The Development of Perceptual-Cognitive Expertise

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A thesis submitted in partial fulfilment of the requirements of

Liverpool John Moores University for the degree of

Doctor of Philosophy

December 2002

Contents

Acknowledgements

My director of studies, Professor Mark Williams guided this process in his own inimitable style and provided a wealth of advice, support, and encouragement for which I am ever grateful. The opportunities offered were boundless and provided much of the stimulus for debate upon which most of this work has been built. There are numerous other people I would like to thank: My remaining supervisors, Professor Tom Reilly, and particularly Dr. Mark Scott, for their collective advice and support, and the statistical solutions offered en route to Starbucks. Dr Nikki Hodges, for her diligence in asking endless questions, and scrutinising were others would have faltered, particularly in the area of deliberate practice. Professor Janet Starkes, for her advice and welcome comments. Don Loran, for providing advice on optometric assessment. Professor Anders Ericsson, for challenging me to think differently and for providing the framework around which this thesis has been written. The players and staff at Liverpool, Everton, Crewe Alexander, and Manchester City Football Academies for making this research possible. I'd also like to thank my fellow graduate students, both past and present, Rob Horn, Nigel Balmer, Nick Smeeton, Spencer Hayes, Andy Franks, and Mick Court for keeping me sane throughout the last few years. It goes without saying that without the intellectual stimulation provided by the numerous instantiations of 'wonderbat', I would have completed this process as a lesser mortal. Lastly, my family and many of my friends for accepting my absence for the majority of the past three years.

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Abstract

An integrated approach to the study of perceptual-cognitive expertise was employed using the three-step approach proposed by Ericsson and Smith (1991). The first step employed a multidimensional test battery to examine the development of basic visual abilities and perceptual and cognitive skills in soccer using elite and sub-elite 9 to 18 year old players. The results suggested that skill groups did not differ on visual abilities, whereas film-based tests of anticipation and situational probabilities were the most discriminating variables of expertise. The second step adapted representative tasks into a free and cued recall paradigm and used verbal report procedures to elicit the cognitive thought processes underlying elite performance in adult soccer players. The data suggest that elite players demonstrated superior skills in encoding information in short-term memory and made more effective use of retrieval cues to access information stored in long-term memory. Elite performance was primarily mediated by perceptual-recognition processes, however, search was used as a confirmatory process. The third and final step examined the process of acquisition using a quasi-longitudinal design. In the absence of any growth-related maturation, elite players were differentiated on deliberate team practice activities from as early as nine years of age. A greater amount of time spent in tactical and strategic decision-making activities by elite players may account for the skill-based differences observed. No differences were found in time spent in deliberate play, sporting diversity, or specialization. Collectively, these experiments provide a crucial insight into the development, structure, and acquisition of perceptual-cognitive expert performance.

Chapter 1

An Integrated Approach to the Study of Perceptual-Cognitive Expertise

> *"We are what we repeatedly do. Excellence then is not an act but a habit."*
>
> (Aristotle, 384-322 BC)

> *"Toil to make yourself remarkable by some talent or other."*
>
> (Seneca, 3 BC - 65 AD)

Around the birth of the first millennia, both Aristotle and Seneca offered some words of wisdom regarding the attainment of excellence. From these early chronicles it is evident that, even then, the origins and means of achieving outstanding levels of performance were often debated. Some 2000 years later, the modern day scientist has arguably progressed somewhat closer to discerning the nature of 'expertise'. However, its conceptualization has not been formulated without discrepancy, and divergent methods of empirical investigation have recurrently been observed.

Presumably, Seneca and Aristotle would have agreed with today's researchers that mere exposure to a domain does not constitute 'toiling toward the remarkable', nor would habitual exposure of this kind move one closer to excellence (cf. Allard, Deakin, Parker & Rodgers, 1993; Williams & Davids, 1995). However, over the last two decades alone, the literature has been fraught with similar hypotheses and a great deal of controversy has emerged regarding the distinction between various constructs, such as ability, skill, talent, experience, and expertise (e.g., Howe, Davidson, & Sloboda, 1998; Simonton, 1999).

Although several approaches have been used to examine high levels of skilled performance over the past century, theoretical constructs and methodologies have typically reflected either primarily innate or acquired capacities, and/or have focused upon either general or specific components of performance (see Ericsson & Smith, 1991).

Sir Francis Galton (1869) undertook some of the earliest work examining the inherited characteristics of exceptional performance. This research suggested that high levels of achievement were recognized as a consequence of the individual's intellectual ability and personal motivation, factors that, according to Galton, were largely determined through heredity. In a similar vein, to elucidate the general, innate characteristics underlying exceptionally high intelligence, Terman and Oden (1959) used a longitudinal approach to study the genetic components of intelligence (IQ), irrespective of domain. While a number of participants from this study proceeded to become very successful, many factors, including socioeconomic status and attained level of education, precluded any causal link between IQ and eventual success.

Since Galton's contribution, the presumed genetic foundation of skilled performance prompted a plethora of research that focused upon identifying individual differences in general and specific characteristics, abilities, and basic cognitive processes. In a motor behavior context, Fleishman (1972; 1982) proposed that 11 perceptual-motor, as well as 9 physical proficiency abilities provided a foundation for skilled motor performance. Similarly, Ackerman (1988) outlined three areas of human ability that related to successful perceptual-motor skill performance, including cognitively-oriented abilities, perceptual-speed ability and psychomotor ability. Whilst these abilities arguably may underpin skill acquisition, little success has been gleaned from using this approach as a means to understand the expertise process. At best, only low correlations have been found between these generic constructs and skilled task performance (see Cooper & Regan, 1982; Kelley, 1964).

In the sports domain, a number of authors have promoted a 'hardware' approach to studying skilled performance in sport (for a recent review, see Starkes, Helsen, & Jack, 2001). That is, to identify those innate characteristics or specific abilities that are thought to underpin expert performance. However, in both mainstream and sport-related research, those that have investigated the relationship between such generic constructs and skilled performance have highlighted only equivocal findings (see Chapter 2, see also Ericsson & Smith, 1991; Starkes & Deakin, 1985; Williams, Davids, & Williams, 1999). Moreover, where specific characteristics are central to task performance it is difficult to distinguish the extent to which these were inherited or are acquired. While genetic constraints (e.g., height) and individual differences (e.g., motivation) are not completely ruled out, recent evidence suggests that domain-specific characteristics are consistent with those of acquired skills (see Ericsson, Krampe, & Tesch-Romer, 1993; Ericsson, 1998).

