature has been published on the training of perceptual-cognitive skills of athletes (Larkin et al., 2015). However, much less attention has been given to the training of coaches (Driska, 2018) and even less research was presented in online coach education (C. Cushion & Townsend, 2019). Thus, this study aimed to develop and demonstrate the effectiveness of the online coach training course which aimed to improve coaches' practical knowledge, diagnostic ability and understanding of the flat tennis serve technique.

One of the key factors in coach development is the effectiveness of coach education programs (Sackey-Addo & Camarero, 2016). The effectiveness of the course presented in this study has been assessed by comparing coaches' practical knowledge and diagnostic ability before and after coaches completed the online course. The present study used a mixed method approach that allowed the researcher to examine the data from two different perspectives: qualitative and quantitative. As a result, several important findings have been found and evidence suggesting the effectiveness of the course has been provided.

7.3.1. Qualitative analysis

One important finding is that two schematic models representing coaches' practical knowledge before and after the intervention have been developed and compared. The pre-test model included five components: the "technical elements", "body elements" and "phases" formed the "biomechanical factors" category and the "concepts", "reasoning chains" formed the "functionality" category (Figure 25). The post-test model was identical to the pre-test model with one additional component: the "key flexion point" that was included in the "biomechanical factor" category (Figure 26).

When comparing the two models, it was observed that coaches demonstrated the practical knowledge on the tennis serve terminology, technical elements and body parts involved in the motion, biomechanical and physics concepts, the phases of the serve as well as an understanding of the connections between various technical elements. However, coaches were able to apply measurements and quantification (e.g. 90 degrees between elbow and forearm) of the tennis serve only after they completed the online course. This difference in the coaches' biomechanical analysis of the tennis serve technique between pre-test and post-test demonstrated the effect of the online course on coaches' practical knowledge. The next step was to analyse

the qualitative characteristics of every component of the models to identify the potential changes in coaches' knowledge, and to identify evidence demonstrating the effectiveness of the online course.

After completing the online course, the coaches improved in all components of practical knowledge by demonstrating a wider range of the technical elements, body elements, phases, concepts, reasoning chains and key flexion points identified in post-test interviews (Tables 26-29). The analysis also revealed the specific changes in coaches' knowledge before and after the course. For example, Table 26 showed that coaches were familiar with the "grip" technical elements before the course and they also mentioned it after the course. By contrast, "co-ordination of 2 arms" was identified only during the post-test interview. Similar observations were made in all components of coaches' practical knowledge. It can be concluded that online course has improved identified aspects of coaches' practical knowledge on the flat tennis serve technique.

In addition to the practical knowledge, strengths and weaknesses identified during pre-test and post-test diagnostic were analysed and compared to demonstrate the effect of the course on coaches' diagnostic skills. The analysis revealed moderate and large treatment effects on diagnostic skill (Table 31). This finding indicated that the online course was an effective tool to improve coaches' diagnostic ability of the tennis serve technique as coaches demonstrated a deeper analysis after they completed the course.

In addition to the findings presented above, some additional interesting observations have been made during the qualitative analysis. For example, some coaches were uncertain on how to analyse a high-performance player during the pre-test interview. They perceived the technique as "perfect" and could not identify any technical weaknesses. By contrast, coaches felt more confident when analysing the technique of high-performance player after the course and provided technical weaknesses. This finding can be explained by their lack of coaching experience and knowledge of the technique of high-performance level players. According to the data from the pre-study Questionnaire, all coaches worked with beginners and intermediate players only at the time of the interview and did not have any experience with high performance players. The online course focused on the technique for an adult high-performance player and included diagnostic examples for this level in addition to beginner and intermediate

levels. Thus, coaches could be more confident when analysing a high-performance player after the intervention due to the course content that included theoretical fundamentals as well as practical application for high performance players.

It can be concluded that novice coaches should be allowed to coach not only beginners and intermediate players, but also high-performance players so that they can obtain experience which is necessary for their learning and developing. It is recommended to provide this opportunity via mentoring programs where the novice coach participates in the training with an expert coach who monitors the process. This finding can be applied in coach education to improve novice coaches' learning and development. It was demonstrated that an online course was an effective tool to improve coaches' diagnostic ability on the tennis serve technique which is a valuable contribution to novice tennis coach development.

A further interesting observation was that some coaches acknowledged that they usually use a slow-motion mode when analysing the technique as it is easier to identify technical strengths and weaknesses when they can observe the motion at a slower speed, or stop the video when needed. Thus, the recommendation for future research is to explore the use of slow-motion video during data collection as richer data and more in-depth analysis may be generated.

Another unusual observation was made when the researcher looked at the variety of diagnostic approaches for each coach: how a coach started and finished the analysis, what was the sequence and specific approach to analyse the serve technique. Surprisingly, no similarities between diagnostic approaches were found amongst the nine coaches. For example, different approaches from the coaches included analysing the serve from the feet and up the kinetic chain, analysing according to phases of the serve, analysis of different body parts and technical elements, or checking only a few important elements of the technique. This observation suggested that each coach had a unique approach to the diagnosis of the serve despite having completed the same coaching certification.

This finding corresponded to previous research in tennis where expert tennis coaches observed the centre of the body when analysing the tennis serve, whereas novice coaches focused on different parts of the body (Reid et al., 2015). Only the visual behaviour of tennis coaches was examined, however, it is still unknown as to why

coaches report observing specific areas and what sequence of analysis coaches use. For example, a previous study in climbing established the connection between specific fixation locations and efficient visual search patterns (Mitchell et al., 2020). In this study, experts could explain their visual search behaviour: they knew why they were fixating their attention on a certain part of the climber and what information they were looking to receive.

By contrast, novice coaches were unable to elaborate on their visual search behaviour. In tennis, it remains unknown why coaches reported that they looked at the centre of the body and why novices concentrated on separate body parts (Mitchell et al., 2020). This conclusion highlights the need for more research to gain a deeper understanding of expert tennis coaches' diagnostic strategies and approaches. The results of the present study should inspire more research on tennis coaches' diagnostic ability of the tennis serve technique as this skill plays an important role in athletes' development.

The unusual contradictions in analysis between coaches were detected when the same technical element was identified as a strength by one coach and as a weakness by another. For example, for the beginner player "knee flexion" was identified as a strength by Coach 3 and as a weakness by Coach 6. This inconsistency might be explained by coaching or playing experience (A. M. Williams et al., 2002), the difference in the internal model, or self-education. These inconsistencies between coaches support the results of Study two of this thesis in which similar contradictions were observed during the diagnostic task and will be discussed in Chapter seven. The inconsistencies between coaches were also in alignment with previous studies in swimming and volleyball in which contradictions were observed on the identified features of technique (Bian, 2003; Leas & Chi, 1993). Thus, it is important to understand coaches' diagnostic ability as this area is currently under investigated. More research is required to understand the diagnostic ability of expert and novice tennis coaches to identify factors that influence this skill which is critical for coaching.

At the end of the online course, coaches were asked to provide their feedback on the course by completing a Questionnaire. All nine coaches assessed the course as "very useful" to "extremely useful" in their understanding of the tennis serve technique. This feedback demonstrated that the online course was perceived by coaches as an effective tool for improving their understanding of the technique which is the essential

attribute of expertise. The complexity of the course was not perceived as either “extremely complex” or “extremely simple” by any of the coaches which is a good indicator that the course was designed according to coaches’ learning ability. It was also found that all coaches were familiar with the connection between biomechanical features of the flat serve before the course. However, the coaches reported this material useful for their understanding of the tennis serve technique. The “connection” module that was presented in the last two sessions of the course was assessed as “extremely and very useful” by coaches for their understanding of the tennis serve technique. This feedback confirmed the quantitative results where the largest improvement was found on the “reasoning chain” component representing coaches’ understanding of the tennis serve technique. This finding indicates that the course can be used in coach education as an effective learning tool on the understating of the functionality of the tennis serve. All coaches reported that they were going to apply this knowledge in their coaching practice.

The coaches also reported the usefulness of the material presented in the course which demonstrates coaches’ understanding of the course content. The coaches were also asked questions on what they liked most about the course: coaches mentioned the good structure of the course, the videos and presentation slides as well as material on connections between technical cues. Finally, coaches were asked to provide their opinion on what can be improved. This feedback can be used in the future to improve the quality of the course. For example, the video quality can be improved, and the number of video examples can be increased. Overall, the results from the Questionnaire supported the results of the qualitative and quantitative analysis of the course and revealed that coaches perceived the course as an effective and well-structured tool to improve their knowledge and understanding of the tennis serve technique.

This feedback corresponded to the previous study in online coach education where the effectiveness of the swimming online coach education program was evaluated. The study revealed coaches’ positive emotional perception of the program in which videos were one of the most valuable learning resources (Driska, 2018). In the present study, videos and diagrams were one of the features of the course that coaches liked and recommended adding more videos in the course. Thus, videos can be considered as a useful tool for online coach education programs. The feedback provided by the

coaches in this study can be taken into consideration by coach education designers when developing future online courses.

7.3.2. Quantitative analysis

In addition to qualitative analysis, the quantitative analysis was performed to identify statistical improvements in coaches' knowledge and diagnostic skills after the intervention. The findings aligned with qualitative results and confirmed the conclusion that the online course improved coaches' practical knowledge and diagnostic ability as large improvements in coaches' practical knowledge were found. Similar findings have been reported in the study evaluating the effectiveness of the swimming online coach education program (Driska, 2018). This study employed utilisation-focused evaluation to assess the effectiveness of the online coaching program (Foundation of Coaching) that has been launched by USA Swimming in 2013 (Driska, 2018). The results demonstrated the strong effect on coaches' knowledge of skills, drills and pedagogy, as reported by 14 coaches during the interviews. These results corroborate the findings from the current study which demonstrated that the online course had moderate, large and very large treatment effects on components of coaches' practical knowledge and diagnostic skills. However, unlike the aforementioned study, the present study applied a pre-test and post-test design that allowed the researcher to present the more specific effects of the course.

Interestingly, the largest improvement was detected for two components: the "reasoning chains" and the "key flexion points". The "reasoning chain" component represented coaches' understanding of the tennis serve functionality. It was previously established that it was possible to educate the learner's attention to detect key information that influences movement (Davids, 2010). The present study utilised this approach by educating coaches to perceive the tennis serve as a network of interacting components after they learnt the separate biomechanical parts. As a result, the largest effect was detected for reasoning chain components that demonstrated that the course has improved coaches' understanding of the tennis serve technique and how one technical element may affect another. This result was in alignment with the naturalistic decision-making paradigm (NDM) that focused on the expert decision-makers (Lipshitz & Strauss, 1997). This paradigm emphasised that novice coaches should be directed to understand the performance of the athletes first (J. Lyle, 2010). Although the expertise is usually attained with time and experience (J. Lyle, 2010),

the online program may help novice tennis coaches to reduce years of coaching experience for attaining the expertise (Abraham & Collins, 1998). The direct knowledge transfer from experts to novices can be used to improve decision making skills of novices.

The “key flexion point” component was only identified during the post-test interview. It is possible that during the coach education course novice coaches were not provided material on tennis serve biomechanics, thus, they did not apply any quantification in the diagnosis of the serve. This conclusion can be validated only through the online coach education provider but the researcher did not have the opportunity to access the content of the course that coaches completed. However, the present course included information on the biomechanics of the tennis serve technique. As a result, the coaches applied this knowledge on the post-test diagnostic. Therefore, the online course improved coaches’ knowledge of the tennis serve biomechanics and it appears that inclusion of measurement and quantification of the motion is possible even for novice coaches.

7.3.3. Significance and practical implication

Study one of this thesis revealed that one of the key distinguishing characteristics between expert and novice coaches was expert’s superior ability to observe a motion as whole and understand how one technical element affects another. This finding was consistent with study two of the current investigation in which expert coaches demonstrated greater ability to understand the cause and effect relationships between technical elements compared to novice coaches. Study three of this thesis applied these finding and developed online training course to improve novice coaches’ understanding of the flat tennis serve technique.

The results of this study supported previous research on athletes where a video-based training method was used to teach novice athletes about the connection between early cues such as soccer goal keepers watching for foot position in the penalty kick, and outcome of the motion such as the direction of the ball flight (R.C. Jackson & Farrow, 2005). However, this method has not been applied to coaching. Thus, the current investigation brings a unique contribution to coach education as the online course significantly improved coaches’ understanding of connections between various technical cues. By completing this online course novice tennis coaches will be able to

provide more effective intervention to the players they coach by correcting the cause of the problem. For example, the “grip” element affects “racket-forearm alignment” which affects “pronation”. Thus, correcting the grip will improve racket-forearm alignment and, consequently, the forearm pronation. Previous research on dynamic interceptive actions in volleyball serving support the importance of learning the movement as a whole rather than separate parts (Davids, Williams, Button, & Court, 2001). The online course can be used to improve novice coaches’ understanding of the tennis serve technique and can be adjusted to other technical elements.

Besides the improvements in coaches’ knowledge and understanding of the tennis serve, a moderate to large increase was identified in coaches’ diagnostic skills of the serve after they completed the course. This finding demonstrated that the online course was an effective tool for improving coaches’ diagnostic ability which is the critical component of coaching expertise (V.E.D. Pinheiro, 1990; V.E.D. Pinheiro & Simon, 1992). Coaches' feedback to the players is directly affected by how coaches analyse the technique (Giblin, 2014). The course provides an important contribution to coach training and development and, consequently, to tennis players’ development.

The present study corresponded to previous research in online coach education where online programs were developed and evaluated. One of the studies designed the online education course for youth sport that coaches focused on sport concussion prevention (Glang et al., 2010). The pre-test and post-test measures were applied to demonstrate the effect of the program on coaches’ knowledge. It was reported that the course improved coaches’ knowledge about sport concussion, management and prevention. Another research study evaluated the existing online coaching program (Foundation of Coaching) in swimming and reported positive effects on coaches’ swimming skills and training practices (Driska, 2018). In addition, online coach training was evaluated in football where the online training reduced the injury of the athletes (Kerr et al., 2015).

Although several studies developed and evaluated online coach education programs on different aspects of coaching, no online training courses have been previously developed and presented in tennis on the tennis serve technique. Knowing the effects of the course on coaches’ knowledge and skills can be extremely useful to course developers to help them revise and improve course content and delivery (Driska,

2018). The present study, therefore, provided an important contribution to tennis coach development by introducing the novel online coach education course, presenting the positive effects on coaches' knowledge and diagnostic skills and demonstrated the effectiveness of the course. These results significantly contribute to the current knowledge of online training programs.

It has previously been suggested that online courses should be supplemented by practical components (Santos et al., 2019). Previous study evaluated a positive youth development-focused online coach education course and found that the course was well-structured but limited the ability of coaches to implement the course material as no practical component was presented (Santos et al., 2019). Therefore, the combination of theoretical and practical components is recommended for future online coach education programs in tennis and other sports to enhance coaches' learning and the ability to implement the knowledge. The present study has included the practical application by providing learning material on technical analysis of the players from different levels of expertise.

Several studies applied a video-based training method to improve the perceptual-cognitive skills of athletes and decision-making skills of referees (Section 2.4.1. of this thesis). However, the area of training coaches is currently under investigated. The present study developed a unique online coach training course that combined the video-based training method, orienting visual attention method, the whole-part-whole learning model, problem-based learning approach, and integrated these methods and approaches with videos, slides and quizzes to reinforce the learning. As a result, the findings from the qualitative and quantitative analysis demonstrated that the online course improved coaches' practical knowledge and diagnostic ability of the flat tennis serve technique. The present course makes a unique contribution to the tennis coach development and learning. Moreover, it has been identified that the key obstacle for coaches to attend coach education events was the lack of time and financial resources (Sackey-Addo & Camarero, 2016). The course can be applied in coach education across the world due to the online nature which can increase the number of coaches participating in the education course.

These results demonstrated that novice coaches were able to improve those skills that are needed to become expert coaches. Thus, the online course can be applied in

tennis coach education to improve novice tennis coaches' diagnostic skills of the tennis serve. This study may encourage more research in training programs for novice coach as it is currently under investigated. The unique part of the course was the "connections" module where coaches learn how one technical element affects another. The analysis revealed that the largest improvement was made in coaches' understanding of the tennis technique. As there is no unified method to analyse the tennis serve technique yet, coaches looked at the serve technique differently. Looking at the serve as a whole motion rather than separate parts may allow coaches to become experts faster, improve the quality of coaching, and, as a result, the performance of the players. "A hundred coaches will see a hundred different things but seeing the connections between technical elements will connect hundreds of things and allows coaches to have a similar voice" (Coach 4).