In an attempt to contrast different approaches to studying the many manifestations and investigations of 'outstanding performance', Ericsson and Smith (1991) suggested that expertise should be limited to those behaviors that can be attributed to relatively stable characteristics, where behavior is repeatable and the prospect of chance diminished. Although this approach omits single achievements that may not be replicable due to circumstance and so may discount records of notable creativity (cf. Simonton, 2000), this definition provides a reliable index of 'outstanding performance' and allows construct validity to be verified through repeated empirical investigation. The expert-performance approach differs from previous approaches and methodologies used to study outstanding performance in a number of ways. Where previous methods have attempted to independently measure constructs deemed to be fundamental to superior performance, the expert-performance approach necessitates that, under standardized conditions, the defining aspects of performance are described and subsequently analyzed, and those components that reflect superior performance elucidated (Ericsson & Smith, 1991).

The original expertise approach was pioneered by de Groot (1965) and Chase and Simon (1973) in the domain of chess. De Groot (1965) suggested that it was possible to effectively capture the nature of chess expertise by designing representative tasks based upon the player's selection of 'next best move'. Through the use of verbal-protocols, and the emerging evidence indicating superior move selection by Grand Master chess players, de Groot (1965) inferred that such tasks would elicit cognitive processes that permitted skill-based differences to be clearly defined. De Groot's (1965) analysis of think-aloud protocols highlighted that superior performance in this domain was often based upon perceptual recognition of the next best move within the first few moments of familiarization with the chess configuration, rather than working through the problem of determining the possible move alternatives and eventually arriving at the answer. Under time duress, the Grand Masters were also able to perceive and recall the configuration into a meaningful 'complex' almost perfectly, specifically noticing unique characteristics, whereas, lesser skilled individuals' recall was much less extensive. De Groot (1965) suggested that the chess masters' superior performance was attributable to greater experience, facilitating the retrieval of important strategic information associated to the presented chess configurations from long-term memory.

Chase and Simon (1973) extended de Groot's research by asking master and novice chess players to recall both game-related and randomized configurations of chess pieces. In the random condition, skill-based differences in recall did not emerge, whereas in the game-related condition the meaningful relations between chess pieces allowed chess masters to recall significantly more pieces compared to their novice counterparts. In a similar vein to de Groot's (1965) description of meaningful complexes, Chase and Simon (1973) hypothesized a chunking mechanism based upon participants' rapid and consecutive recall of groups of structurally related chess pieces, delineated by brief pauses in the recall process. This grouping process allowed the limits of human information processing (e.g., storage of 7 ± 2 pieces of information in short-term memory) to be circumvented (cf. Miller, 1956): the chess masters were able to recognize and encode 15 to 30 recalled chess pieces into more complex chunks, affording a greater number of pieces per chunk, compared to novice participants.

Simon and Chase (1973) estimated that it would take around 10 years to acquire the number of chunks necessary to become a chess master (e.g., acquisition of 10,000 to 100,000 chunks; see Simon & Gilmartin, 1973) and consequently, suggested that practice was the major variable in the acquisition of skilled performance. More recently, Ericsson, Krampe, and Tesch-Romer (1993) suggested that some 10,000 hours of deliberate practice would be necessary to acquire the mechanisms that sub-serve expertise in any domain.

From these classic contributions examining the structure and acquisition of expert performance, Ericsson and Smith (1991) proposed a three-step process to the empirical study of expertise. The first step is to identify a representative task(s) from the domain of expertise that is replicable under standardized laboratory conditions. The design of representative laboratory-based tasks should not only differentiate skilled from less skilled individuals, but also capture the essence of the specific facets of expertise under investigation. Early research in sport, tended to rely upon this maxim by directly utilizing mainstream psychology paradigms without modifying the task to elicit truly representative performance, highlighting concern for the applicability of research findings (see Abernethy, Thomas, & Thomas, 1993). Researchers, such as Starkes (e.g., Starkes, 1987; Starkes & Deakin, 1985), Abernethy (e.g., Abernethy and Russell, 1987a, 1987b; Abernethy, 1988), Helsen (e.g., Helsen & Pauwels, 1993), and Williams (e.g., Williams & Burwitz, 1993; Williams & Davids, 1995), have successfully designed representative laboratory tasks that have differentiated experts and novices on their level of perceptual-cognitive skill. However, identifying which task is the most representative of the domain of expertise or whether each task truly captured the 'essence' of expert performance has only been partially answered. Research adopting a multidisciplinary approach in soccer has made the first steps in determining the relative contribution of factors that are critical to attaining an expert level of performance (e.g., Helsen & Starkes, 1999). On a similar note, only one author has examined the issue of representative task performance in the context of developing elite sports performance using the guidelines provided by the expertise approach (see Abernethy, 1988). Consideration of these factors will provide a more comprehensive understanding of expert performance and its development. These issues are examined in Chapter 2.

The second step of the expertise approach is to analyze the stable characteristics of expert performance via the use of verbal report techniques and/or representative task manipulations. Ericsson and colleagues (Chase & Ericsson, 1982; Ericsson & Kintsch, 1995; Ericsson & Delaney, 1999) have demonstrated that experts acquire mental representations and memory skills that mediate performance, facilitate cognitive adaptability, aid in monitoring and controlling their performance, promote planning and reasoning about future events, and permit future retrieval demands to be anticipated. This second step in the expertise approach allows the key mediating mechanisms to be examined via analysis of the cognitive processes that lead to superior performance. In the sports domain, and particularly soccer, a number of authors have investigated related process measures (e.g., visual search behaviors) in an attempt to provide an insight into the nature of expertise (e.g., Helsen & Pauwels, 1993; Williams & Davids, 1998). Visual search data from these studies, however, have typically been used to quantify differences between skilled and less skilled participants rather than to elucidate the cognitive processes sub-serving expert performance. Presumably due to the arduous process of examining verbal report data, very few researchers in the sports domain have embarked upon this second step. Helsen and Pauwels (1993) and Starkes et al. (2001) summarize a handful of studies across all sporting domains using this approach. Very few published studies, however, have made task manipulations and recorded verbal report data using the representative laboratory-based context outlined by the expertise approach (for an exception, see Williams & Davids, 1997). Verbal reports in the Williams and Davids (1997) study were primarily used as verification for the locus of attention in eye movement recording rather than as an indication of cognitive processing per se. Whilst some authors have conducted field-based research using verbal reports (e.g., McPherson, 1999; 2000), which has made significant contribution to the knowledge base, field conditions do not allow replication and control from trial to trial, and hence, the cognitive processes used to perform the task under identical conditions to be compared. Preliminary steps to elicit the mediating mechanisms detailed through the second step of the expert-performance approach are presented in Chapter 3.

Although Ericsson and Smith (1991) provided a clear outline for steps one and two of the expert-performance approach, step three was only minimally detailed. This step involves efforts to detail the adaptive learning and explicit acquisition process relevant to a real world context that is integral to the development of expertise. Ericsson, Krampe and Tesch-Romer (1993) elaborated upon this final step and detailed the type of activities and acquisition process which, when engaged in with the deliberate intent to improve beyond current levels, result in concomitant increases in performance. There has been a recent focus in sport-related research in this area and the likes of Hodges, Helsen, and Starkes have lead the way in this regard (e.g., Helsen Starkes, & Hodges, 1998; Hodges & Starkes, 1996; Starkes, Deakin, Allard, Hodges, & Hayes, 1996). These authors expanded upon Ericsson et al.'s (1993) original theory of deliberate practice and demonstrated its application to the domain of sport. With some refinement, this approach has been successfully utilized to document the practice histories of adult sports players. However, more recently, some of these issues have been contested with regards to the nature of activities in which participants engage throughout development (see Cote & Hay, 2002; Cote, Baker, & Abernethy, 2001), the methods of data collection used, and the factors which cause an individual to invest in their development. Many of these issues are addressed in some detail in Chapter 4.

Since its inception in 1991, the expert-performance approach has been developed over the ensuing decade into an integrated framework (see Ericsson 1996, 1998, 2001). As briefly mentioned, some ground-breaking work has been conducted in specific pockets of these areas. However, only by considering this framework as a whole will it be possible to correctly interpret its many difference facets and make significant progress to our collective understanding of the development, structure, and acquisition of expert performance (Ericsson, 2001). The aims of this thesis are to successively address each of these three steps in an attempt to provide a holistic and integrated analysis of elite sports performance and its development. In addition, the aim is to present a coherent assessment of some of the critical issues which have been raised at each step of the expert-performance approach and examine these issues with regards to the cohorts under investigation.

Chapter 2

Perceptual and Cognitive Skill Development in Sport: The Multidimensional Nature of Expert Performance

Abstract

The relative contribution of visual, perceptual, and cognitive skills to the development of expertise in soccer was examined. Elite and sub-elite players, ranging in age from 9 to 17 years, were assessed using a multidimensional battery of tests. Four aspects of visual ability were measured: static and dynamic visual acuity; stereoscopic depth sensitivity; and peripheral awareness. Perceptual and cognitive skills were assessed via the use of situational probabilities, as well as tests of anticipation and memory recall. Stepwise discriminant analyses revealed that the tests of visual ability did not consistently discriminate between skill groups at any age. Tests of anticipatory performance and use of situational probabilities were the most successful in discriminating across skill groups. Recall of structured patterns of play from memory was most predictive of age. As early as 9 years of age, elite soccer players demonstrated superior perceptual and cognitive skills when compared to their sub-elite counterparts. Implications for training perceptual and cognitive skill in sport are discussed.

Key words: Anticipation, Memory Recall, Situational Probabilities, Visual Ability.

The quest to identify key factors underlying the acquisition of expert performance has stimulated much discussion in recent years (e.g., Howe, Davidson, & Sloboda, 1998). The nature-nurture debate has often taken centre stage and divergent explanations of exceptional performance have emerged (e.g., Winner, 1996; Ericsson, Krampe, & Tesch-Römer, 1993). Although polar accounts of expertise have been considered contentious (e.g., Sternberg, 1998), particularly in sport (Singer & Janelle, 1999), research promoting a parochial view of skilled performance still exists. A popular standpoint advocated by optometrists is that successful athletes are endowed with superior visual systems, supporting a 'hardware' account of expert performance (e.g., Coffey & Reichow, 1995; Loran & Griffiths, 1998; Sherman, 1990). It has been argued that above average levels of visual function are essential for athletes to meet sporting demands and efficiently fulfil their role (Gardner & Sherman, 1995). However, support for the presumption that athletes possess superior vision is, at best, equivocal (see Williams, Davids, & Williams, 1999). Attempts to characterize expertise from this perspective appear to provide only a limited insight into the factors underlying the development of visual-perceptual skill.

It is clear from the increasing body of knowledge on expertise that skill, and talent, are multifaceted in nature (e.g., Helsen & Starkes, 1999; Simonton, 1999; Williams & Reilly, 2000). Wrisberg (1993) was amongst the first to suggest that expertise research should be both interactionist and multidimensional and that the relative contribution of factors contributing to skilled performance in each domain should be examined. Researchers using such an approach have investigated the visual, perceptual, and cognitive skills of adult athletes in field hockey (Starkes, 1987), snooker (Abernethy, Neal, & Koning, 1994), and soccer

(Helsen & Starkes, 1999). This research suggests that expert athletes are not endowed with superior visual ability and that perceptual and cognitive factors are better discriminators of skilled performance in adult populations (for a recent review, see Starkes, Helsen, & Jack, 2001). When compared with their less-skilled counterparts, adult experts are better at anticipating opponents' intentions based on partial information or advance cues (Abernethy & Russell, 1987; Jones & Miles, 1978; Williams & Burwitz, 1993), and can more consistently pick up the minimal essential information (e.g., relative motion) necessary for successful anticipation (e.g., Ward, Williams, & Bennett, 2002). Experts typically exhibit more effective visual search strategies (Helsen & Starkes, 1999; Williams, Davids, Burwitz, & Williams, 1994; Williams & Davids, 1998), and are faster and more accurate at recognizing and recalling typical patterns of play from memory (Starkes, 1987; Williams, Davids, Burwitz, & Williams, 1993; Williams & Davids, 1995).