Although various training courses in sport coaching are available online (SportAus & AIS, 2020; Swimming Australia, 2020; Tennis Australia, 2020a; US Lacrosse, 2020), no previous research has developed and demonstrated the effectiveness of online coach education courses in tennis. This study brings an original contribution to the tennis coach development as it is the first study in tennis that developed and evaluated the effectiveness of the online coach education course on the tennis serve technique. The results demonstrated that the online course was an effective tool to improve coaches' practical knowledge, understanding and diagnostic ability of the tennis serve technique. Moreover, the course provided a convenient method to deliver knowledge as it can be accessed by coaches worldwide. Coaches have an opportunity to study at a time convenient for them, repeat the material if required and learn at their own pace. The online training course developed in the current study is unique and novel and should inspire more research in coach education in tennis and other sports. Finally, the COVID-19 pandemic highlighted the value of online coach education (Callary et al., 2020). Thus, the present study provides a valuable opportunity for tennis coaches to continue their professional knowledge and skills development even at the uncertain and unusual conditions.

7.4. The integration of internal model, diagnostic skills and coaches' learning

Overall, this thesis provided a coherent story where results from Study one complements the results of study two and then were practically applied in Study three. The connection between the technical elements was a thread that runs through the

whole story. In study one, it was found that tone of the key distinguishing characteristics between expert and novice coaches' declarative knowledge was experts' ability to perceive the tennis serve technique as a whole movement, and to understand the connection between technical elements. Study two was in alignment with study one and reported expert's superior ability to understand the cause and effect relationships between technical elements when coaches analysed the tennis serve technique. As the key attribute of tennis coach expertise has been identified, the need to improve novice coaches' ability to look at the serve as a whole movement and to understand the connections between the technical elements has arisen. Study three, therefore, focused on the development and evaluating of the online training course to provide practical application of the findings identified in Study one and two of this thesis.

In addition to the valuable results presented above, the understanding of the technique is the key finding of this thesis. The importance of this finding for coaches was expressed by one of the participating coaches during the post-test interview: "A hundred coaches will see a hundred different things but seeing the connections between technical elements will connect hundreds of things and allows coaches to have a similar voice" (Coach 4).

Chapter 8 Conclusion

I have started this research journey as a former high-performance tennis player and an experienced tennis coach. Being the researcher has deepened my understanding of tennis serve technique, coach expertise and education. The application of the mixed-method approach created an in-depth understanding of the expertise in practical knowledge and diagnosis of the tennis serve technique. It allowed me to look at the data from two different perspectives and develop a coherent story where the results of the quantitative analysis complemented the results of qualitative analysis.

This thesis aimed to examine novice and expert coaches' internal models, practical knowledge and diagnostic ability of the flat tennis serve technique, to identify the key distinguishing characteristics between expertise levels, and to develop and demonstrate the effectiveness of an online training course focused on developing novice tennis coaches' knowledge and diagnostic skill for the flat tennis serve. The results of this thesis have been discussed earlier in Chapter seven. This chapter summarises the major findings, provides practical applications and makes recommendations for future research.

8.1. General conclusion and major findings

This thesis generated the following findings:

- This thesis made the first attempt to capture coaches' internal models on the tennis serve technique which provides a unique contribution to the tennis coach expertise field. The expert internal model consisted of seven components which expanded the previous research on internal models where fewer components have been presented.
- The interpretation accuracy depended on the internal model as it determined which errors could be identified or missed (V.E.D. Pinheiro, 1990). This thesis demonstrated that every coach has a unique internal model even at the same certification level. Therefore, it is important to ensure that coaches are provided with the correct and complete internal model of the tennis serve technique during coach education programs from the beginning of the coaching pathway as it affects their diagnostic ability and, as a result, player's performance.
- This thesis introduced the "functionality" component of the internal model that has not been found previously. Therefore, the present investigation highlighted

the importance for novice coaches in developing the knowledge of motor skills from two perspectives: not only technical but functional as well.

- "Functionality" component refers to what is effective for the successful motor skill performance. Although obtaining internal model of technically correct movement is critical for coaches, "functionality" to accept variability between players as soon as the movement remains functional.
- Expert tennis coaches demonstrated greater declarative and practical knowledge of the flat tennis serve technique in addition to superior diagnostic ability.
- The key distinguishing characteristics between expert and novice tennis coaches on their declarative and practical knowledge were identified. Expert tennis coaches demonstrated more advanced and specific knowledge, a greater ability to perceive the tennis serve technique as a whole movement, and a greater understanding of the connection between technical elements compare to novices.
- Expert coaches exhibited superior diagnostic ability on the tennis serve technique compared to novice coaches. Expert coaches were more expressive when analysing the technique, demonstrated more detailed analysis, and applied more advanced biomechanical principles.
- A unique online training course was developed and the effectiveness of the course on novice coaches' practical knowledge and diagnostic ability of the tennis serve technique was demonstrated. The strongest effect of the course was found on coaches' understanding of the technique and their knowledge of the tennis serve biomechanics. This study provides an original contribution to tennis coach development as it is the first study in tennis that developed and evaluated the effectiveness of the online coach education course focused on the technique.
- The coaches perceived the online course as an effective tool for improving their understanding and knowledge of the flat tennis technique. Based on their evaluation feedback, novice coaches especially enjoyed learning about the connections between technical elements of the tennis serve.
- The online questionnaire that was developed in this thesis brings a unique contribution to the knowledge of tennis coaching expertise as a valuable tool to

examine coaches' practical knowledge and diagnostic ability on the tennis serve technique.

- It was discovered that every coach had a unique approach for the diagnostic of the tennis serve technique although coaches completed the same coaching certification. It was suggested that no specific diagnostic approach was provided to coaches during the certification course.

8.2. Practical applications

This research generated a considerable amount of unique knowledge that can be utilised by those who are involved in coach learning and development in tennis and other sports.

Firstly, the identified difference in coaches' declarative and practical knowledge and their diagnostic ability of the tennis serve technique may provide guidance for coach education providers as this research demonstrated specific knowledge that novice tennis coaches should learnt (Abernethy, 2007). The practical application of this knowledge may help to improve tennis coach education programs and reduce the current time taken by a novice coach to become an expert (Abraham & Collins, 1998; Petrakis, 1986).

Secondly, it was concluded that the level of the athletes that coaches usually work with influenced their internal model, and the internal model affected their diagnostic ability. Therefore, novice coaches should work not only with beginner and intermediate players but also have an opportunity to participate in coaching activities associated with high-performance players. This would allow novice coaches to acquire the necessary experience and accelerate their pathway to a higher level of expertise. It is recommended that the expert coach works with the novice coach during the training session with a high-performance player to ensure the quality of the training, but at the same time allow the novice coach to get experience at a high-performance level.

Finally, the online training course brings a unique and valuable contribution to tennis coach education. The effectiveness of the course and guidance on how the course is structured should allow the training course to be successfully applied to improving novice coaches' practical knowledge and diagnostic ability of the tennis serve technique. Furthermore, coaches' feedback confirmed the value of the course and provided recommendations for future improvements. Hence, tennis coach education

providers have an opportunity to apply this knowledge and improve the development of the next generation of tennis coaches (Giblin, 2014).

8.3. Future research

This thesis makes a valuable contribution to the area of tennis coach expertise and development. There are, however, several recommendations for future research:

- This thesis made the first attempt to examine the coaches' internal model on the flat tennis serve technique. More research is required to examine expert coaches' knowledge of other technical elements in tennis such as forehand and in other sports, as this area is currently not sufficiently investigated. Furthermore, examining the components of the expert internal model individually is recommended to get an even deeper understanding of experts' knowledge.
- The emergence of the "functionality" component of the internal model has the potential to open a new avenue of research in tennis and other sports as more research is recommended to investigate and substantiate this new attribute of coaches' knowledge.
- The understanding of how the internal model of technical element influences the diagnostic ability of a coach may bring a valuable contribution to coaches' expertise as this connection can be crucial for coaches' performance and development.
- It was found that coaches' knowledge is different along the expertise continuum even if they completed the same certification level. Therefore, it is important to further examine this difference and factors that may affect coaches' internal model at the same level of expertise.
- Further research is needed to examine coaches' practical knowledge on other technical elements such as forehand, backhand, slice as the research in this area is scarce.
- This thesis did not assess the correctness of the coaches' diagnostic of the serve technique. Therefore, it is recommended to examine the accuracy of expert and novice coaches' diagnostic of the tennis serve technique to get a deeper understanding of the expertise.
- The online Questionnaire developed in Study two of this thesis provided a valuable tool to examine coaches' diagnostic ability and practical knowledge. The design of the Questionnaire allows future researchers to adjust it for other

elements of tennis (e.g. forehand) as well as applying the Questionnaire to other sports.

- The application of the expert-novice paradigm revealed that novice coaches need to learn to observe a motion as a whole and to understand how one technical element affects another. Therefore, there is a need to teach novice coaches this knowledge to improve novice coach development and learning. Thus, a more specific training program can be developed and validated in the future.
- Although tennis coaches' visual search behaviour has been previously examined (Reid et al., 2015), it is still unknown why coaches focus on certain parts of the body. It is recommended to study expert and novice coaches' visual search behaviours on the tennis serve in combination with examining coaches' decision-making underlying mechanisms to synthesise this knowledge, and get a deeper understanding of expertise.
- More research is recommended to examine experts' internal model, their diagnostic skills on the tennis serve technique and the underlying mechanics of their decision-making.
- To date a wide range of coach education programs are available around the world. However, there is a lack of scientific evidence demonstrating the effectiveness of these programs. This thesis should inspire more research to verify the effectiveness of the programs.

In conclusion, this research produced many unique and novel findings that extended the current understanding of tennis coach expertise and education. The inclusion of qualitative and quantitate methods for data analysis resulted in a comprehensive understanding of tennis coaches' declarative and practical knowledge and their diagnostic skills. This research has provided numerous practical ideas that may support and enhance coach education. Multiple directions for future research have also been presented and should inspire more studies in this field.

References

Abdullah, A. R. (2014). *Dental practitioners' knowledge of the management of child abuse and neglect: survey and development of an online training program.* King's College London, London.

Abernethy, B. (1990). Expertise, visual search, and information pick-up in squash. *Perception 19*, 63-77.

Abernethy, B. (1991). Visual Search Strategies and Decision-Making in Sport. *International Journal of Sport Psychology, 22*, 189-210.

Abernethy, B. (2007). Pickup of essential kinematics underpins expert perception of movement patterns. *Journal of Motor Behaviour 39*(5), 353-367.

Abernethy, B., Gill, D. P., Parks, S. L., & Packer, S. T. (2000). Expertise and the perception of kinematic and situational probability information *Perception, 30*, 233-252.

Abernethy, B., Wood, J. M., & Parks, S. (1999). Can the anticipatory skills of experts be learned by novices? *Research Quarterly for Exercise and Sport, 70*(3), 313-318.

Abernethy, B., & Woolstein. (1988). *Improving anticipation in racquet sports*.

Abernethy, B., & Zawi, K. (2007). Pickup of essential kinematics underpins expert perception of movement patterns *Journal of Motor Behaviour, 39*(5), 353-367.

Abraham, A., & Collins, D. (1998). Examining and extending research in coach development. *Quest, 50*(1), 59-79.

Abraham, A., Collins, D., & Martindale, R. (2006). The coaching schematic: Validation through expert coach concensus. *Journal of Sport Sciences, 24*(6), 549-564.

AdobePremierePro. (2018). Adobe Premiere Pro. Retrieved from https://www.adobe.com/au/

Adolphe, R. M., Vickers, J. N., & La Plante, G. (1997). The effects of training visual attention on gaze behaviour and accuracy: A pilot study. *International Journal of Sports Vision, 4*(1), 28-33.

Allan, V., Vierimaa, M., Gainforth, H. L., & Cote, J. (2018). The use of behaviour change theories and techniques in research-informed coach development programmes: A systematic review. *International Review of Sport and Exercise Psychology, 11*(1), 47-69.

Allen, S. J. (2007). Adult learning theory and leadership development. *Leadership Review, 7*, 26-37.

Altman, B. A. (2009). Determining US workers' training: history and constructivist paradigm. *Journal of European Industrial Training, 33*(6), 480-491.

Antunez, R. M., Hernandez, F. J. M., Garcia, J. P. F., Vaillo, R. R., & Arroyo, J. S. D. (2012). Relationship between motor variability, accuracy, and ball speed in the tennis serve. *Journal of Human Kinetics, 33*, 45-53.

Araujo, D., Chow, J. Y., & Passos, P. (2009). The development of decision making in sport: An ecological dynamic perspective. In D. Araujo, H. Ripoll, & M. Raab (Eds.), *Perspectives on cognition and action in sport* (pp. 157-169). New York: Nova Science Publishers.

Arghode, V., Brieger, E. W., & McLean, G. N. (2017). Adult learning theories: implications for online instruction. *European Journal of Training and Development, 41*(7), 593-609.

Armstrong, C. W., & Hoffman, S. J. (1979). Effect of teaching experience, knowledge of performer competence, and knowledge of performance outcome on performance error identification. *Research Quarterly, 50*(3), 318-327.

Arroyo, M. P. M., Dominguez, A. M., Arias, A. G., Garcia-Gonzalez, L., & Alvarez, F. D. V. (2016). Influence of experience in procedural knowledge in volleyball: application for training. *International Journal of Sport Science & Coaching, 11*(2), 191-199.

Barrow, H., & Tamblyn, R. M. (1980). *Problem-based learning: An approach to medical education*. New York: Springer.

Berliner, D. C. (1994). Expertise: The wonders of exemplary performance. In J. N. Mangieri & C. C. Block (Eds.), *Creating powerful thinking in teachers and students*. Ft. Worth, TX: Holt, Rinehart and Winston.

Bian, W. (2003). *Examination of expert and novice volleyball coaches' diagnostic ability.* (Doctor of Philosophy). The University of Georgia, Athens, Georgia.

Biniecki, S. M. Y., & Conceigao, S. C. O. (2016). Using concept maps to engage adult learners in critical analysis. *Adult Learning, 27*(2), 51-59.

Boghossian, P. (2006). Behaviorism, constructivism, and Socratic pedagogy. *Educational Philosophy and Theory, 38*(6), 713-722.

Bound, D., & Feletti, G. (1991). *The challenge of problem-based learning*. London: Kogan Page.

Boyd, L. (2004). *Visual perception of swimming technique: an investigation of observational expertise in sport* School of Exercise and Nutrition Sciences.

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology of Sport and Expertise, 3*, 77-101.

Brenton, J., Müller, S., & Dempsey, A. (2019). Visual-perceptual training with acquisition of the observed motor pattern contributes to greater improvement of visual anticipation. *Journal of Experimental Psychology Applied, 25*(3), 333-342.

Broadbent, D. P., Causer, J., Williams, A. M., & Ford, P. R. (2015). Perceptual-cognitive skill training and its transfer to expert performance in the field: Future research directions. *European Journal of Sport Science, 15*(322-331).

Burroughs, W. A. (1984). Visual simulation training of baseball batters. *International Journal of Sport Psychology, 15*, 117-126.

Callary, B., Brady, A., Kiosoglous, C., Clewer, P., Resende, R., Mehrtens, T., . . . Horvarth, R. (2020). Making sense of coach development worldwide during the COVID-19 pandemic. *International Journal of Sport Communication, 13*, 575-585.

Canal-Bruland, R., Van Der Kamp, J., & Van Kesteren, J. (2010). An examination of motor and perceptual contributions to the recognition of deception from other's actions. *Human Movement Science, 29*, 94-102.

Chalkiadakis, C., Iordanopoulos, P., & Malin, F. (2019). *An online training tool for better understanding the operation and significance of ITS*. Paper presented at the 6th International Conference on Models and Technologies for Intelligent Transportation Systems, Kraków, Poland.

Chamberlain, C. J., & Coelho, A. J. (1993). Chapter 8 The perceptual side of action: decision-making in sport. *Advances in Psychology, 102*, 135-157.

Charters, E. (2003). The use if think-aloud methods in qualitative research: an interdiction to think-aloud methods. *Brock Education Journal, 12*(2), 68-82.

Chow, J. Y., Davids, K., Button, C., & Renshaw, I. (2016). *Nonlinear pedagogy in skill acquisition: an introduction* New York: Routledge.