The relative contribution of visual, perceptual, and cognitive skills to sporting expertise throughout late childhood, adolescence, and early adulthood has received limited attention. Sports vision research has typically focused on the effects of chronological age as opposed to the interaction between age and expertise. Current understanding suggests that the visual system develops throughout infancy and early childhood (Hubel, 1988). For instance, peripheral visual field size increases in breadth from 15° at 2 weeks to 40° by the 5th month (Tronick, 1972), and binocularity and depth perception improve substantially between 2 and 5 years of age (Williams, 1983). Adult levels of acuity (Williams, 1983) and contrast sensitivity (Banks & Salapatek, 1983) are attained by 10-12 years of age, and synaptic junction density in the striate cortex reaches adult level at a similar age (Teller, 1997). Whether the development of the visual system, and the subsequent quality of visual information available for processing, are related to sporting performance has not yet been adequately addressed.

Our understanding of how motor and cognitive aspects of performance contribute to the development of expertise during childhood and adolescence has been considerably enhanced by the work of Thomas and colleagues (for a recent summary, see French & McPherson, 1999; Thomas & Thomas, 1999; Thomas, Gallagher, & Thomas, 2001). However, relatively few studies have examined how skills such as anticipation and pattern recognition improve with age and experience (for exceptions, see Abernethy, 1988; Tenenbaum, Sar El, & Bar Eli, 2000). Chase and Simon (1973) originally proposed that expert performance could be explained on the basis of superior domain-specific knowledge. Rather than possessing a greater general capacity, skilled chess players used their more elaborate knowledge to create meaningful 'chunks', enabling a faster and more accurate response. It appears that children can develop chunking skills as early as 5 years of age when prompted to adopt a modified strategy, and from 9 years of age without external assistance (Zaichowsky, 1974). When comparing skilled 10-year-old chess players with novice adults, Chi (1978) noted that the acquisition of appropriate knowledge structures allowed age-related differences in performance to be circumvented. Early perceptual organization and the associated domain-specific knowledge base have also been hypothesized to be critical factors in skilful soccer performance (Williams et al., 1993, 1994; Williams & Davids, 1995; 1998).

While some components of perceptual skill appear to emerge relatively early in development, the ability to accurately 'read the play' in sport may not develop until much later. Abernethy (1988) used both temporal and event occlusion techniques to examine the development of anticipatory skill in 12, 15, and 18 year-old badminton players. Although experts' ability to utilize advance cues improved with age, skill-based differences in anticipatory performance were not evident until adulthood, as determined from an earlier study using adult participants (see Abernethy & Russell, 1987). Tenenbaum et al. (2000) recently reported similar observations when comparing anticipatory skills of low and high skill tennis players throughout development (i.e., 8-10, 11-13, 14-17, 18+ years). In the absence of significant differences, the authors reported only low to moderate effect sizes between skill groups for the three youngest age groups. These effect sizes were not as consistent, or of comparable magnitude to those reported for the oldest age group. Abernethy (1988) and Tenenbaum et al.'s (2000) research examined the ability to 'read' postural cues in a racket sport context. An interesting issue is whether similar findings may be observed in team sports and whether other perceptual and cognitive skills such as pattern recognition and use of situational probabilities develop at comparable rates.

In recent years, researchers have also examined the development of tactical and strategic decision-making in sport (e.g., French et al., 1996; McPherson & Thomas, 1989; McPherson, 1999). These studies suggest that the knowledge bases and cognitive strategies underlying effective performance develop gradually as a result of extensive task-specific practice. Prior to the teenage years, skilled tennis and baseball players are generally unable to discriminate task-relevant from irrelevant information (McPherson & Thomas, 1989; McPherson, 1999; French et al., 1996). In addition, relatively few specialized processing strategies are developed that would allow future actions to be monitored, planned, and predicted (McPherson, 1999, 2000). Expert problem representations were suggested to be more elaborate than novices' between 7 and 12 years of age, although still limited when compared to adult experts (French et al., 1996; Nevett & French, 1997). Novices have been shown to adopt far weaker strategies to resolve problems at all ages, and are much less likely to reach an appropriate solution under time pressure (French & McPherson, 1999). Chi (1977) observed that these age-related differences in memory performance are not necessarily reflective of structural limitations but of faster encoding times and a greater number of alternative or mnemonic strategies.

During the development of expertise, task-relevant knowledge structures and both general and domain-specific processing strategies have been hypothesized to combine into two specific memory adaptations or 'profiles' (McPherson, 1999b). As children acquire greater experience with age and task-specific practice, rule-based problem representations emerge with increasing complexity (i.e., action plan profiles). The ability to accurately monitor current task demands, use strategic and tactical planning, predict probable outcome with increasing sophistication, and anticipate opponents' intentions (i.e., current event profiles) continues to develop into early adulthood. Integral to the development of these current event profiles is the ability to synthesize contextual information with expectations stored in memory via the acquisition, adaptation, and development of domain-specific skills (Ericsson & Kintsch, 1995). However, domain-specific memory skills and related current event profiles may take up to ten years to acquire (Chase & Simon, 1973; Ericsson et al., 1993; Ericsson & Kintsch, 1995), and are rarely demonstrated before 15-16 years of age (French & McPherson, 1999).

One of the most effective ways of assessing expert performance is by asking players to select the next best move (de Groot, 1978). In determining the outcome of an evolving pattern of play, it is likely that novices of all ages may use an inappropriate selection strategy and generate far fewer task solutions. In soccer, experts are likely to dismiss many events as being highly improbable and attach a hierarchy of probabilities to the remaining possibilities (Gottsdanker & Kent, 1978). Such strategies are likely to become more refined with experience and age as their domain-specific knowledge and associated memory skills become more sophisticated. The suggestion is that anticipatory decisions are initially guided by expectations of what is likely to happen next (i.e., use of situational probabilities). As the action unfolds, expectations are integrated with contextual information to provide an 'on-line' confirmation or modification of the anticipated response (McPherson, 1999; Williams, 2000). The role of expectations has been particularly under researched in soccer (for an exception, see Cohen & Dearnaley, 1962). In a racket sport context, Alain and Proteau (1980) required participants to anticipate an opponent's actions, and then asked them to comment upon the probabilities they had assigned to each possible outcome. Participants were found to initiate a response once a probability threshold of 70% had been surpassed. At this threshold, the benefits of anticipation were perceived to far outweigh the costs of responding incorrectly. In soccer, novices may not be adept at assigning an appropriate probability hierarchy to important events and may be over-exclusive or -inclusive in their selection strategy (Ross, 1976). In comparison, experts are likely to 'hedge their bets' judiciously, putting situational probabilities and contextual information to effective use. While these information sources would appear to be an important precursor to skilled prediction, no published research has examined the use of situational probabilities in soccer, or in a developmental context.

The aim of this study was to examine how visual, perceptual, and cognitive skills develop as a function of age and skill in soccer. A secondary aim was to determine the measures that most discriminate between age and skill groups. In view of the relative lack of research work in this area, this study was partly exploratory in nature. While performance on tests of visual and perceptuo-cognitive skill was expected to improve as a function of age and experience, the exact nature of any interaction was difficult to predict. Previous research suggests that visual function improves with age, but how this interacts with the performer's skill level or the development of sport-specific perceptual and cognitive skills has not yet been addressed. Research on strategic and tactical decision making suggests that the underlying knowledge bases develop gradually throughout childhood and adolescence (French & McPherson, 1999), however, research in racket sports indicates that the ability to anticipate may develop only in early adulthood (Abernethy, 1988). These findings may not generalize to more open-play team sports such as soccer, and to other perceptual and cognitive skills.

Method

Participants

Elite and sub-elite, male soccer players (n=137) were selected as participants. Elite players were recruited from English Premier League Academies, while sub-elite players were recruited from local elementary and high schools. Elite participants played at the highest level of national competition for their respective age, whereas sub-elite participants played no higher than recreational or school level. Both groups commenced participation in soccer at similar ages (M age: elite = 6.04 ± 2.15, sub-elite = 6.42 ± 3.07 years of age). Within each skill group, an average of 14 participants were recruited from each of five different age groups; 9 and under (U-9), U-11, U-13, U-15, U-17. The mean age of participants in each sub-group, and the amount time accrued in a professional coaching environment by the elite group is summarized in Table 2.1. The U-17 elite players attended the Academy full time from 16 years of age. The elite 9 to 15 year olds attended the Academy on a part-time basis. The sub-elite players had not received any form of specialized training other than through regular physical education classes at school. Informed consent was gained prior to participation in the study.

Procedure

Using standardized equipment, four measures of visual ability were recorded: static visual acuity; dynamic visual acuity; stereoscopic depth sensitivity; and peripheral awareness (see Gardner & Sherman, 1995). Participants were tested in the field, on an individual basis, and in their normal viewing mode (no correction = 79%, spectacles = 15%, and contact lenses = 6%). A counterbalanced design was used to minimize any potential order effect.

Static visual acuity. A Bailey-Lovie logMAR eye chart was used to test binocular static acuity at a distance of 6 meters (m). Players commenced reading rows of letters diminishing in size until the letters could no longer be accurately discriminated. Static visual acuity was measured in minutes of arc (min.arc) and compared to a 6/6 (20/20) standard.

Table 2.1. Demographic information for the elite and sub-elite players at each age group

	Age group	Mean age (SD) of participants	Mean number of years (SD) in the Academy
Elite	U-9	9.32 (0.34)	1.32 (0.82)
	U-11	11.37 (0.41)	1.90 (1.07)
	U-13	13.25 (0.29)	2.77 (1.91)
	U-15	15.14 (0.29)	4.65 (2.28)
	U-17	17.59 (0.54)	5.08 (2.15)
Sub-elite	U-9	9.42 (0.30)	-
	U-11	11.29 (0.33)	-
	U-13	13.11 (0.30)	-
	U-15	15.35 (0.25)	-
	U-17	17.39 (0.32)	-

Dynamic visual acuity. The Sherman Dynamic Acuity Disc was used to assess players' dynamic visual acuity levels. This test was designed specifically for testing sports vision (Gardner & Sherman, 1995). Participants tracked a disc rotating with decreasing velocity until they could accurately discriminate various letters (sized at 10/30) placed 10.5 cm from the central axis of rotation. Testing was conducted at a distance of 3m. Binocular dynamic acuity was measured in revolutions per minute (rpm).

Stereoscopic depth sensitivity. A random dot stereogram (TNO test) was used to assess stereoscopic depth sensitivity (i.e., binocular depth perception) by viewing standard anaglyphs through filter spectacles. Participants attempted to perceive an embedded object at six levels of retinal disparity. Success rate was measured in seconds of arc (sec.arc) at a distance of 40 cm.

Peripheral awareness. The Wayne Peripheral Awareness Tester was used to assess the ability to respond to peripheral stimuli (see Coffey & Reichow, 1995). While participants fixated upon a central target, a light emitting diode was randomly illuminated in each of eight different meridians (0°, 45°, 90°, 135°, 180°, 225°, 270°, and 315°). The stimulus subtended a visual angle of approximately 60°, standing 40cm from the apparatus. Participants responded using a hand held joystick. Response time was measured in milliseconds (ms).

Film-based simulations were used to examine perceptual skill. Action sequences were edited from professional and semi-professional matches and presented on a large video screen. Participants responded using pencil and paper in a time-constrained context. Although previous reviews have argued that more ecological responses are needed to preserve expert-novice differences (Abernethy, Thomas, & Thomas, 1993; Williams, Davids, Burwitz, & Williams, 1992), construct validity is retained and significant skill-based differences still emerge when using techniques similar to those employed in this study (cf. Williams et al., 1999). Participants were tested on anticipatory performance, memory recall, and use of situational probabilities.