Christie, M., Carey, M., Robertson, A., Grainger, P., & USC. (2015). Putting transformative learning theory into practice. *Australian Journal of Adult Learning, 55*(1), 9-31.

Christina, R. W., Baressi, J. V., & Shaffner, P. (1990). The development of response selection accuracy in a football linebacker using video training. *The Sport Psychologist, 4*(1), 11-17.

Consul, P. C., & Famoye, F. (1990). Generalized poisson regression model. *Communications in Statistics - Theory and Methods, 21*(1), 89-109.

Corbin, J., & Strauss, A. (2008). *Basics of qualitative research: Techniques and procedures for developing grounded theory* Thousand Oaks, CA: Sage.

Cote, J. (2006). The development of coaching knowledge *International Journal of Sport Science & Coaching, 1*(3), 217-222.

Côté, J., Bruner, M., Erickson, K., Strachan, L., & Fraser-Thomas, J. (2010). Athlete development and coaching. In J. Lyle & C. Cushion (Eds.), *Sport coaching: Professionalization and practice*. Oxford, UK: Elsevier.

Cote, J., & Gilbert, W. (2009). An integrative definition of coaching effectiveness and expertise *International Journal of Sports Science & Coaching 4*(3), 307-323.

Cote, J., Salmela, J., Trudel, P., & Baria, A. (1995). The coaching model: a grounded assessment of expert gymnastic coaches' knowledge. *Journal of Sport and Exercise Psychology, 17*(1), 1-16.
Cote, J., & Salmela, J. H. (1995). The knowledge of high-performance gymnastic coaches: Methodological Framework. *The Sport Psychologist, 9*, 65-75.
Coughlan, E., Williams, A. M., McRobert, A. M., & Ford, P. (2014). A novel test of deliberate practise theory: how experts learn. *Journal of Experimental Psychology: Learning, Memory & Cognition, 40*, 449-458.
Crespo, M., & Reid, M. (2009). ITF coaches educational program: session guidelines for advanced training. Retrieved from http://en.coaching.itftennis.com/media/113928/113928.pdf
Creswell, J. W. (2007). *Research design: Qualitative and quantitative approaches*. Thousand Oaks, CA: Sage.
Cushion, C., & Nelson, L. (2013). Coach eduation and learning: Developing the field. In P. Potrac, W. D. Gilbert, & J. Denision (Eds.), *Routledge handbook of sport coaching* (pp. 359-373). London: Routledge
Cushion, C., & Townsend, R. C. (2019). Technology-enhanced learning in coaching: A review of literature. *Educational Review, 71*(631-649).
Cushion, C. J., Nelson, L., Armour, K., Lyle , J., Jones, R. L., Sandford, R. A., & O'Callaghan, C. U. (2010). *Coach learning and development: A review of literature*. Leeds, UK: Sports coach UK.
Damron, C. (1995). Two and three dimensional slide images used with tachistoscopic training techniques in instructing high school football players in defense. *Research Quarterly, 26*, 36-43.
Davids, K. (2010). Implications for a non-linear pedagogy in sport and physical education In I. Renshaw, K. Davids, & G. J. P. Savelsbergh (Eds.), *Motor Learning in Practice: a constraints-led approach*. Taylor & Francis e-Library: Routledge.
Davids, K., Button, C., & Bennett, S. (2008). *Dynamics of skill acquisition: A constraints-led approach* USA: Human Kinetics.
Davids, K., Hristovski, R., Araújo, D., Serre, N. B., Button, C., & Passos, P. (2013). *Complex systems in sport*. London: Routledge.
Davids, K., Williams, A. M., Button, C., & Court, M. (2001). An integrative modeling approach to the study of intentional movement behaviour. In R. N. Singer, H. Hausenblas, & C. Janelle (Eds.), *Handbook of sport psychology* (2nd ed., pp. 144-173). New York: John Wiley & Sons.
Day, L. J. (1980). *Anticipation in junior tennis players.* Paper presented at the International Symposium on the Effectiveness of Teaching of Racquet Sports Champaign, IL.
De Groot, A. D. (1978). *Thought and choice in chess* The Netherlands: Mounton Publisher.
De Marco, G. M., & McCullick, B. A. (1997). Developing expertise in coaching: Learning from the legends. *Journal of Physical Education, Recreation, and Dance, 68*(3), 37-41.
De Subijana, C. L., & Navarro, E. (2010). Kinetic energy transfer during the tennis serve. *Biology of Sport, 27*(4), 279-287.
Dewey, J. (1910). *How we think*. Boston, MA: DC Health.
Dewey, J. (1938). *Experience and education* New York: MacMillan.
DiCicco, G. L. (1990). *The effect of playing and coaching experience on ability to perform a diagnostic task.* Paper presented at the Annual Convention Consortium Meetings of the American Alliance for Health, Physical Education, Recreation and Dance, New Orleans, Louisiana.
Dieffenbach, K. D., & Wayda, V. (2010). A critical review of American coaching education programs. *Journal of Coaching Education, 3*(2), 21-39.
Dorgo, S. (2003). *An expert strength and conditioning coach's practical knowledge* The University of Georgia, Athens, Georgia.
Dorgo, S. (2009). Unfolding the practical knowledge of an expert strength and conditioning coach *International Journal of Sport Science & Coaching, 4*(1), 17-30.
Dreyfus, S. E. (2004). The five-stage model of adult skill acquisition. *Bulletin of Science Technology & Society, 24*(3), 177-181.

Driska, A. P. (2018). A formative, utilization-focused evaluation of USA swimming's nationwide online coach education program. *International Sport Coaching Journal, 5*, 261-272.

Durovic, N., Lozovina, V., & Mrduljas, D. (2008). New biomechanical model for tennis serve. *Acta Kinesiologica, 2*, 45-49.

Elliott, B. (2006). Biomechanics and tennis. *British Journal of Sports Medicine, 40*(5), 392-396.

Elliott, B., Reid, M., & Crespo, M. (2003). *ITF Biomechanics of Advanced Tennis*. Spain: ITF Ltd.

Engel, C. (1999). Problem-based learning in medical education. In J. Leach & B. Moon (Eds.), *Learners and Pedagogy* (pp. 202-209).

Engelbrecht, L., Terblance, E., & Welman, K. E. (2016). Video-based perceptual training as a method to improve reactive agility performance in rugby union players. *International Journal of Sports Science & Coaching, 11*(6), 799-809.

Erickson, K., Bruner, M. W., MacDonald, D. J., & Cote, J. (2008). Gaining Insight into Actual and Preferred Sources of Coaching Knowledge *International Journal of Sports Science & Coaching, 3*(4), 527-538.

Ericsson, K. A., & Simon, H. A. (1993). *Protocol analysis: verbal reports as data.* . A Bradford Book, London: The MIT Press

Ericsson, K. A., & Smith, J. (1991). *Toward a general theory of expertise: Prospects and limits.* New York: Cambridge University Press.

Evans, J. S. B. T. (1989). Problem solving, reasoning and decision making. In N. O. Baddeley & N. O. Bernsen (Eds.), *Cognitive psychology: research directions in cognitive science: European perspectives* (pp. 85-102). Hove: Lawrence Erlbaum Associates.

Evans, M. B., McGuckin, M., Gainforth, H. L., Bruner, M. W., & Côté, J. (2015). Coach development programmes to improve interpersonal coach behaviours: A systematic review using the re-aim framework. *British Journal of Sports Medicine, 49*(13), 871-877.

Farrow, D., & Abernethy, B. (2001). Can anticipatory skills be learnt through implicit video-based perceptual training? *Journal of Sports Sciences, 20*, 471-485.

Farrow, D., & Abernethy, B. (2003). Do expertise and the degree of perception – action coupling affect natural anticipatory performance? *Perception, 32*, 1127-1139.

Farrow, D., Chivers, P., Hardingham, C., & Sachse, S. (1998). The effect of video-based perceptual training on the tennis return of serve. *International Journal of Sport Psychology, 29*(3), 231-242.

Ferrauti, A., & Bastiaens, K. (2007). Short-term effects of light and heavy load interventions on service velocity and precision in elite young tennis players. *British Journal of Sport Medicine, 41*(11), 750-753.

Fink, A., Kosecoff, J., Chassin, M., & Brook, R. H. (1984). Consensus methods: Characteristics and guidelines for use. *American Journal of Public Health 74*(9), 979-983.

Fitts, P. M. (1964). Perceptual-motor skills learning. In A. W. Melton (Ed.), *Categories of human learning* New York: Academic Press.

Foer, J. (2011). *Moonwalking with Einstein: The art and science of remembering everything*. London: Penguin.

Ford, P., Coughlan, E., & Williams, M. (2009). The Expert-performance approach as a framework for understanding and enhancing coaching performance, expertise and learning. *International Journal of Sport Science & Coaching, 4*(3), 451-463.

Franks, I. M. (1993). The effects of experience on the detection and location of performance differences in a gymnastic technique. *Research Quarterly for Exercise and Sport, 64*(2), 227-231.

Franks, I. M., McGarry, T., & Hanvey, T. (1997). Cues for goalkeepers. *Soccer Journal May-June*, 30-38.

Furley, E., & Dorr, J. (2016). “Eddie would(n’t) go!” Perceptual-cognitive expertise in surfing. *Psychology of Sport and Expertise 22*, 66-71.

Furley, P., & Dörr, J. (2016). “Eddie would(n't) go!” perceptual-cognitive expertise in surfing. *Psychology of Sport and Exercise, 22*, 66-71. doi:10.1016/j.psychsport.2015.06.008

Gabbett, T., Carius, J., & Mulvey, M. (2008). Does improved decision-making ability reduce the physiological demands of game-based activities in field sport athletes? *Journal of Strength & Conditioning Research, 22*(6), 2027-2035.

Gabbett, T., Rubinoff, M., Thorburn, L., & Farrow, D. (2007). Testing and training anticipation skills in softball fielders. *International Journal of Sports Science & Coaching, 2*(1), 15-24.

Galatti, L., Bettega, O. B., Brasil, V. Z., De Souza Sobrinho, A. E. P., Bertram, R., Tozetto, A. V. B., & Milistetd, M. (2016). Sport coaching as a profession in Brazil: Analysis of the coaching literature in Brazil from 2000-2015. *International Sport Coaching Journal, 3*(3), 316-331.

Gallant, A., & Gilham, V. (2014). Differentiated coaching: developmental needs of coachees. *International Journal of Mentoring and Coaching in Education*.

Gayed, A., LaMontagne, A. D., Milner, A., Deady, M., Calvo, R. A., Christensen, H., . . . Harvey, S. B. (2018). A new online mental health training program for workplace managers: Pre-post pilot study assessing feasibility, usability, and possible effectiveness. *JMIR Mental Health, 5*(3), e10517.

Ghasemi, A., Momeni, M., Jafarzadehpur, E., Rezaee, M., & Taheri, H. (2011). Visual skills involved in decision making by expert referees. *Perceptual and Motor Skills, 112*(1), 161-171.

Giblin, G. (Producer). (2013, 12/02/2017). Keep your eye off the ball: the secrets of elite tennis coaching. *The Conversation* Retrieved from http://theconversation.com/keep-your-eye-off-the-ball-the-secrets-of-elite-tennis-coaching-11645

Giblin, G. (2014). *What a coach can see and an athlete can feel.* (Doctor of Philosophy). Victoria University,

Gilbert, W., & Cote, J. (2013). Defining coaching effectiveness: A focus on coaches' knowledge. In P. Potrac, W. Gilbert, & J. Denision (Eds.), *Routledge Handbook of Sport Coaching* (pp. 359-374). London: Routledge.

Glang, A. M. C., Koester, S., Beaver, J. C., & McLaughlin, K. (2010). Online training in sport concussion for youth sports coaches *International Journal of Sport Science & Coaching, 5*(1), 1-11.

Glaser, B. G., & Strauss, A. L. (1967). *The discovery of grounded theory: strategies for qualitative research*. Hawthorn, NY: Aldine.

Glaser, R. (1987). *Thoughts on expertise*. Norwood, NJ: Ablex.

Golafshani, N. (2003). Understanding reliability and validity in qualitative research. *The Qualitative Reports, 8*(4), 597-607.

Gonzalez-Rivera, M. D., Campos-Izquierdo, A., Villalba, A. I., & Hall, N. D. (2017). Sources of knowledge used by Spanish coaches: A study according to competition level, gender and professional experience. *Sports Science & Coaching, 12*(2), 162–174.

Gorman, A., & Farrow, D. (2009). Perceptual training using Explicit and implicit instructional techniques: Does it benefit skilled performers? *International Journal of Sport Science & Coaching, 4*(2), 193-208.

Gould, D., & Mallett, C. (2021). Sport coaches’ handbook. In D. Gould & C. Mallett (Eds.). Champaign, IL: Human Kinetics.

Goulet, C., Bard, C., & Fleury, M. (1989). Expertise differences in preparing to return a tennis serve: a visual information processing approach. *Journal of Sport & Exercise Psychology, 11*, 382-398.

Grant, A., & Williams, A. M. (1996). *Training cognitive decision making in intermediate youth soccer players* Liverpool John Moores University

Grgantov, Z., Jurko, D., & Milic, M. (2013). Evaluation of volleyball techniques – differences between expert and novice coaches. *Sport Science, 6*(1), 61-65.

Grundel, A., Schorer, J., Strauss, B., & Baker, J. (2013). Does playing experience improve coaching? An exploratory study of perceptual-cognitive skill in soccer coaches. *Frontiers in Psychology, 21*(4), 129.

Guion, L. A., Diehl, D. C., & McDonald, D. (2011). *Conducting an in-depth interview*. University of Florida.
Gurgis, J. J., Kerr, G. A., & Stirling, A. E. Investigating the barriers and facilitators to achieving coaching certification. *International Sport Coaching Journal, 7*(2), 189-199.
Hagemann, N., Strauss, B., & Canal-Bruland, R. (2006). Training perceptual skill by orienting visual attention. *Journal of Sport & Exercise Psychology, 28*(2), 143-158.
Handford, C., Davids, K., Bennett, S. J., & Button, C. (1997). Skill acquisition in sport: Some applications of an evolving practice ecology. *Journal of Sport Sciences, 15*, 621-640.
Hannays, K. (2020). Attitudes of tennis coaches towards continuous eductation: A Caribbean perspective *ITF Coaching and Sport Science Review, 80*, 9-11.
Harrison, R. L., Reilly, T. M., & Creswell, J. W. (2020). Methodological rigor in mixed methods: An application in management studies. *Journal of Mixed Methods Research, 14*(4), 473-495.
Haskins, M. J. (1965). Development of a response recognition training film in tennis. *Perceptual and Motor Skills, 21*, 207-211.
Hassmen, P., Keegan, R., & Piggott, D. (2016). *Rethinking sport and exercise psychology research: Past, present and future*. London, United Kingdom: Palgrave Macmillan.
He, C., Trudel, P., & Culver, D. (2018). Actual and ideal sources of coaching knowledge of elite Chinese coaches. *International Journal of Sports Science & Coaching, 13*(4), 496–507.
Helsen, W. F., & Starkes, J. L. (1999). A multidimensional approach to skilled perception and performance in sport. *Applied Cognitive Psychology, 13*(1), 1-27.
Hervas, J. I. (2014). 3D variability in ball toss and impact location for tennis serve in collegiate female players. *Electronic Thesis and Dissertations, 27*. Retrieved from http://scholarworks.uni.edu/etd/27
Hohmann, T., & Munzert, J. (2007). Expert versus novice difference in the perception of basketball dribbles *Journal of Sport & Exercise Psychology, 29*, 86.
Hopkins, W. G. (2019). A spreadsheet for bayesian posterior compatibility intervals and magnitude-based decisions. *Sports Sci, 23*, 5-7. doi:Available online at: http://sportsci.org/2019/bayes.htm
Hopkins, W. G., & Batterham, A. M. (2018). The vindication of magnitude-based Inference. *Sports Sci, 22*, 19-29. doi:Available online at: http://sportsci.org/2018/mbivind.htm
Hopkins, W. G., Marshall, S. W., Batterham, A. M., & Hanin, J. (2009). Progressive statistics for studies in sports medicine and exercise science. *Med Sci Sports Exerc, 41*(1), 3-13. doi:10.1249/MSS.0b013e31818cb278
Hopkins, W. G., Marshall, S. W., Batterham, A. M., & Hanin, J. (2009). Progressive statistics for studies in sports medicine and exercise science. *Medicine and Science in Sports and Exercise, 41*, 3-12.
Hopwood, M. J., Mann, D. L., Farrow, D., & Nielsen, T. (2011). Does visual-perceptual training augment the fieding performance of skilled cricketers? *International Journal of Sports Science & Coaching, 6*(4), 523-535.
Hsu, C., & Sandford, B. (2007). The Delphi technique: Making sense of consensus. *Practical Assessment Research & Evaluation 12*(10).
Hubball, H., & Robertson, S. (2004). Using problem-based learning to enhance team and player development in youth soccer. *The Journal of Psychical Education, Recreation and Dance, 75*(4), 38-45.
Hullinger, A. M., & DiGirolamo, J. A. (2020). A professional development study: The lifelong journeys of coaches. *International Coaching Psychology Review, 15*(1), 8-19.
Imwold, C. H., & Hoffman, S. J. (1983). Visual Recognition of a Gymnastic skill by experienced and inexperienced instructors. *Research Quarterly for Exercise and Sport, 54*(2), 149-155.
International Council for Coaching Excellence, Association for Summer Olympic International Federations, & Leeds Becket University. (2013). *International sport coaching framework* (Vol. 1.2). Champaign, IL: Human Kinetics.