Anticipation. The temporal occlusion paradigm was used to assess anticipatory performance (see Abernethy & Russell, 1987). Participants were presented with soccer action sequences including 1 v 1 (2-choice response), 3 v 3 (4-choice response), and 11 v 11 (10-choice response) simulations (see Williams et al., 1994; Williams & Davids, 1998). Each clip was edited 120 milliseconds (ms) prior to foot/ball contact. After three practice trials, eight test trials were randomly presented for each type of soccer simulation (N=24). Trials lasted approximately 10s and were interspersed with a 5s inter-trial interval. Participants attempted to anticipate the direction of a dribble (1 v 1) or pass (3 v 3, 11 v 11). Response accuracy was reported as a percentage.

Memory recall. The recall paradigm was used to assess participants' skill in encoding and retrieving typical patterns of structured and unstructured play from memory (see Williams et al., 1993; Williams & Davids, 1995). Structured conditions included 11 v 11 attacking and defensive action sequences. Unstructured trials included periods of inactive play (i.e., warm up sessions, players walking on and off the field of play, or players standing around during a break). Following three practice trials, eight test trials were randomly presented in each condition (N=16). After every 10s trial, participants were asked to recall the position of particular players from both teams using a procedure employed by Williams and colleagues (see Williams et al., 1993; Williams & Davids, 1995). Participants marked player positions on a replication of the field of play (30 x 20cm) using an 'X' to represent the location of the player's hip. The x and y co-ordinates of recalled and actual player positions were compared. Response accuracy was measured in radial error using simple Pythagoras.

Situational probabilities. A novel paradigm was used to assess the use of expectations. Offensive 11 v 11 patterns of play were filmed from an elevated perspective behind the goal. Each simulation lasted approximately 10s and was then frozen 120 ms prior to the player in possession passing the ball. The still image remained on screen for 20 seconds while participants completed the following tasks. First, they were requested to highlight key players in a good position to receive the ball, based on players' expectations of what should happen next. The percentage of key players correctly highlighted, and total number of non-key players selected were measured against a panel of expert coaches (inter observer agreement = 90.4%). Second, participants ranked each highlighted player in terms of their perceived attacking importance. A point system was devised, where one point was awarded for correctly matching the assigned importance of each player previously determined by the panel of coaches. Three practice trials and 18 test trials were presented.

Data Analyses

Separate two-way ANOVAs were used to analyze three of the four visual ability variables (static visual acuity, stereoscopic depth sensitivity, peripheral awareness), as well as the anticipation and situational probabilities variables. The between-participant factors were age (U-9, U-11, U-13, U-15, U-17) and skill (elite, sub-elite). Where the normality assumption was violated, data were first transformed using either reflect and square root (anticipation: 1 v 1), square root (peripheral awareness, situational probabilities: non-key players), logarithmic (stereoscopic depth sensitivity), or inverse (static visual acuity) transformations. Significant main effects and interactions were followed up using Scheffe post-hoc tests. Where a suitable transformation was not available, a generalized rank-order method for non-parametric analysis of data was employed (see Thomas, Nelson, & Thomas, 1999). The Puri and Sen (1985) L statistic was then calculated for dynamic visual acuity using a two-way ANOVA, and for memory recall using a three-way ANOVA in which condition (structured, unstructured) was the within-participant factor. The Bonferroni procedure was used to adjust for the overall number of statistical tests performed (0.05/13). The alpha level was set at 0.004.

Effect sizes (Cohen's d) were calculated using pooled standard deviation (see Thomas, Salazar, & Landers, 1991).

Separate forward stepwise discriminant function analyses were employed to determine which variables were most predictive of age and skill, respectively, and to determine how accurately the model predicted group membership. The criteria for entering and removing variables in the discriminant function model was based upon the adjusted alpha (see Biddle, Markland, Gilbourne, Chatzisarantis, & Sparkes, 2001). The L statistic was calculated at each step.

Results

Visual Ability

Static visual acuity. A significant main effect was observed for age, F (4, 127) = 5.78, $p<.001$. Post-hoc analyses indicated a significant improvement in static acuity between 9 and 13 years of age for all participants (d = 1.12). The results of all visual ability tests are presented in Table 2.2.

Dynamic visual acuity. No significant effects were found.

Stereoscopic depth sensitivity. A total of 5.1% (3 elite, 4 sub-elite) of the sample tested were unable to perceive an embedded image within the random dot stereogram. This proportion is within the normal range (Julesz, 1971). These participants did not achieve a valid score on the TNO test and were excluded from the analysis. An age x skill interaction was observed, F (4, 118) = 9.903, $p<.001$. Post hoc comparisons did not reveal the source of this interaction. However, effect sizes indicate a meaningful difference in favor of sub-elite participants at 11 and 13 years of age (d = 0.96, 0.74 respectively), and elite players at 15 years of age (d = 0.59).

Table 2.2. Mean scores (SD) for the elite and sub-elite players on the four vision tests

	Group	Visual Acuity Static (min.arc)	Visual Acuity Dynamic (rpm)	Stereoscopic Depth Sensitivity (sec.arc)	Peripheral Awareness (ms)
	U-17	-0.10	89.93	28.75	1380
		(0.07)	(10.89)	(16.25)	(510)
	U-15	-0.07	83.00	26.54	1750
		(0.10)	(14.59)	(12.48)	(650)
Elite	U-13	-0.03	77.00	52.50	960
		(0.18)	(16.24)	(28.96)	(250)
	U-11	-0.01	78.00	63.75	1850
		(0.03)	(11.73)	(25.04)	(1000)
	U-9	0.06	77.98	52.50	2700
		(0.11)	(11.98)	(15.29)	(1250)
	U-17	-0.02	72.13	41.79	1450
		(0.13)	(9.78)	(26.43)	(380)
	U-15	-0.03	75.31	64.00	1570
		(0.08)	(11.00)	(37.38)	(440)
Sub-	U-13	-0.12	79.53	32.50	2250
elite		(0.07)	(9.44)	(17.15)	(630)
	U-11	-0.02	74.43	31.15	3670
		(0.11)	(9.96)	(14.31)	(780)
	U-9	-0.01	77.36	49.29	3370
		(0.07)	(10.92)	(27.24)	(750)

Peripheral awareness. There were significant main effects for age, F (4, 127) = 28.40, p<.001, and skill, F (1, 127) = 43.34, p<.001, and an age x skill interaction, F (4, 127) = 10.40, p<.001. Significant differences in peripheral awareness were found between elite U-9 and U-13 age groups, p<.001 (d = 2.21). Both the U-11 and U-13 elite groups responded significantly quicker than their age-matched, sub-elite counterparts, p<.001 (d = 2.08, 3.11 respectively). Sub-elite players improved their response times later in development, between 11 and 15 years of age, p<.001 (d = 1.52). At 15 and 17 years of age, no skill-based differences were evident.