Isaacs, L. D., & Finch, A. E. (1983). Anticipatory timing of beginning and intermediate tennis players. *Perceptual and Motor Skills, 57*, 451-454.
ITF. (2004). *International tennis manual*.
ITF (Producer). (2007). Coaches educational program level 2 coaching course. Retrieved from http://en.coaching.itftennis.com/media/114010/114010.pdf
ITF. (2016). *Video analysis for the tennis coach*.
Ivancevic, T. T., Jovanovic, B., Jovanovic, S., Djukic, M., Djukic, N., & Lukman, A. (2011). *Paradigm shift for future tennis: The art of tennis physiology, biomechanics and psychology*. Berlin: Springer.
Jaaskelainen, R. (2010). Think aloud protocol. In Y. Gambier & L. V. Doorslaer (Eds.), *Handbook of translation studies* (Vol. 1, pp. 371-373). Amsterdam: John Benjamins Publishing Company.
Jackson, R. C., & Farrow, D. (2005). Implicit perceptual training: how, when, and why? . *Human Movement Science, 24*(308-325).
Jackson, R. C., & Mogan, P. (2007). Advance visual information, awareness, and anticipation skill. *J Mot Behav, 39*(5), 341-351. doi:10.3200/JMBR.39.5.341-352
Janelle, M., J.D., C., Coombes, S. A., & Mousseau, M. B. (2003). Mechanisms of attentional cueing during observational learning to facilitate motor skill acquisition. *Journal of Sports Sciences, 21*, 825-838.
Jennett, S. (Ed.) (2008). Elsevier Limited
Johnson, R. B., Onwuegbuzie, A. J., & Turner, L. A. (2007). Towards a definition of mixed methods research. *Journal of Mixed Methods Research, 1*(2), 112-133.
Jones, C. M., & Miles, T. R. (1978). Use of advance cues in predicting the flight of a lawn tennis ball. *Journal of Human Movement Studies, 4*, 231-235.
Jones, D. F., Housner, L. D., & Kornspan, A. S. (1995). A comparative analysis of expert and novice basketball coaches' practice planning. *Applied Research in Coaching and Athletic Annual*, 201-227.
Jones, I. (2014). *Research methods for sport studies* (3rd ed.). ProQuest Ebook Central: Routledge
Jones, I., Holloway, I., & Brown, L. (2013). *Qualitative research in sport and physical activity*. London: SAGE Publications Ltd.
Jones, R., Bezodis, I., & Thompson, A. (2009). Coaching sprinting: expert coaches' perception of race phases and technical constructs. *International Journal of Sport Science and Coaching, 4*(3), 385-396.
Jones, R., Harris, R., & Miles, A. (2009). Mentoring in sports coaching: A review of the literature. *Physical Education and Sport Pedagogy, 14*(3), 267–284.
Jones, R. L., & Turner, P. (2006). Teaching coaches to coach holistically: can problem-based learning (PBL) help? *Physical Education and Sport Pedagogy, 11*(2), 181-202.
Kaushik, V., & Walsh, C. A. (2019). Pragmatism as a research paradigm and its implications for social work research. *Social Sciences, 8*(9), 255.
Kerr, Z. Y., Yeargin, S., McLeod, T. C. V., Nittoli, V. C., Mensch, J., Dodge, T., & Dompier, T. P. (2015). Comprehensive coach education and practice contact restriction guidelines result in lower injury rates in youth American football. *Orthopaedic Journal of Sports Medicine, 3*(7), 1-8.
Kioumourtzoglou, E., Kourtessis, T., Michalopoulou, M., & Derri, V. (1998). Differences in several perceptual abilities between experts and novices in basketball, volleyball and water-polo. *Perceptual and Motor Skills, 86*, 899-912.
Kirk, D. (2000). A task-based approach to critical pedagogy in sport and psychical education. In R. L. Jones & K. M. Armour (Eds.), *Sociology of Sport: Theory and practise* (pp. 201-216).
Kittel, A., Larkin, P., Elsworthy, N., & Spittle, M. (2019). Video-based testing in sporting officials: A systematic review. *Psychology of Sport and Exercise, 43*, 261-270.
Knowles, M. S. (1980). *The modern practice of adult education* Englewood Cliffs, NJ: Prentice Hall.
Knudson, D. (2007). Qualitative biomechanical principles for application in coaching. *Sport Biomechanics, 6*(7), 109-118.

Koh, K. T., Lee, T. P., & Lim, S. H. (2017). The Internet as a source of learning for youth soccer coaches. *Sports Science & Coaching 13*(2), 278-289.
Kolb, D. A. (1984). *Experiental Learning: Experience as the source of learning and development* Englewood Cliffs, NJ: Prentice-Hall.
Kolb, S. M. (2012). Grounded theory and the constant comparative method: valid research strategies for educators. *Journal of Emerging Trends in Educational Research and Policy Studies, 3*(1), 83-86.
Korstjens, I., & Moser, A. (2018). Series: Practical guidance to qualitative research. Part 4: Trustworthiness and publishing. *European Journal of General Practice, 24*(1), 120-124.
Kovacs, M., & Ellenbecker, T. (2011). An 8-stage model for evaluating the tennis serve: implications for performance enhancement and injury prevention. *Sport Health, 3*(6), 504-513.
Lakens, D., Scheel, A. M., & Isager, P. M. (2017). Equivalence testing for psychological research: a tutorial. *Adv Methods Pract Psychol Sci*(1), 259-269. doi:10.1177/2515245918770963
Lan, Y., & Chang, K. (2012). CoCAR: An online synchronous training model for empowering ICT capacity of teachers of Chinese as a foreign language. *Australasian Journal of Educational Technilogy 28*(6), 1020-1038.
Langan, E., Blake, C., & Lonsdale, C. (2013). Systematic review of the effectiveness of interpersonal coach education interventions on athlete outcomes. *Psychology of Sport and Exercise, 14*(1), 37–49.
Larkin, P., Berry, J., Dawson, B., & Lay, B. (2011). Perceptual and decision-making skills of Australian football umpires. *International Journal of Performance Analysis in Sport, 11*(3), 427-437.
Larkin, P., Mesagno, C., Berry, J., Spittle, M., & Harvey, J. T. (2018). Video-based training to improve perceptual-cognitive decision-making performance of Australian football umpires. *Journal of Sport Sciences, 36*(3), 239-246.
Larkin, P., Mesagno, C., Spittle, M., & Berry, J. (2015). An evaluation of video-based training programs for perceptual-cognitive skill development. A systematic review of current sport-based knowledge. *International Journal of Sport Psychology, 46*, 555-586.
Leas, R. R., & Chi, M. T. H. (1993). Analysing diagnostic expertise of competitive swimming coaches. *Advances in Psychology, 102*, 75-94.
Lees, A. (2002). Technique analysis in sports: a critical review. *J Sports Sci, 20*(10), 813-828. doi:10.1080/026404102320675657
Lefebvre, J. S., Evans, M. B., Turnnnidge, J., Gainforth, H. L., & Côté, J. (2016). Describing and classifying coach development programmes: A synthesis of empirical research and applied practice. *International Journal of Sports Science & Coaching, 11*(6), 887–899.
Lesgold, A. M., Glaser, R., Rubinson, H., Klopfer, D., Feltovich, P., & Wang, Y. (1998). Expertise in a complex skill: Diagnosing X-ray pictures. In C. M.T.H., R. Glaser, & F. M.J. (Eds.), *The nature of expertise* (pp. 311–342). Hillsdale, NJ: Erlbaum.
Liamputtong, P. (2017). *Research methods in health: Foundations for evidence based practice*. Melbourne: Oxford University Press.
Lipshitz, R., & Strauss, O. (1997). Coping with uncertainty: a naturalistic decision-making analysis. *Organisational Behaviour and Human Decision Processes, 6*, 149-163.
Loffing, F., & Hagemann, N. (2014). Skill differences in visual anticipation of type of throw in team-handball penalties. *Psychology of Sport and Expertise, 15*, 260 - 267.
Londerlee, B. (1967). Effect of training with motion pictures versus flash cards upon football play recognition. *Research Quarterly, 38*, 202-207.
Lyle, J. (2007). A review of the research evidence for the impact of coach education. *International Journal of Coaching Science, 1*(1), 19-36.
Lyle, J. (2010). Coaches' decision making: a Naturalistic Decision Making analysis. In J. Lyle & C. Cushion (Eds.), *Sports coaching e-book: professionalisation and practice*
Lyle, J., & Cushion, C. (2017). *Sport coaching concepts: A framework for coaching practise.* New York: Routledge.

MacMahon, C., & Ste-Marie, D. M. (2002). Decision-making by experienced rugby referees: Use of perceptual information and episodic memory. *Perceptual and Motor Skills, 95*(2), 570-572.
Mallet, C. J., Trude, P., Lyle, J., & Rynne, B. (2009). Formal vs. informal coach education *International Journal of Sport Science & Coaching, 4*(3).
Mann, D. T. Y., Williams, A. M., Ward, P., & Janelle, C. M. (2007). Perceptual-cognitive expertise in sport: A meta-analysis. *Journal of Sport & Exercise Psychology, 29*, 457-478.
Martin, C., Bideau, B., Bideau, N., Nicolas, G., Delamarche, P., & Kulpa, R. (2014). Energy flow analysis during the tennis serve: comparison between injured and noninjured tennis players. *The American Journal of Sport Medicine, 42*(11), 2751-2760.
Mascarenhas, D. R. D., Collins, D., Mortimer, P. W., & Morris, B. (2005). Training accurate and coherent decision making in rugby union referees. *The Sport Psychologist, 19*(2), 131.
McDougall, J. (2015). The quest for authenticity: a study of an online discussion forum and the needs of adult learners. *Australian Journal of Adult Learning, 55*(1), 94-113.
McMorris, T., & Hauxwell, B. (1997). Improving anticipation of soccer goalkeepers using video observation. In T. Reilly, J. Bangsbo, & M. Hughes (Eds.), *Science and Football III* (Vol. 290-294). London: E&FN Spon.
McRobert, A. P., Ward, P., Eccles, D. W., & Williams, A. M. (2011). The effect of manipulating context-specific information on perceptual–cognitive processes during a simulated anticipation task. *British Journal of Psychology, 102*(3), 519-534.
Memmert, D., Hagemann, N., Althoetmar, N., Geppert, S., & Seiler, D. (2009). Conditions of practice in perceptual skill learning. *Research Quarterly for Exercise and Sport, 80*(1), 32-43.
Memmert, D., Simons, D. J., & Grimme, T. (2009). The relationship between visual attention and expertise in sport. *Psychology of Sport and Expertise, 10*(1), 146-151.
Memmert, D., Simons, D. J., & Grimme, T. (2009). The relationship between visual attention and expertise in sports. *Psychology of Sport and Exercise, 10*(1), 146-151. doi:10.1016/j.psychsport.2008.06.002
Merriam, S. B., & Ca. (2007). *Learning in Adulthood: A Comprehensive Guide*. San Francisco, CA: Jossey-Bass.
Mezirow, J. (1997). Transformative learning: Theory to practice *New Directions for Adult and Continuing Eduction 74*, 5-12.
Microsoft10. (2015). Retrieved from https://www.microsoft.com/en-au/windows/get-windows-10
Mitchell, J., Maratos, F. A., Giles, D., Taylor, N., Butterworth, A., & Sheffield, D. (2020). The visual search strategies uderpinning effective observational analysis in the coaching of climbing movement *Frontiers in Psychology, 11*(1025).
Moe, V. F. (2004). How to understand skill acquisition in sport. *Bulletin of Science, Technology & Society, 24*(3), 213-224.
Morante, S. (2008). Analysing performance analysis *Australian Tennis Magazine* 52-53.
Moreno, F. J., Saavedra, J. M., Sabido, R., & Luis, V. (2006). Visual search strategies of experienced and nonexperienced swimming coaches. *Perceptual and Motor Skills, 103*, 861-872.
Mori, S., Ohtani, Y., & Imanaka, K. (2002). Reaction times and anticipatory skills of karate athletes. *Human Movement Science 21*, 213-230.
Morrison, C. S., & Knudson, D. V. (2002). *Qualitative analysis of human movement* Champaign, IL: Human Kinetics
Müller, S., Fitzgerald, C., & Brenton, J. (2020). Considerations for application of skill acquisition in sport: an example from tennis. *Journal of Expertise, 3*(3), 175-182.
Murgia, M., Sors, F., Muroni, A. F., Santoro, I., Prpic, V., Galmonte, A., & Agostini, T. (2014). Using perceptual home-training to improve anticipation skills of soccer goalkeepers. *Psychology of Sport and Exercise, 15*, 642-648.
Murphy, C. A., Keiffer, E. A., Neal, J. A., & Crandall, P. G. (2013). A customizable evaluation instrument to facilitate comparisons of exisitng online trainign programs. *Knowledge Management & E-Learning, 5*(3), 251-268.

Murray, N., Harris, C., & De La Pena, D. (2007). Expertise in change detection. *Journal of Sport & Exercise Psychology, 29*, 191-191.
Nadin, S., & Cassell, C. (2006). The use of a research diary as a tool for reflexive practice: Some reflections from management research. *Qualitative Research in Accounting and Management, 3*, 208-217.
Nakamoto, H., & Mori, S. (2012). Experts in fast-ball sports reduce anticipation timing cost by developing inhibitory control. *Brain and Condition, 80*(1), 23-32.
Nash, C., & Collins, D. (2006). Tacit Knowledge in Expert Coaching: Science or Art? *Quest, 58*(4), 465-477.
Nash, C., Martindale, R., Collins, D., & Martindale, A. (2012). Parameterising expertise in coaching: past, present and future. *Journal of Sport Sciences, 30*(10), 985-994.
National-Coaching-Certification-Program. (2020). Baseball Canada NCCP. Retrieved from https://nccp.baseball.ca/index.php?page=175
Navin, A., & Vinson, D. (2020). Seeking consensus regarding the characteristics of expertise and development requirements across five domains of netball coaching in the United Kingdom. *International Journal of Applied Sports Sciences, 32*(1), 69-90.
Nazarudin, M. N., Abdullah, M. R., Suppiah, P. K., Fauzee, M. S. O., Parnabas, V., & Abdullah, N. M. (2015). Decision making and performance of Malaysian rugby sevens referees. *Movement, Health & Exercise, 4*(1), 61-75.
NVIVO. (2018). NVIVO qualitative data anakysis software (Version 12): QSR International Pty Ltd.
Oakley, B., & Twitchen, A. (2018). How might online distance learning contribute to coach development. *Applied Coaching Research Journal, 2*, 24-31.
Oates, T. (1992). Core skills and transfer: aiming high. *Education and Training Technology International, 29*(3), 227-239.
Over, S., & Sharp, B. (2008). Information technology in tennis. *ITF Coaching and Sport Science Review, 15*(45), 24-25.
Pallant, J. (2016). *SPSS survival manual : a step by step guide to data analysis using SPSS*. Sydney: Allen & Unwin.
Paradis, K., Larkin, P., & O'Connor, D. (2016). The effect of physical exertion on decision-making performance of Australian football umpires *Journal of Sport Sciences, 34*(16), 1-7.
Passos, P., Araujo, D., & Davids, K. (2016). Competitiveness and the process of co-adaptation in team sport performance. *Frontiers in Psychology, 7*, 15-62.
Patton, M. Q. (2002). *Qualitative research and evaluation method*. Thousand Oaks: Sage Publications.
Paull, G., & Giencross, D. (1997). Expert perception and decision making in baseball. *International Journal of Sport Psychology, 28*(1), 35-56.
Pearce, M. J., Pargament, K. I., Oxhandler, H. K., Vieten, C., & Wong, S. (2019). Novel online training program improves spiritual competencies in mental health care *Spirituality in Clinical Practice, 6*(2), 73-82.
Petrakis, E. (1986). Visual Observation Patterns of Tennis Teachers. *Research Quarterly for Exercise and Sport, 57*(3), 254-259.
Petrov, P. K. (2018). Online training courses: Application experience in sport specialist training disciplines *Theory and practise of physical culture, 12*, 12-14.
Pinheiro, V. E. D. (1990). *Motor skill diagnosis: diagnostic processes of expert and novice coaches*. Paper presented at the Annual Convention Consortium Meetings if the American Alliance for Health, Physical Education, Recreation and Dance, New Orleans, Louisiana.
Pinheiro, V. E. D., & Simon, H. A. (1992). An operational model of motor skill diagnosis. *Journal of Teaching in Physical Education, 11*, 288-302.
Pluim, B., & Safran, M. (2004). *From breakpoint to advantage: A practical guide to optimal tennis health and performance*. Vista, CA: Racket Tech Publishing

Poulter, D. R., Jackson, R. C., Wann, J. P., & Berry, D. C. (2005). The effect of learning condition on perceptual anticipation, awareness, and visual search. *Human Movement Science, 24*(3), 345-361.