Perceptual and Cognitive Skills

Anticipation: 1 v 1. A significant main effect was found for skill, F (1, 127) = 9.206, p<.003. Elite players demonstrated superior anticipatory performance in 1 v 1 simulations when compared with sub-elite participants (d = 0.50) (see Table 2.3.).

Anticipation: 3 v 3. There was a main effect for age only, F (4, 127) = 5.71, p<.001. The U-13 groups performed significantly poorer than both the U-9, (d = 0.91) and U-17 (d = 1.13) age groups on the 3 v 3 simulations.

Anticipation: 11 v 11. ANOVA revealed a significant main effect for skill, F (1, 127) = 30.85, p<.001. Irrespective of age, elite players were more successful at anticipating pass destination in 11 v 11 simulations (d = 0.95).

Memory recall. A significant main effect was found for structure only, L (4) = 16.47, p<.004. All participants made more errors in recalling player positions during structured compared to unstructured trials. However, the magnitude of the difference between structured conditions represented only a small effect (d = 0.19). The mean (± SD) radial error for structured trials was

Table 2.3. Mean percentage accuracy (±SD) for elite and sub-elite players on the 1 v 1, 3 v 3, and 11 v 11 anticipation tests

Group		1 v 1 (%)	3 v 3 (%)	11 v 11 (%)
	U-17	84.33	56.25	70.83
		(10.92)	(12.50)	(12.31)
	U-15	87.31	48.08	67.31
		(11.20)	(21.56)	(13.05)
Elite	U-13	82.69	33.65	63.46
		(9.60)	(20.66)	(9.49)
	U-11	80.00	45.00	65.00
		(15.81)	(17.87)	(11.49)
	U-9	72.32	66.96	65.18
		(14.85)	(18.09)	(17.11)
	U-17	78.33	56.67	50.83
		(8.80)	(15.57)	(15.28)
	U-15	77.34	48.44	55.47
		(17.21)	(19.83)	(17.06)
Sub-elite	U-13	66.67	42.50	54.17
		(16.28)	(17.38)	(17.68)
	U-11	76.79	47.32	46.43
		(9.63)	(12.19)	(10.32)
	U-9	76.79	42.86	54.47
		(9.63)	(11.72)	(13.53)

30.18 ± 13.90 mm, and 29.77 ± 14.42 mm for unstructured trials. Although the age main effect and the skill x age x structure interaction were not significant (p=.02, and .04 respectively), moderate to large effect sizes indicated that meaningful differences were apparent. All participants improved their general memory recall between 11 and 13 years of age (d = 1.42). In the structured condition only, elite players made fewer recall errors at 9 years of age (d = 0.65) and improved beyond their sub-elite counterparts between 15 and 17 years of age (d = 1.32) (see Figure 2.4).