Qualtrics. (2005). Qualtrics. USA: Provo, Utah. Retrieved from https://www.qualtrics.com

Randel, J. M., Pugh, H. L., & Reed, S. K. (1996). Differences in expert and novice situation awareness in naturalistic decision making. *International Journal of Human-Computer Studies, 45*, 579-597.

Reichardt, C. S. (2009). Quasi-Experimental Design. In R. E. Millsap & A. Maydeu-Olivares (Eds.), *The SAGE handbook of quantitative methods in psychology*

. SAGE Research Methods.

Reid, M., Elliott, B., & Crespo, M. (2015). *Tennis Science: Optimizing performance on the court*. UK: The Ivy Press.

Reilly, T., Williams, A. M., & Nevill, A. M. (2000). A multidisciplinary approach to talent identification in soccer. *Journal of Sport Sciences, 18*(9), 695-702.

Renshaw, I., Chow, J. Y., Davids, K., & Hammond, J. (2010). A constraints-led perspective to understand skill acquisition and game play: a basis for integration of motor learning theory and physical education praxis? *Psysical Education and Sport Pedagogy 15*(2), 117-137.

Renshaw, I., Davids, K., Phillips, E., & Kerheve, H. (2012). Developing talent in athletes as complex neurobiological systems. In J. Baker, S. Cobley, & J. Schorer (Eds.), *Talent identification and development in sport: International perspectives* (pp. 64-80). London: Routledge.

Renshaw, I., Davids, K., & Savelsbergh, G. J. P. (2010). *Motor learning in practice: a constraints-led approach*. Taylor & Francis e-Library: Routledge

Richards, P., Collins, D., & Mascarenhas, D. R. D. (2012). Developing rapid high-pressure team decision-making skills. The integration of slow deliberate reflective learning within the competitive performance environment: A case study of elite netball. *International Journal of Reflective Practice*, 1-18.

Richards, P., Collins, D., & Mascarenhas, D. R. D. (2017). Developing team decision-making: a holistic framework integrating both on-field and off-field pedagogical coaching processes. *Sports Coaching Review*.

Roetert, E. P., Ellenberker, T. S., & Reid, M. (2009). Biomechanics of the tennis serve: implications for strength training. *Strength and Conditioning Journal, 31*(4), 35-40.

Rogers, C. (1980). *A way of being*. Boston, MA: Houghton Mifflin Harcourt.

Rowe, R., Horswill, M. S., Kronvall-Parkinson, M., Poulter, D. R., & McKenna, F. P. (2009). The effect of disguise on novice and expert tennis players' anticipation ability. *Journal of Applied Sport Psychology, 21*, 178-185.

Rynne, S. B., Mallett, C., & Tinning, R. (2006). High performance sport coaching: Institutes of sport as sites for learning. *International Journal of Sports Science & Coaching, 1*(3), 223–234.

Ryu, D., Kim, S., Abernethy, B., & Mann, D. L. (2013). Guiding attention aids the acquisition of anticipatory skill in novice soccer goalkeepers. *Research Quarterly for Exercise and Sport, 84*, 252-262.

Sackey-Addo, R., & Camarero, J. P. (2016). The evolution of online education for sports coaches: A tennis perspective. *ITF Coaching and Sport Science Review, 68*(24), 27-28.

Santos, F., Camire, M., MacDonald, D. J., Campos, H., Conceicao, M., & Silva, A. (2019). Process and outcome evaluation of a positive youth development-focused online coach education course. *International Sport Coaching Journal, 6*, 1-12.

Saury, J., & Durand, M. (1998). Practical knowledge in expert coaches: on site study of coaching in sailing. *Research Quarterly for Exercise and Sport, 69*(3), 254-266.

Savelsbergh, G. J., Van Gastel, P. J., & Van Kampen, P. M. (2010). Anticipation of penalty kicking direction can be improved by directing attention through perceptual learning

Savelsbergh, G. J. P., Davids, K., Van Der Kamp, J., & Bennett, S. J. (2003). *Development of movement co-ordination in children: Applications in the fileds of ergonomics, health sciences and sport*. London: Routledge.

Savelsbergh, G. J. P., Williams, A. M., Van Der Kamp, J., & Ward, J. (2002). Visual search, anticipation and expertise in soccer goalkeepers. *Journal of Sport Sciences, 20*, 279-287.

Schempp, P. G., & Woorons, S. (2018). Differences Between Expert and Novice Tennis Coaches' Perceptual Capacities. *International Sport Coaching Journal, 5*(3), 251-261.

Schon, D. A. (1983). *The reflective practitioner: How professionals think in action*. New York: Basic Books.

Schorer, J., Canal-Bruland, R., & Cobley, S. (2010). Frequency of knowledge of results does not influence perceptual learning and retention in novices. *International Journal of Sport Psychology, 41*(2), 107.

Schweizer, G., Plessner, H., Kahlert, D., & Brand, R. (2011). A video-based training method for improving soccer referees' intuitive decision-making skills. *Journal of Applied Sport Psychology, 23*(4), 429-442.

Scott, D., Scott, L. M., & Howe, B. L. (1998). Training anticipation for intermediate tennis players. *Behavior Modofication 22*(3), 243-261.

Shafizadeh, M., & Platt, G. K. (2012). Effect of verbal cueing on trajectory anticipation in the penlty kick among novice football goalkeepers. *Perceptual and Motor Skills, 114*(1), 174-184.

Sheets, A., Abrams, G. D., Corazza, S., Safran, M. R., & Andriacchi, T. P. (2011). Kinematics differences between the flat, kick, and slice serves measured using a markerless motion capture method. *Annals of Biomechanical Engineering, 39*(12), 3011-3020.

Sherman, C. A., Sparrow, W. A., Jolley, D., & Eldering, J. (2001). Coaches' perceptions of golf swing kinematics. *International Journal of Sport Psychology, 31*, 257-270.

Shim, J., Carlton, L. G., Chow, J. W., & Chae, W. (2005). The use of anticipatory visual cues by highly skilled tennis players. *Journal of Motor Behaviour, 37*(2), 164-175.

Shukala, G., Paul, M., & Jaspar, S. (2011). The effect of vision training on performance in tennis players. *Serbian Journal of Sport Sciences, 5*(1), 11-16

Silva, E. J. D., Evans, M. B., Lefebvre, J. S., Allan, V., Cote, J., & Palmeira, A. (2020). A systematic review of intrapersonal coach development programs: Examining the development and evaluation of programs to elicit coach reflection. *15*(5-6), 818-837.

Singer, R. N., Cauraugh, J. H., Chen, D., Steinberg, G. M., & Frehlich, S. G. (1996). Visual search, anticipation, and reactive comparisons between highly-skilled and beginning tennis players. *Journal of Applied Sport Psychology, 8*(1), 9-26. doi:10.1080/10413209608406305

Singer, R. N., Cauraugh, J. H., Chen, D., Steinberg, G. M., Frehlich, S. G., & Wang, L. (1994). Training mental quickness in beginning/intermediate tennis players. *The Sport Psychologist, 8*, 305-318.

Skinner, B. F. (1938). *The behavior of organisms*. New York: Appleton-Century.

Skrinar, G. S., & Hoffman, S. J. (1979). Effect of outcome information on analytic ability of golf teachers. *Perceptual and Motor Skills, 48*, 703-708.

Smeeton, N. J., Hibbert, J. R., Stevenson, K., Cumming, J., & Wiiliams, A. M. (2013). Can imagery facilitate improvements in anticipation behavior? *Psychology of Sport and Exercise, 14*, 200-210.

Smeeton, N. J., & Huys, R. (2011). Anticipation of tennis-shot direction from whole-body movement: the role of movement amplitude and dynamics. *Hum Mov Sci, 30*(5), 957-965. doi:10.1016/j.humov.2010.07.012

Smeeton, N. J., Williams, A. M., Hodges, N. J., & Ward, P. (2005). The relative effectiveness of various instructional approaches in developing anticipation skill. *Journal of Experimental Psychology Applied, 11*(2), 98-110.

Smith, A., Roberts, J., Wallace, E., & Forrester, S. (2012). Professional golf coaches' perceptions of the key technical parameters in the golf swing. *Procedia Engineering, 34*, 224-229. doi:10.1016/j.proeng.2012.04.039

Smith, A., Roberts, J., Wallace, E., Kong, P. W., & Forrester, S. (2015). Golf coaches' perceptions of key technical swing parameters compared to biomechanical literature. *International Journal of Sport Science & Coaching, 10*(739-755), 739.

Smith, B., & McGannon, K. R. (2018). Developing rigor in qualitative researchproblems and opportunities within sport and exercise psychology. *International Review of Sport and Exercise Psychology, 11*(1), 101-121.

Smith, S. L., & Kelloway, E. K. (2016). Respect in the workplace: An evaluation of a short online intervention program *Journal of Organizational Effectiveness: People and Performance 3*(4), 395-410.

Solomon, M. A., & Lee, A. M. (1991). A contrast of planning behaviour between expert and novice adapted physical education teachers. *Adapted Physical Activity Quarterly, 8*, 115-127.

Souchon, N., Livingstone, A. G., & Maio, G. R. (2013). The influence of referees' expertise, gender, motication, and time constraints on decisional bias against women. *Journal of Sport & Exercise Psychology, 35*(6), 585-599.

Spittle, M. (2021). *Motor learnign and skill acquisition: Applications for physical education and sport*. UK: RED GLOBE PRESS.

Spitz, J., Put, K., Wagemans, J., Williams, A. M., & Helsen, W. F. (2016). Visual search behaviors of association football referees during assessment of four play situation *Cognitive Research: Principles and Implications, 1*(1), 12.

Spitz, J., Put, K., Wagemans, J., Williams, A. M., & Helsen, W. F. (2017). Does slow motion impact on the perception of foul play in football? *European Journal of Sport Science 17*(6), 748-756.

Spitz, J., Put, K., Wagemans, J., Williams, A. M., & Helsen, W. F. (2018). The role of domain-generic and domain-specific perceptual-cognitive skills in assiciation football referees. *Psychology of Sport and Exercise, 34*(Suppl. C), 47-56.

SportAus, & AIS. (2020). Training Retrieved from https://www.sportaus.gov.au/participation/inclusive_sport/training

Starker, J. L., Edwards, P., Dissanayake, P., & Dunn, T. (1995). A new technology and field test of advance cue usage in volleyball. *Research Quarterly for Exercise and Sport, 66*, 162-167.

Ste-Marie, D. M. (1999). Expert-novice differences in gymnastic judging: an information processing perspective. *Applied Cognitive Psychology, 13*(3), 269-281.

Stoszkowski, J., & Collins, D. (2016). Sources, topics and use of knowledge by coaches. *Journal of Sport Sciences, 34*(9), 794–802.

Stoszkowski, J., MacNamara, A., Collins, D., & Hodgkinson, A. (2021). "Opinion and fact, perspective and truth": Seeking truthfulness and integrity in coaching and coach education. *International Sport Coaching Journal, 8*, 263-269.

Swanson, H. L., O'Connor, J. E., & Cooney, J. B. (1990). An information processing analysis of expert and novice teacher's problem solving. *American Educational Research Journal, 27*, 533-556.

Swanson, R. A., & Law, B. (1993). Whole-part-whole learning model. *Performance Improvement Quarterly, 6*(1), 43-53.

Swimming Australia. (2020). Coach Education. Retrieved from https://www.swimming.org.au/community-1/coaches/coach-education

Tabachnick, G., & Fidell, l. S. (2013). *Using Multivariate Statistics*. USA: Pearson.

Tan, S. K. S. (1997). The elements of expertise. *Journal of Physical Education, Recreation, and Dance, 68*(2), 30-33.

Tayler, M. A., Burwitz, L., & Davids, K. (1994). Coaching perceptual strategy in badminton. *Journal of Sport Sciences, 12*, 213.

Tenenbaum, G., Levy-Kolker, N., Sade, S., Liebermann, D. G., & Lidor, R. (1996). Anticipation and confidence of decisions related to skilled performance. *International Journal of Sport Psychology, 27*, 293-307.
Tennis Australia. (2010). Player Development stroke and tactical fundamentals. In.
Tennis Australia. (2013). Coach Development technical fundamentals. Retrieved from http://www.tennis.com.au/wp-content/uploads/2014/11/Technical-and-Tactical-fundamentals-guidelines_low-res.pdf
Tennis Australia. (2020a). Bounce. Retrieved from https://www.tennis.com.au/coaches/bounce
Tennis Australia. (2020b). Coach education Retrieved from https://www.tennis.com.au/coaches/coach-education
Tennis Australia. (2020c). High Performance. Retrieved from https://www.tennis.com.au/coaches/coach-education/high-performance
Tennis Australia. (2020d). Junior Development Retrieved from https://www.tennis.com.au/coaches/coach-education/junior-development
Thelen, E., & Smith, L. B. (1994). *A dynamic systems approach to the development of cognition and action*. Cambridge, MA: MIT Press.
Thomas, K. T., & Thomas, J. R. (1994). Developing expertise in sport: The relation of knowledge and performance *International Journal of Sport Psychology, 25*, 295-312.
Thompson, A., Bezodis, I. N., & Jones, R. L. (2009). An in-depth assessment of expert sprint coaches' technical knowledge. *Journal of Sports Sciences, 27*(8), 855-861. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/19551551
Thorndike, E. L. (1927). The law of effect. *American Journal of Psychology, 39*, 212-222.
Tooth, J., Nielsen, S., & Armstrong, H. (2013). Coaching effectiveness survey instruments: taking stock of measuring the immeasurable. *An international journal of theory, research and practice*
Trudel, P., Culver, D., & Werthner, P. (2013). Looking at coach development from the coach-learner's perspective. In P. Potrac, W. Gilbert, & J. Denision (Eds.), *Routledge handbook of sports coaching* USA: Taylor & Francis.
Trudel, P., & Gilbert, W. (2006). Coaching and coach education. In D. Kirk, D. MacDonald, & M. O'Sullivan (Eds.), *The handbook of physical education*. London: SAGE Publications.
Trudel, P., Milestetd, M., & Culver, D. (2020). What the empirical studies on sport coach education programs in higher education have to reveal: A review. *International Sport Coaching Journal, 7*, 61-73.
US Lacrosse. (2020). Online courses. Retrieved from https://www.uslacrosse.org/coaches/coach-development-program/online-courses
Vergeer, I., & Lyle, J. (2013). Mixing method in assessing coaches' decision making. *Research Quarterly for Exercise and Sport, 78*(3), 225-235.
Vicente, K. J., & Wang, J. H. (1998). An ecological theory of expertise effects in memory recall. *Psychological Review, 105*(1), 33-57.
Walker, L. F., Thomas, R., & Driska, A. P. (2018). Informal and nonformal learning for sport coaches: A systematic review. *International Journal of Sports Science & Coaching, 13*(5), 694–707.
Wang, Y., & Zhi, X. (2009). An evaluation system for the online training programs in meteorology and hydrology. *International Eductional Studies 2*(4), 45-48.
Ward, P., & Smeeton, N. J. (2003). Anticipation skill in a real-world task: measurement, training and transfer in tennis. *Journal of Experimental Psychology Applied, 8*(4), 259-270.
Ward, P., & Williams, A. M. (2003). Perceptual and Cognitive Skill Development in Soccer: The Multidimensional Nature of Expert Performance. *Journal of Sport & Exercise Psychology, 25*(1), 93-111.
Ward, P., Williams, A. M., & Bennett, S. J. (2002). Visual search and biological motion perception in tennis. *Res Q Exerc Sport, 73*(1), 107-112. doi:10.1080/02701367.2002.10608997
Weber, J. E. (2014). Humanism within globalization. *Adult Learning, 25*(2), 66-68.

Wharton, L., & Rossi, T. (2015). How would you recognise an expert coach if you saw one? . *International Journal of Sport Science and Coaching, 10*(2), 577-588.
Whelan, N., Kenny, I. C., & Harrison, A. J. (2016). An insight into track and field coaches' knowledge and use of sprinting drills to improve performance. *International Journal of Sport Science & Coaching, 11*(2), 182-190.
Wilkerson, L., & Gijselaers, W. (1996). *Bringing problem-based learning to higher education: Theory and practise*. San Francisco, CA: Jossey-Bass.
Williams, A., & Hodges, N. (2005). Practice, instruction and skill acquisition in soccer: Challenging tradition. *Journal of Sports Sciences, 23*(6), 637-650.
Williams, A. M. (2000). Perceptual skill in soccer: Implications for talent identification and development. *Journal of Sports Sciences, 18*, 737-740.
Williams, A. M., & Abernethy, B. (2012). Anticipation and decision-making: Skills, methods and measures. In G. Tenenbaum, R. C. Eklund, & A. Kamata (Eds.), *Measurement in Sport and Exercise Psychology* (pp. 191-202). Champaign, Ill., U.S.A.: Human Kinetics.
Williams, A. M., & Burwitz, L. (1993). Advance cue utilization in soccer. In T. Reilly, J. Clarys, & A. Stibbe (Eds.), *Science and Football II* (pp. 239–243). London: E&FN Spon.
Williams, A. M., & Davids, K. (1988). Perceptual expertise in sport: research, theory and practice. In H. Steinberg, I. Cockerill, & A. Dewey (Eds.), *What sport psychologists do* (pp. 48-57).
Williams, A. M., & Ericsson, K. A. (2005). Perceptual-cognitive expertise in sport: some considerations when applying the expert performance approach. *Human Movement Science, 24*(3), 283-307.
Williams, A. M., Fawver, B., & Hodges, N. J. (2017). Using the "expert performance approach" as a framework for improving understanding of expert learning. *Frontline Learning Research, 5*(3), special issue.
Williams, A. M., Ward, P., & Chapman, C. (2003). Training perceptual skill in field hockey: Is there transfer from the laboratory to the field? *Research Quarterly for Exercise and Sport, 74*(98-104).
Williams, A. M., Ward, P., Knowles, J. M., & Smeeton, N. J. (2002). Anticipation skill in a real-world rask: Measurement, training and transfer in tennis. *Journal of Experimental Psychology: Applied, 8*(259-270).
Wilson, A. W., & Mock, S. E. (2013). Association of certification level and assertiveness with accuracy of calls among ice hockey referees. *International Journal of Sport Science & Coaching, 8*(3), 505-512.
Woodworth, R. S. (1899). The accuracy of voluntary movement *Psychological Review Monographs, 13*.
Woorons, S. I. (2001). *An analysis of expert and novice tennis instructors perceptual capacities* (Doctor of Philosophy). The University of Valenciennes, Athens, Georgia. Retrieved from https://getd.libs.uga.edu/pdfs/woorons_sophie_i_200112_phd.pdf
World Economic Forum. (2021). The COVID-19 pandemic has changed education forever. This is how Retrieved from https://www.weforum.org/agenda/2020/04/coronavirus-education-global-covid19-online-digital-learning/
Wu, Y., Zeng, Y., Zhang, L., Wang, S., Wang, D., Tan, X., . . . Zhang, J. (2013). The role of visual perception in action anticipation in basketball athletes. *Neuroscience, 237*, 29-41. doi:10.1016/j.neuroscience.2013.01.048
Yanofsky, K. (1998). *Volleyball coaches perception of performance* (Maste of Science). Dalhousie University, Halifax, Nova Scotia.
Yilmaz, K. (2011). The cognitive perspective on learning: its theoretical underpinnings and implications for classroom practices. *The Clearing House: A Journal of Educational Strategies, Issues and Ideas, 84*(5), 204-212.
Yuan, E. (2012). Zoom. Retrieved from https://zoom.us/

Zohrabi, M. (2013). Mixed method research: Instruments, validity, reliability and reporting findings. *Theory and Practise in Languages Studies 3*(2), 254-262.

Appendices

Appendix A Tennis Australia Coaching Qualification Description

During the Junior Development coaching course, participants learn to develop the skills of junior tennis players through the delivery of the ANZ Tennis Hot Shots program. There is a major focus on planning, delivering and reflecting on coaching sessions and creating positive learning environments for children. The course covers the Tennis Australia technical and tactical fundamentals, Cardio Tennis, legal and ethical responsibilities of a coach, risk management, program planning, tennis rules, personal development and using technology (Tennis Australia, 2020d).

The Tennis Australia High Performance coaching course prepares coaches for a career in high performance coaching and participation in a Tennis Australia National Camp. This is achieved through a number of face-to-face workshops. To cater for the individual needs of our course participants and their coaching journey, the course consists of eleven core units and twenty-two elective units. All coaches complete the core units and then select a number of elective units, which best suit their needs (Tennis Australia, 2020c).

Appendix B Interview Guides

Study 1

Introduction

Sign the consent form

Explain the procedure: think-aloud protocol/no time limit to answer the questions/voice recording/ answer any questions

Recorder is on

Interview

“Can you please describe me your vision of ideal flat tennis serve technique for a high-performance adult player?”

Listen and ask clarification questions.

Recorder is off

Conclusion

Explain member checking technique/Answer any questions/Thank you

Study 2

Introduction

Signing the consent form

The explanation of the procedure. “I’m going to show you a series of three video of the tennis serve. After every video you will be asked to assess the technique of the players. Can you please think aloud as it’s important for this study. You will have an option to repeat the video as many times as you like and analyse the serve as long as you need. Do you have any questions before we start?

Interview

Recorder is on

Video 1

Q1 What are the strengths of this players? Listen and ask any clarification questions.

Q2 What are the weaknesses? Listen and ask any clarification questions

Same protocol for video 2 and 3.

Conclusion

Answer any questions/Thank you

Study 3

Introduction

The explanation of the procedure. I'm going to provide you with three videos of the tennis serve. After every video you will be asked to assess the technique of the player. You will have an option to repeat the video as many times as you like and analyse the serve as long as you need. Can you please think aloud as it's important for this study. Do you have any questions before we start?

Interview

Recorder is on

Video 1

Do you recognise this player?

What are the technical strengths of this serve?

Listen and ask any clarification questions

What are technical weaknesses of this serve?

Listen and ask any clarification questions

Same protocol for video 2 and 3.

Recorder is off.

Conclusion

Explaining member checking procedure, the next step of the research, answering any questions

Appendix C Consent Form for Participants Involved in Research - Interview

INFORMATION TO PARTICIPANTS:

You are invited to participate in a research project entitled “Coach Expert-Novice Paradigm: internal model of the tennis serve”. Coaches perform many different roles. One of the most important is to analyse sport-specific skills and provide accurate and timely feedback to their athletes to improve their performance. The overall aim of this project is to investigate the key technical parameters (internal model) that expert tennis coaches associate with an elite level tennis serve, the expert-novice difference in diagnostic ability and knowledge on tennis serve technique of Australian tennis coaches. This research will increase our understanding of coach’s observational ability and make an important contribution to the field of knowledge among expert tennis coaches and their understanding of the tennis serve.

CERTIFICATION BY SUBJECT

I, _____ (name) of _____ (suburb)

certify that I am at least 18 years old* and that I am voluntarily giving my consent to participate in the study:

“Coach Expert-Novice Paradigm: internal model of the tennis serve” being conducted at Victoria University by: Dr Andrew Dawson (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: Yulia Fetisova (student researcher)

And that I freely consent to participation involving the below mentioned procedures:

- One-on-one semi-structured interview

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

Dr Andrew Dawson (Chief Investigator)

T: +61 3 99199465

E: andrew.dawson@vu.edu.au

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.

[*please note: Where the participant/s are aged under 18, separate parental consent is required; where the participant/s are unable to answer for themselves due to mental illness or disability, parental or guardian consent may be required.

Appendix D Information to Participants

You are invited to participate

You are invited to participate in a research project entitled ""Coach Expert-Novice Paradigm: internal model of the tennis serve".

This project is being conducted by a student researcher Yulia Fetisova as part of a Master by Research at Victoria University under the supervision of Dr Andrew Dawson, Dr James Zois and Associate Professor Michael Spittle from the College of Sport and Exercise Science.

Project explanation

Coaches perform many different roles. One of the most important is to analyse sport-specific skills and provide accurate and timely feedback to their athletes to improve their performance. This study will investigate the key technical parameters (internal model) that expert tennis coaches associate with an elite level tennis serve, and find out if differences in diagnostic ability and knowledge exist between expert and non-expert Australian tennis coaches. This research will increase our understanding of coach's observational ability and make an important contribution to the field of knowledge among expert tennis coaches and their understanding of the tennis serve.

What will I be asked to do?

You will be asked to participate in a one-on-one semi-structured interview with the student researcher. In the first part of the interview open ended questions will be asked relating to your professional background, education, coaching and playing experience. After that you will be asked to report your vision of the ideal competitive flat tennis serve. The response will be audiotaped. In the second part you will be asked to analyse the serve technique of three tennis players presented in the video. The interview should be approximately 30 minutes – 1 hour in duration however, there are no time restrictions.

What will I gain from participating?

Your participation will make a significant contribution to the tennis coach expertise field and coach learning and development. You may also gain a better understanding of your own professional practice.

How will the information I give be used?

Information from this study will be used to inform future research into this area and potentially applied in the tennis coach development program. It will also be presented in a research based journal article, potential conference presentation and the student researcher's Master thesis. All published results will be de-identified so no responses will be able to be attributed back to the participant.

What are the potential risks of participating in this project?

There are no major risks associated with this research. However, should you feel uncomfortable you are able to withdraw from this research at any stage. You are under no obligation to answer every question and your responses will not be collected, if desired.

How will this project be conducted?

The interview audio will be recorded and professionally transcribed at a later date. Once this transcription has been completed a copy will be sent to the interviewee for a final read through and consent to use the interview data for analysis will be requested. Once consent has been given, the interview data will be coded into major and minor themes and then collated with other coded interview data. This information will then be compared to survey data collected previously and relevant published scientific literature.

Who is conducting the study?

This study is being conducted by Victoria University

Chief Investigator: Dr Andrew Dawson (T: +61 3 99199465 E: andrew.dawson@vu.edu.au)

Student Researcher: Yulia Fetisova (T: +61 4 11607305 E: fetisovayulia@gmail.com)

Any queries about your participation in this project may be directed to the Chief Investigator listed above.

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.

Appendix E Pre-Interview Questionnaire

Q1 What is your age?___

Q2 How many years have you coached at your current level? _____

Q3 How many years have you been coaching tennis overall?___

Q4 What level of players do you work with at the moment?

- Beginner
- Intermediate
- High Performance

Q5 Did you participate in tennis as a player?

- Yes>>go to question 7
- No>>this is the end of questionnaire

Q6 Approximately how many years did you play competitions?_____

Q7 What was the highest level of competition you participated in?

- International
- National
- States
- AMT
- Club
- Other (please specify)_____

Appendix F International Tennis Number

The following is an extract from the ITN Description of Standards and gives a concise summary of the 10 ITN rating categories:

ITN 1 This player has had intensive training for national tournament competition at the junior and senior levels and has extensive professional tournament experience. Holds or is capable of holding an ATP / WTA ranking and their major source of income is through tournament prize money.

ITN 2 This player has power and / or consistency as a major weapon. Can vary strategies and styles of play in a competitive situation. Is usuallly a nationally ranked player.

ITN 3 This player has good shot anticipation and frequently has an outstanding shot or attribute around which a game may be structured. Can regularly hit winners and force errors off short balls. Can put away volleys and smashes and has a variety of serves to rely on.

ITN 4 This player can use power and spins and has begun to handle pace. Has sound footwork, can control depth of shots, and can vary game plan according to opponents. Can hit first serves with power and can impart spin on second serves.

ITN 5 This player has dependable strokes, including directional control and depth on both groundstrokes and on moderate shots. Has the ability to use lobs, overheads, approach shots and volleys with some success.

ITN 6 This player exhibits more aggressive net play, has improved court coverage, improved shot control and is developing teamwork in doubles.

ITN 7 This player is fairly consistent when hitting medium paced shots, but is not yet comfortable with all strokes. Lacks control over depth, direction and power.

ITN 8 This player is able to judge / control where the ball is going and can sustain a short rally.

ITN 9 This player needs on court experience and strokes can be completed with some success.

ITN 10 This player is starting to play competitively (can serve and return / rally) on a full court using a normal ITF approved ball.

ITN 10.1 This player is able to rally with movement and control.

ITN 10.2 This player has developed some simple tennis-specific skills in hitting an oncoming ball regularly, however rallying with movement and control is not yet achieved.

ITN 10.3 The player is in the early stages of tennis skills development and is primarily learning simple tennis co-ordination tasks / exercises.

* The ITN 10.1 to 10.3 categories will usually be done in a modified environment using transition / soft balls on a reduced court and / or using adapted rackets as appropriate.

** For a more comprehensive description of the ITN levels please refer to the ITN Description of Standards (see Appendix).

WHY USE ONLY 10 RATING CATEGORIES?

The number of rating categories is limited to 10 so that the system is simple, easily understood and relatively easy to promote and to use. The number of rating categories was discussed extensively by the Taskforce and, while recognising that the rating categories could be expanded at national level, the ITF's intention is to maintain at the international level 10 rating categories as per the chart. However, the rating categories ITN 1 – ITN 10 should not be restrictive and National Associations should be able to expand and adapt by adding sub-levels within each category (e.g. 1.0, 1.5, 2.0, 2.5 etc) if they feel it is beneficial to tennis in their country.

Appendix G Information to Participants - Video Recording

INFORMATION TO PARTICIPANTS INVOLVED IN RESEARCH

You are invited to participate

You are invited to participate in a research project entitled ""Coach Expert-Novice Paradigm: internal model of the tennis serve".
This project is being conducted by a student researcher Yulia Fetisova as part of a Doctor of Philosophy degree at Victoria University under the supervision of Dr Andrew Dawson, Dr James Zois and Associate Professor Michael Spittle from the College of Sport and Exercise Science.

Project explanation

Coaches perform many different roles. One of the most important is to analyse sport-specific skills and provide accurate and timely feedback to their athletes to improve their performance. The overall aims of this project: to investigate the key technical parameters (internal model) that expert tennis coaches associate with an elite level tennis serve, to examine if the expert-novice difference in diagnostic ability and knowledge on tennis serve technique of Australian tennis coaches exist and to develop online training tool to improve diagnostic ability and knowledge of novice coaches. This research will make an important contribution to coach development in tennis and potentially in other sports.

What will I gain from participating?

Your participation will make a significant contribution to the tennis coach expertise field and coach learning and development. You will have an opportunity to improve your serve as the technique of your serve is going to be assessed by expert Australian coaches. You will be given their conclusion and recommendation, if requested.

How will the information I give be used?

The video footage will be used to develop the online coaching training program. Information from this study will be used to inform future research into this area and potentially applied in the tennis coach development program. It will also be presented in a research based journal article, potential conference presentation and the student researcher's thesis. All published results will be de-identified so no responses will be able to be attributed back to the participant.

What are the potential risks of participating in this project?

There are no major risks associated with this research. Your identity will be hidden for the observer by having your face blacked out. However, should you feel uncomfortable you are able to withdraw from this research at any stage. Your video recording will also be removed from the online training program.

How will this project be conducted?

The video will be shown to tennis coaches at the different level of expertise during the interview and training program tasks. Coaches will be asked to assess the technique of your serve and then will watch the video with visual and audio comments for technique corrections.

Who is conducting the study?

This study is being conducted by Victoria University

Chief Investigator: Dr Andrew Dawson (T: +61 3 99199465 E: andrew.dawson@vu.edu.au)

Student Researcher: Yulia Fetisova (T: +61 4 11607305 E: fetisovayulia@gmail.com)

Any queries about your participation in this project may be directed to the Chief Investigator listed above.
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.

Appendix H Consent Form - Video Recording

CONSENT FORM FOR PARTICIPANTS INVOLVED IN RESEARCH

INFORMATION TO PARTICIPANTS:

You are invited to participate in a research project entitled “Coach Expert-Novice Paradigm: internal model of the tennis serve”. Coaches perform many different roles. One of the most important is to analyse sport-specific skills and provide accurate and timely feedback to their athletes to improve their performance. The overall aimы of this project are to investigate the key technical parameters (internal model) that expert tennis coaches associate with an elite level tennis serve, the expert-novice difference in diagnostic ability and knowledge on tennis serve technique of Australian tennis coaches and develop online training tool to improve diagnostic ability and knowledge of coaches. This research will make an important contribution to coach development in tennis and potentially in other sports.

CERTIFICATION BY SUBJECT

I, _____ (name) of _____ (suburb)

certify that I am at least 18 years old* and that I am voluntarily giving my consent to participate in the study:
“Coach Expert-Novice Paradigm: internal model of the tennis serve” being conducted at Victoria University by: Dr Andrew Dawson (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:
Yulia Fetisova (student researcher)
And that I freely consent to participation involving the below mentioned procedures:

- Video recording

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
Dr Andrew Dawson (Chief Investigator)
T: +61 3 99199465
E: andrew.dawson@vu.edu.au

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.

[*please note: Where the participant/s are aged under 18, separate parental consent is required; where the participant/s are unable to answer for themselves due to mental illness or disability, parental or guardian consent may be required.]

Appendix I Information to Participants - Diagnostic Ability

INFORMATION TO PARTICIPANTS INVOLVED IN RESEARCH

You are invited to participate

You are invited to participate in a research project entitled ""Coach Expert-Novice Paradigm: internal model of the tennis serve".

This project is being conducted by a student researcher Yulia Fetisova as part of a Doctor of Philosophy degree at Victoria University under the supervision of Dr Andrew Dawson, Dr James Zois and Associate Professor Michael Spittle from the College of Sport and Exercise Science.

Project explanation

Coaches perform many different roles. One of the most important is to analyse sport-specific skills and provide accurate and timely feedback to their athletes to improve their performance. The overall aims of this project: to investigate the key technical parameters (internal model) that expert tennis coaches associate with an elite level tennis serve, to examine if the expert-novice difference in diagnostic ability and knowledge on tennis serve technique of Australian tennis coaches exist and to develop online training tool to improve diagnostic ability and knowledge of novice coaches. This research will make an important contribution to coach development in tennis and potentially in other sports.

What will I be asked to do?

You will be asked to participate in two one-on-one semi-structured interview with the student researcher. Before the interview you will be explained the procedure in details and asked to sigh the consent form. Then you will be asked to watch 3 videos of the tennis players performing serve and provide strengths, weaknesses and recommendations for corrections. The interview will be recorded and then transcribed verbatim for further qualitative analysis.

What will I gain from participating?

You will make a significant contribution to the tennis coach development in tennis and potentially in other sports. The data obtained will be used to test the effectiveness of the program.

How will the information I give be used?

Information from this study will be used to inform future research into this area and potentially applied in the tennis coach development program. It will also be presented in a research based journal article, potential conference presentation and the student researcher's thesis. All published results will be de-identified so no responses will be able to be attributed back to the participant.

What are the potential risks of participating in this project?

There are no major risks associated with this research. However, should you feel uncomfortable you are able to withdraw from this research at any stage. You are under no obligation to answer every question and your responses will not be collected, if desired.

How will this project be conducted?

The interview audio will be recorded and professionally transcribed at a later date. Once this transcription has been completed a copy will be sent to the interviewee for a final read through and consent to use the interview data for analysis will be requested. Once consent has been given, the interview data will be coded into major and minor themes and then collated with other coded interview data. This information will then be compared to previous relevant published scientific literature.

Who is conducting the study?

This study is being conducted by Victoria University

Chief Investigator: Dr Andrew Dawson (T: +61 3 99199465 E: andrew.dawson@vu.edu.au)

Student Researcher: Yulia Fetisova (T: +61 4 11607305 E: fetisovayulia@gmail.com)

Any queries about your participation in this project may be directed to the Chief Investigator listed above.

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.

Appendix J Online Questionnaire Structure

Q1 Thank you for agreeing to take part in this important research about tennis coach development. You are about to undertake a survey on tennis serve technique. The survey should take approximately 3-5 minutes to complete. Be assured that all answers you provide will be kept in the strictest confidentiality.

Please click ">>" to begin.

Q2 What is your age?_____

Q3 Gender

- Male
- Female

Q4 What is your current Tennis Australia coaching qualification:

- Junior Development
- Club Professional
- Master Club Professional
- High Performance
- Other: please specify

Q5 How many years have you been coaching tennis?_____

Q6 How many hours per week do you coach at this moment?

Q7 What is the highest level of competition you participated in?

- International
- National
- States
- AMT
- Club
- Other (please specify)
- Not applicable

Q8How many years did you play competitions?_____

Q9 You will be shown 3 tennis players performing a FLAT tennis serve. You will be asked to analyse the technique of each player (their strengths, weaknesses and recommendations for corrections). You can repeat the video as many times as you need but you cannot stop it during the action. There is also no time limitation.

Q10 Player 1 What are technical strengths? What are technical weaknesses? What would you recommend correcting?

Q11 Player 2 What are technical strengths? What are technical weaknesses? What would you recommend to correct?

Q12 Player 3 What are technical strengths? What are technical weaknesses? What would you recommend to correct?

Appendix K Information to Participant - Online survey

INFORMATION TO PARTICIPANTS INVOLVED IN RESEARCH

You are invited to participate

You are invited to participate in a research project entitled ""Coach Expert-Novice Paradigm: internal model of the tennis serve".This project is being conducted by a student researcher Yulia Fetisova as part of a Doctor of Philosophy degree at Victoria University under the supervision of Dr Andrew Dawson, Dr James Zois and Associate Professor Michael Spittle from the College of Sport and Exercise Science.

Project explanation

Coaches perform many different roles. One of the most important is to analyse sport-specific skills and provide accurate and timely feedback to their athletes to improve their performance. The overall aims of this project: to investigate the key technical parameters (internal model) that expert tennis coaches associate with an elite level tennis serve, to examine if the expert-novice difference in diagnostic ability and knowledge on tennis serve technique of Australian tennis coaches exist and to develop online training tool to improve diagnostic ability and knowledge of novice coaches. This research will make an important contribution to coach development in tennis and potentially in other sports.

What will I gain from participating?

Your participation will make a significant contribution to the tennis coach expertise field and coach learning and development. You will have an opportunity to improve your serve as the technique of your serve is going to be assessed by expert Australian coaches.

How will the information I give be used?

Information from this study will be used to inform future research into this area and potentially applied in the tennis coach development program. It will also be presented in a research based journal article, potential conference presentation and the student researcher's thesis. All published results will be de-identified so no responses will be able to be attributed back to the participant.

What are the potential risks of participating in this project?

There are no major risks associated with this research. Your identity will be hidden for the observer by having your face blacked out. However, should you feel uncomfortable you are able to withdraw from this research at any stage. Your video recording will also be removed from the online training program.

How will this project be conducted?

The online questionnaire link will be provided to tennis coaches at the different level of expertise. Coaches will be asked to watch the video and assess the technique of the tennis serve.

Who is conducting the study?

This study is being conducted by Victoria University
Chief Investigator: Dr Andrew Dawson (T: +61 3 99199465 E: andrew.dawson@vu.edu.au)
Student Researcher: Yulia Fetisova (T: +61 4 11607305 E: fetisovayulia@gmail.com)
Any queries about your participation in this project may be directed to the Chief Investigator listed above.
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.

Appendix L Consent form - Online Questionnaire

CONSENT FORM FOR PARTICIPANTS INVOLVED IN RESEARCH
INFORMATION TO PARTICIPANTS:

You are invited to participate in a research project entitled “Coach Expert-Novice Paradigm: internal model of the tennis serve”. Coaches perform many different roles. One of the most important is to analyse sport-specific skills and provide accurate and timely feedback to their athletes to improve their performance. The overall aimы of this project are to investigate the key technical parameters (internal model) that expert tennis coaches associate with an elite level tennis serve, the expert-novice difference in diagnostic ability and knowledge on tennis serve technique of Australian tennis coaches and develop online training tool to improve diagnostic ability and knowledge of coaches. This research will make an important contribution to coach development in tennis and potentially in other sports.

CERTIFICATION BY SUBJECT

I, _____ (name) of _____ (suburb)

certify that I am at least 18 years old* and that I am voluntarily giving my consent to participate in the study:
“Coach Expert-Novice Paradigm: internal model of the tennis serve” being conducted at Victoria University by: Dr Andrew Dawson (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:
Yulia Fetisova (student researcher)
And that I freely consent to participation involving the below mentioned procedures:

- Online questionnaire

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
Dr Andrew Dawson (Chief Investigator)
T: +61 3 99199465
E: andrew.dawson@vu.edu.au

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.

*[*please note: Where the participant/s are aged under 18, separate parental consent is required; where the participant/s are unable to answer for themselves due to mental illness or disability, parental or guardian consent may be required.]*

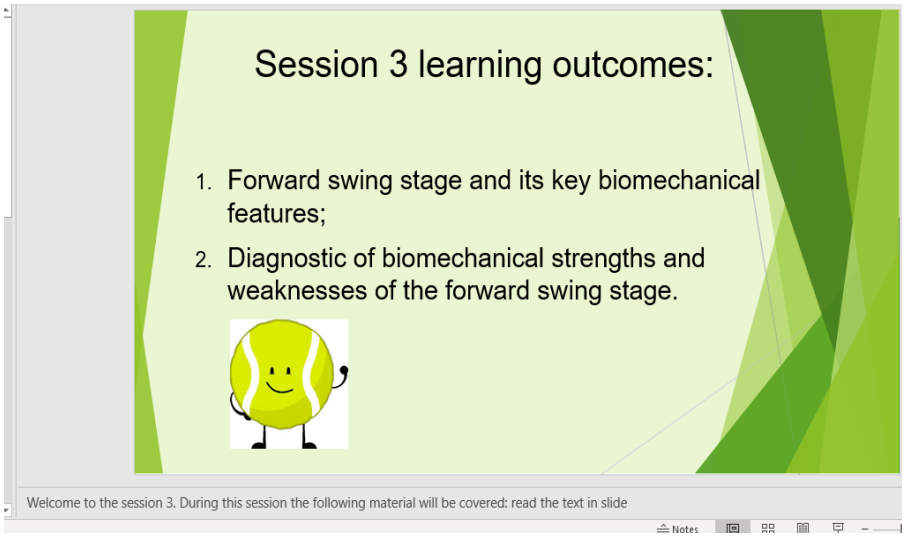
Appendix M Evaluation Questionnaire Online Course

Evaluation questions:

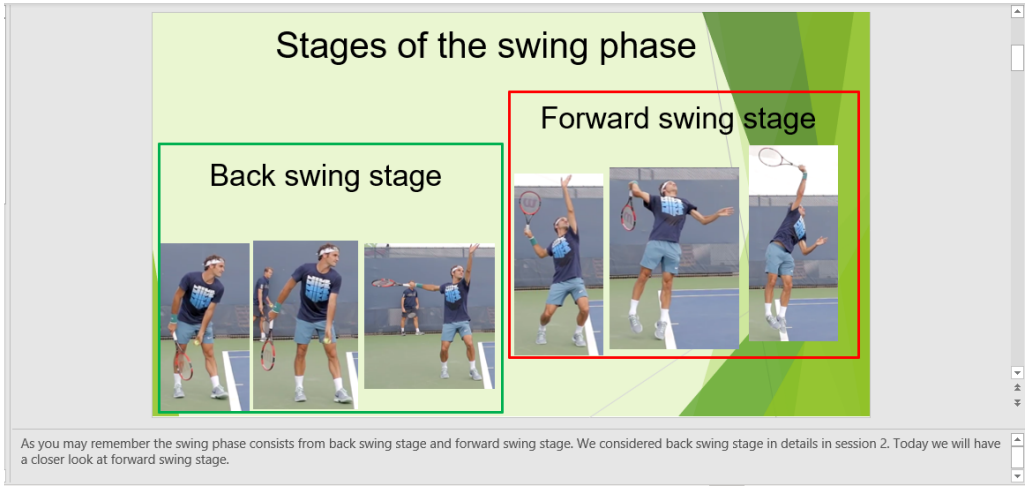
1. How useful was this course for your understanding of the tennis serve technique? Extremely useful/Very useful/Somewhat useful/ Not very useful/Not at all useful
2. How would you rate your knowledge about the connections between the biomechanical features before you took this course? Clearly understood it/Understood it/Somewhat understood it/Had heard about it but didn't understand it/Never heard of it.
3. How useful was the "connections" concept for your understanding of the tennis serve technique? Extremely useful/Very useful/Somewhat useful/Not so useful/Not at all useful
4. Rate the level of complexity of the course: Extremely complex/Very complex/Somewhat complex/Not very complex/Not complex at all
5. How likely you are going to apply the knowledge about the connections between the biomechanical features in your coaching? /Very likely/Somewhat likely/ Not very likely/Not likely at all
6. What did you like most about this course: open response
7. What are some ways this course could be improved? open response

Appendix N Session Three Online Course

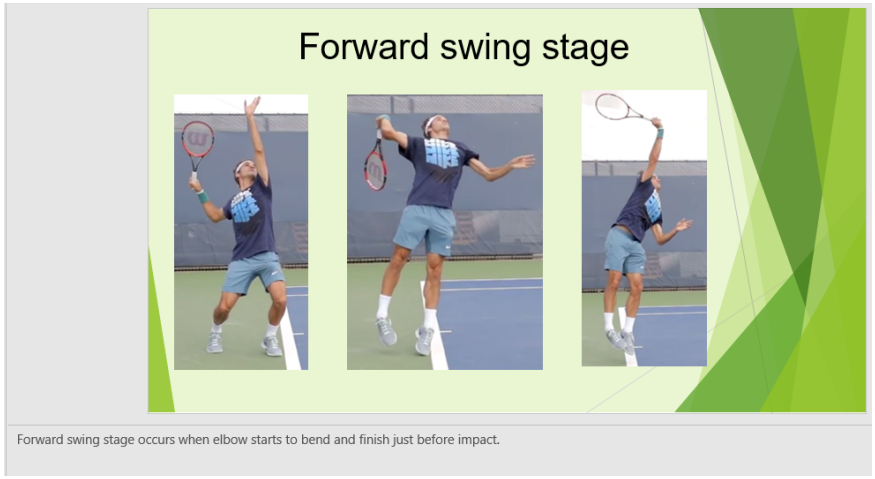
Slide 1



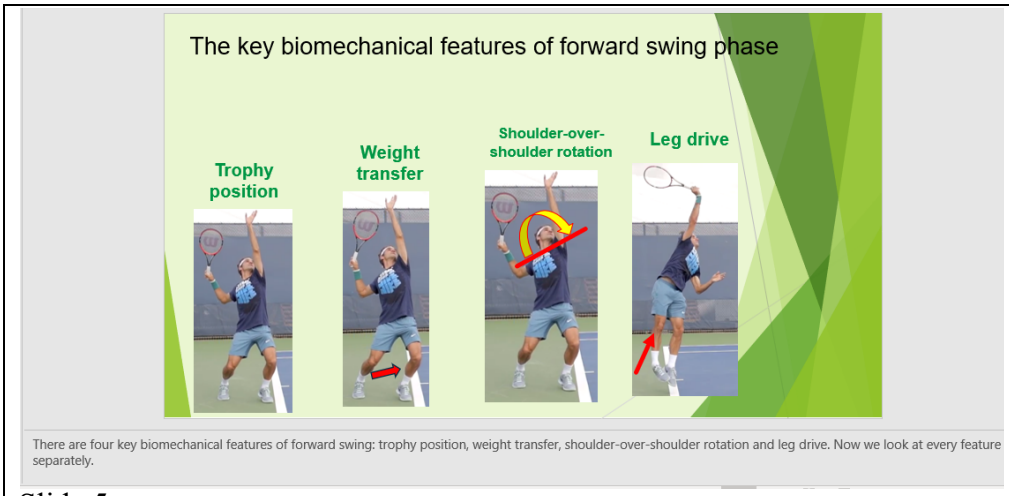
Slide 2



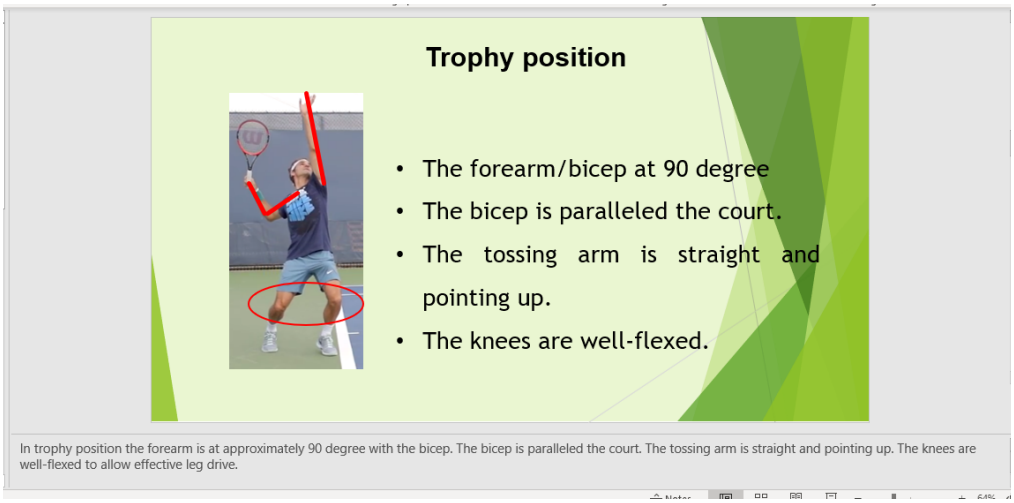
Slide 3



Slide 4

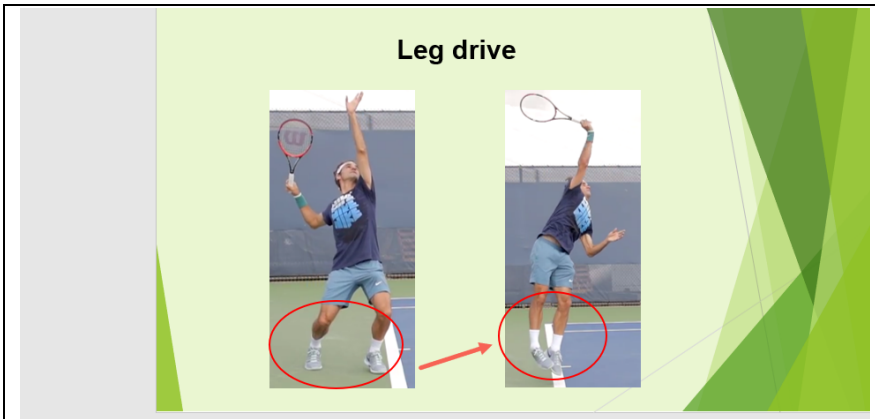


Slide 5



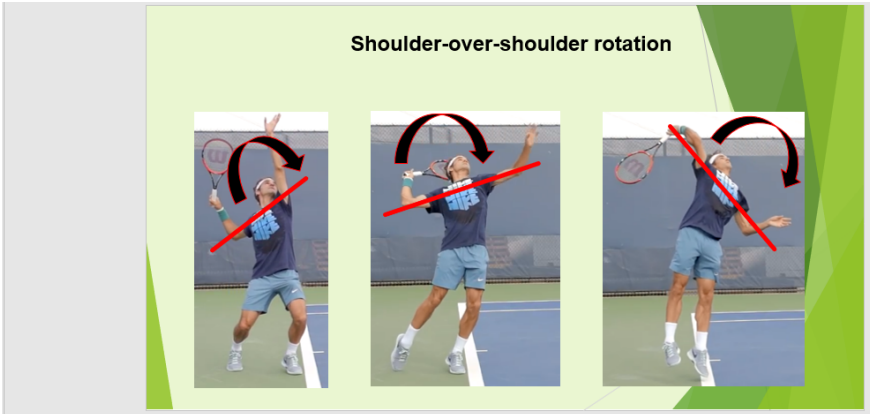
Slide 6

Slide 7



Leg drive allows for the body to be moving forward and upward for impact.

Slide 8

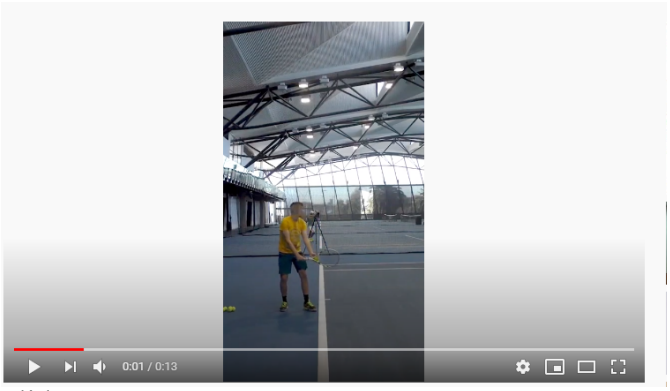


During shoulder-over-shoulder rotation the right shoulder moves over the left shoulder.

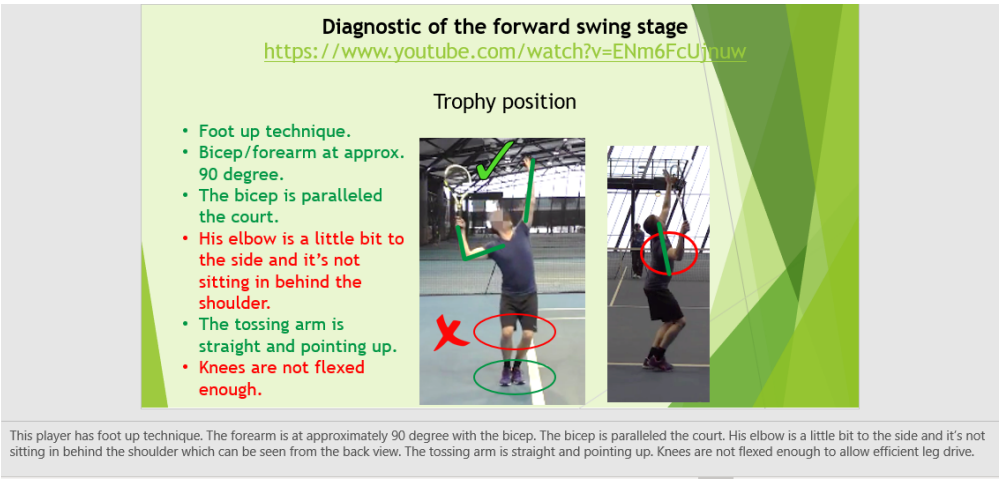
Slide 9

There are two types of backswing technique: foot up and foot-back. Click the links to watch the video. The both technique are acceptable. However, different consideration should be taken into account. Foot back technique allows better preparation to the net, foot up provides better vertical drive.

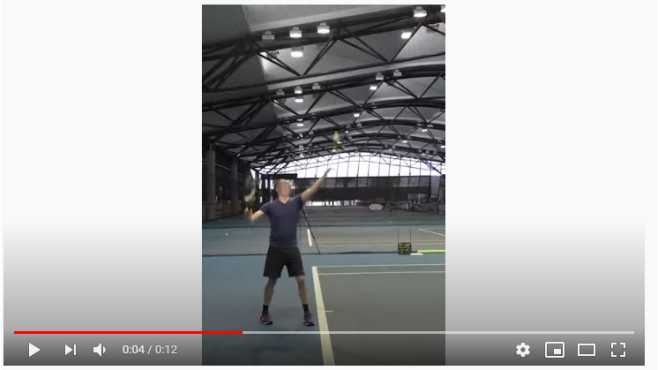
Videos for slide 9 representing foot back technique



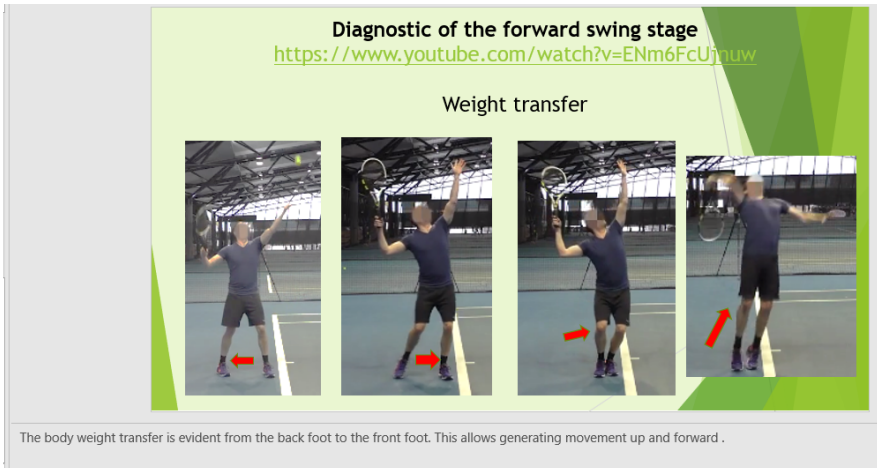
Slide 10



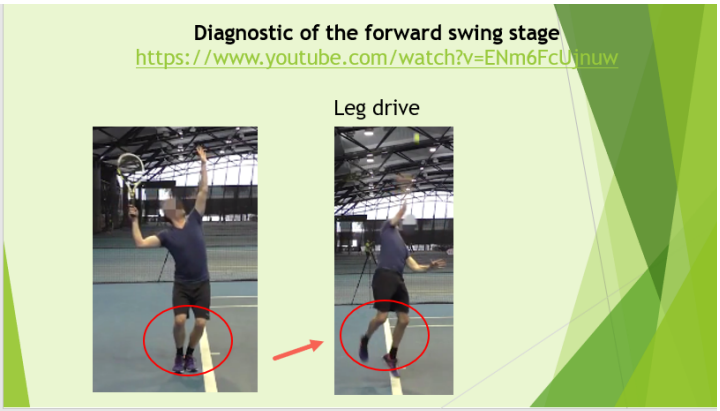
Video for slide 10



Slide 11

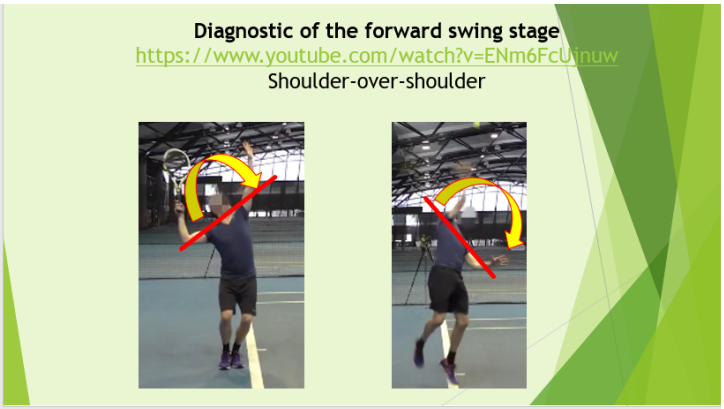


Slide 12



Leg drive moves body forward and upward for impact.

Slide 13



Shoulder-over-shoulder is evident with the right shoulder moves over the left shoulder.

Appendix O Information to Participants - Online Course

INFORMATION TO PARTICIPANTS INVOLVED IN RESEARCH
You are invited to participate

You are invited to participate in a research project entitled ""Coach Expert-Novice Paradigm: internal model of the tennis serve".
This project is being conducted by a student researcher Yulia Fetisova as part of a Doctor of Philosophy degree at Victoria University under the supervision of Dr Andrew Dawson, Dr James Zois and Associate Professor Michael Spittle from the College of Sport and Exercise Science.

Project explanation

Coaches perform many different roles. One of the most important is to analyse sport-specific skills and provide accurate and timely feedback to their athletes to improve their performance. The overall aims of this project: to investigate the key technical parameters (internal model) that expert tennis coaches associate with an elite level tennis serve, to examine if the expert-novice difference in diagnostic ability and knowledge on tennis serve technique of Australian tennis coaches exist and to develop online training tool to improve diagnostic ability and knowledge of novice coaches. This research will make an important contribution to coach development in tennis and potentially in other sports.

What will I be asked to do?

You will be asked to participate in two one-on-one semi-structured interviews with the student researcher and complete online training on the tennis serve technique. Two (one-on-one) semi-structured interviews will be separated by the training process that you will be able to complete online. In the first interview you will be explained the procedure in details and asked to sigh the consent form. Then you will be asked to watch 3 videos of the tennis players performing serve and provide technical strengths and weaknesses. The interview will be recorded (voice only) and then transcribed verbatim for further qualitative analysis. After that you will be given the link to the training course and asked to complete it in according to the created schedule in convenient for you time (8 sessions over 4 weeks). The final stage will include a second interview where you will be asked to follow the same protocol from interview 1.

What will I gain from participating?

Your participation will allow you to experience the first in Australia online education tennis course on the diagnostic of tennis serve technique. You will gain a better understanding of your own professional practise as the course is based on the knowledge of experts Australian tennis coaches. In addition, it will make a significant contribution to the tennis coach development in tennis and potentially in other sports. The data obtained will be used to test the effectiveness of the course.

How will the information I give be used?

Information from this study will be used to inform future research into this area and potentially applied in the tennis coach development programs. It will also be presented in a research based journal article, potential conference presentation and the student researcher's thesis. All published results will be de-identified so no responses will be able to be attributed back to the participant.

What are the potential risks of participating in this project?

There are no major risks associated with this research. However, should you feel uncomfortable you are able to withdraw from this research at any stage. You are under no obligation to answer every question and your responses will not be collected, if desired.

How will this project be conducted?

The interview audio will be recorded and professionally transcribed at a later date. Once this transcription has been completed a copy will be sent to the interviewee for a final read through and

consent to use the interview data for analysis will be requested. Once consent has been given, the interview data will be coded into major and minor themes and then collated with other coded interview data. This information will then be compared to previous relevant published scientific literature.

Who is conducting the study?

This study is being conducted by Victoria University
Chief Investigator: Dr Andrew Dawson (T: +61 3 99199465 E: andrew.dawson@vu.edu.au)
Student Researcher: Yulia Fetisova (T: +61 4 11607305 E: fetisovayulia@gmail.com)

Any queries about your participation in this project may be directed to the Chief Investigator listed above.
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.

Appendix P Consent Form - Online Course

CONSENT FORM FOR PARTICIPANTS INVOLVED IN RESEARCH
INFORMATION TO PARTICIPANTS:
You are invited to participate in a research project entitled "Coach Expert-Novice Paradigm: internal model of the tennis serve". Coaches perform many different roles. One of the most important is to analyse sport-specific skills and provide accurate and timely feedback to their athletes to improve their performance. The overall aims of this project are to investigate the key technical parameters (internal model) that expert tennis coaches associate with an elite level tennis serve, the expert-novice difference in diagnostic ability and knowledge on tennis serve technique of Australian tennis coaches and develop online training tool to improve diagnostic ability and knowledge of coaches. This research will make an important contribution to coach development in tennis and potentially in other sports.

CERTIFICATION BY SUBJECT

I, _____ (name) of _____ (suburb)

certify that I am at least 18 years old* and that I am voluntarily giving my consent to participate in the study:
"Coach Expert-Novice Paradigm: internal model of the tennis serve" being conducted at Victoria University by: Dr Andrew Dawson (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:
Yulia Fetisova (student researcher)
And that I freely consent to participation involving the below mentioned procedures:

- One-on-one semi-structured interviews
- Online learning

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
Dr Andrew Dawson (Chief Investigator)
T: +61 3 99199465
E: andrew.dawson@vu.edu.au

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.
[*please note: Where the participant/s are aged under 18, separate parental consent is required; where the participant/s are unable to answer for themselves due to mental illness or disability, parental or guardian consent may be required.

Appendix R Questionnaire Online Course

Q1 What is your age?___
Q2 What is your current coaching qualification? ___
Q3 How many years have you coached at this level? ___
Q4 How many years have you been coaching tennis overall? ___
Q5 Did you participate in tennis as a player?
Yes>>go to question 6
No>>this is the end of questionnaire
Q6 Approximately how many years did you play competitions?___
Q7 What was the highest level of competition you participated in?
International
National
States
AMT
Club
Other (please specify)_____