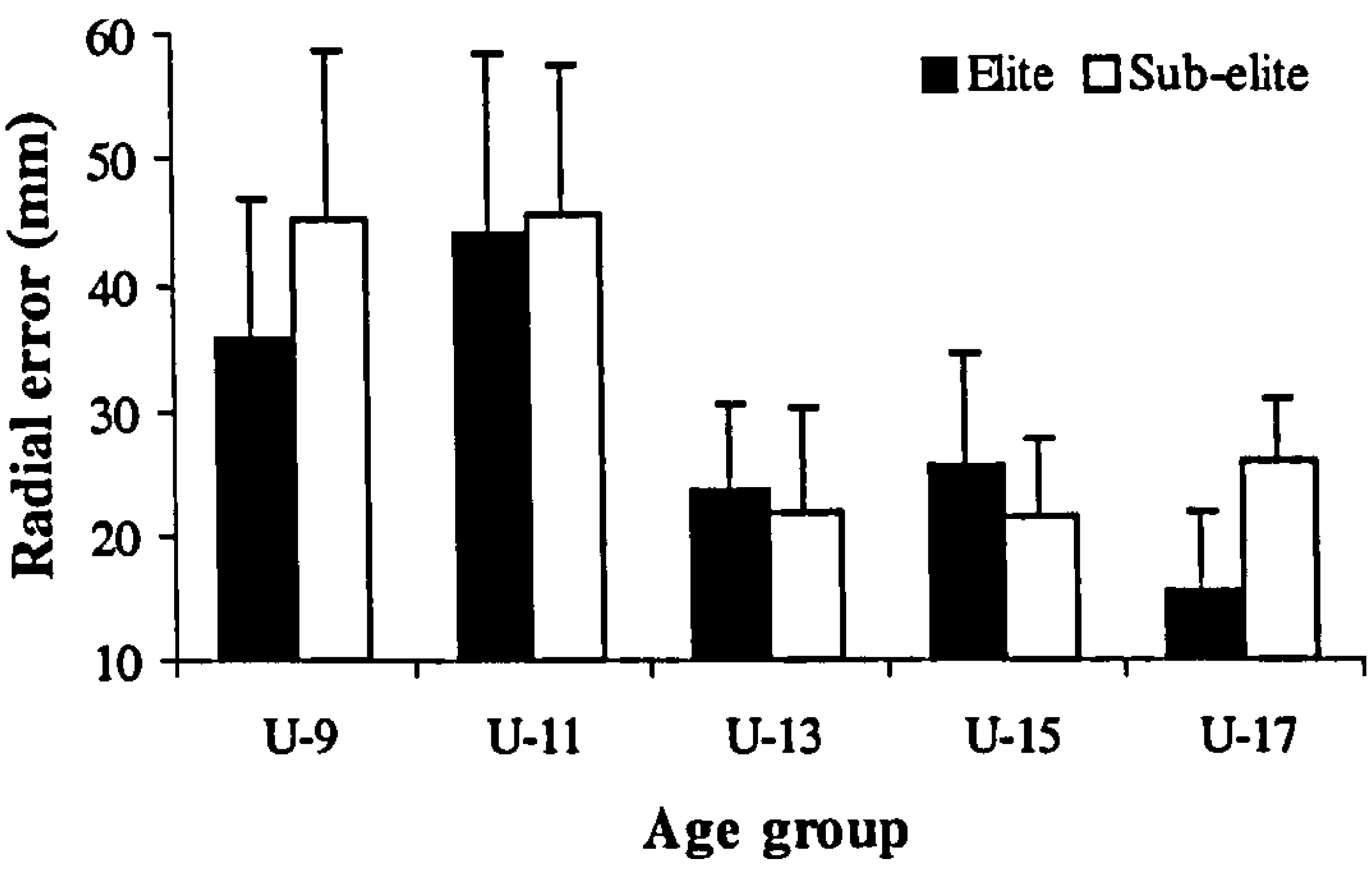


Figure 2.4. Error in recalling structured patterns of play from memory.

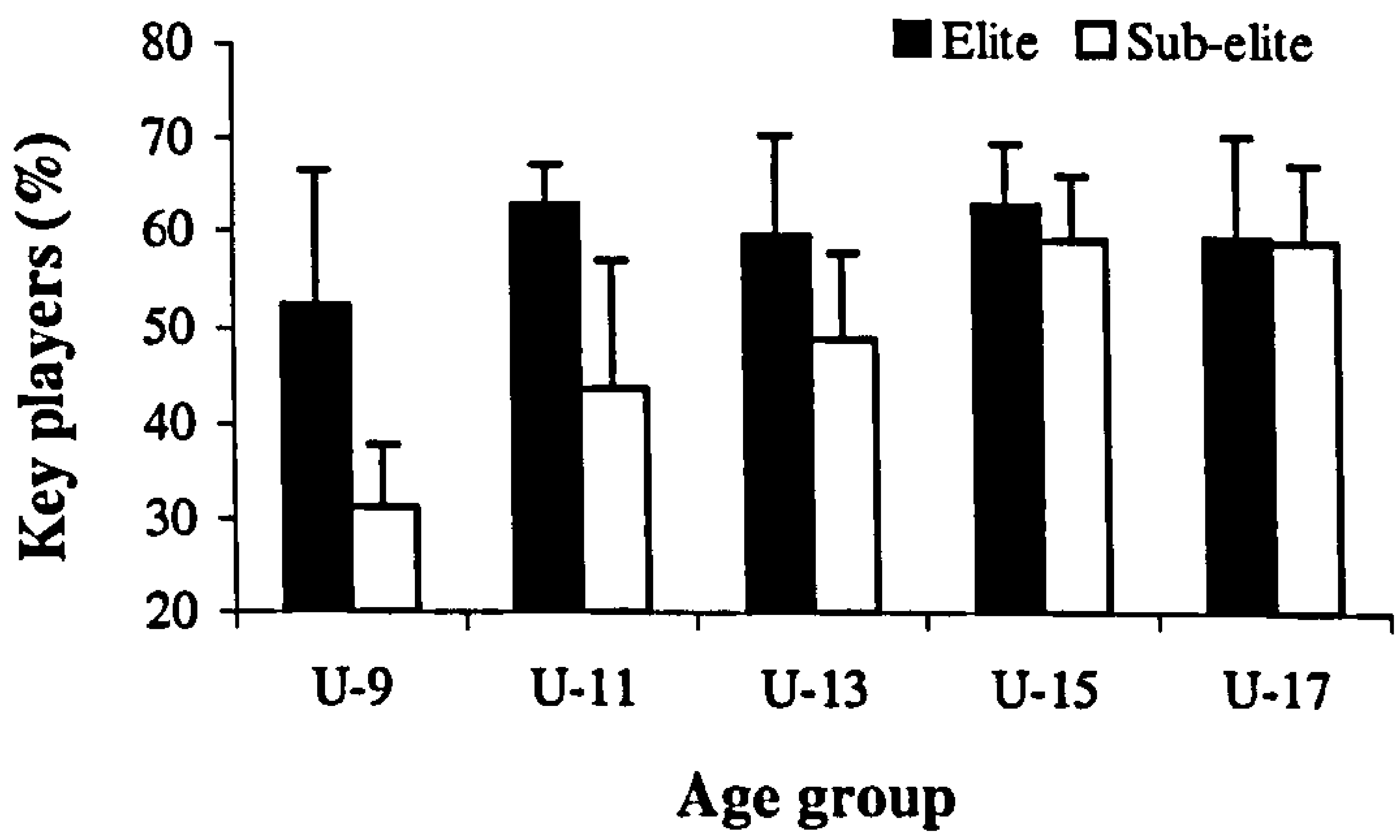


Figure 2.5. Percentage of key players highlighted.

Situational probabilities: Key players. Main effects for age, F (4, 127) = 6.10, p<.001, and skill, F (1, 127) = 44.76, p<.001, and an age x skill interaction, F (4, 127) = 17.00, p<.001 were obtained. Sub-elite participants' performance improved significantly between 9 and 13 years of age, p<.004 (d = 2.23). In comparison, elite players maintained the same level of performance across age groups, although they more accurately highlighted a greater percentage of key players than the sub-elite participants at 9, p<.001 (d = 1.94), and 11 years of age, p<.003 (d = 1.83). While there was no statistical difference between elite and sub-elite players in the older age groups, the effect size indicated that the observed differences in skill were also meaningful at 13 years of age (d = 1.08) (see Figure 2.5).

Situational probabilities: Non-key players. A significant main effects was obtained for age only, F (4, 127) = 8.56, p<.001. Players from both skill groups reduced the number of non-key players highlighted between 11 and 17 years of age, p<.002. The age x skill interaction approached significance, p=.005. Moderate to large effects sizes for comparisons across skill groups at U-13, U-15, and U-17 suggest that as age increased, the elite players meaningfully reduced the number of non-key players selected in comparison to sub-elite players (d = 0.53, 0.83, and 1.27, respectively) (see Figure 2.6).

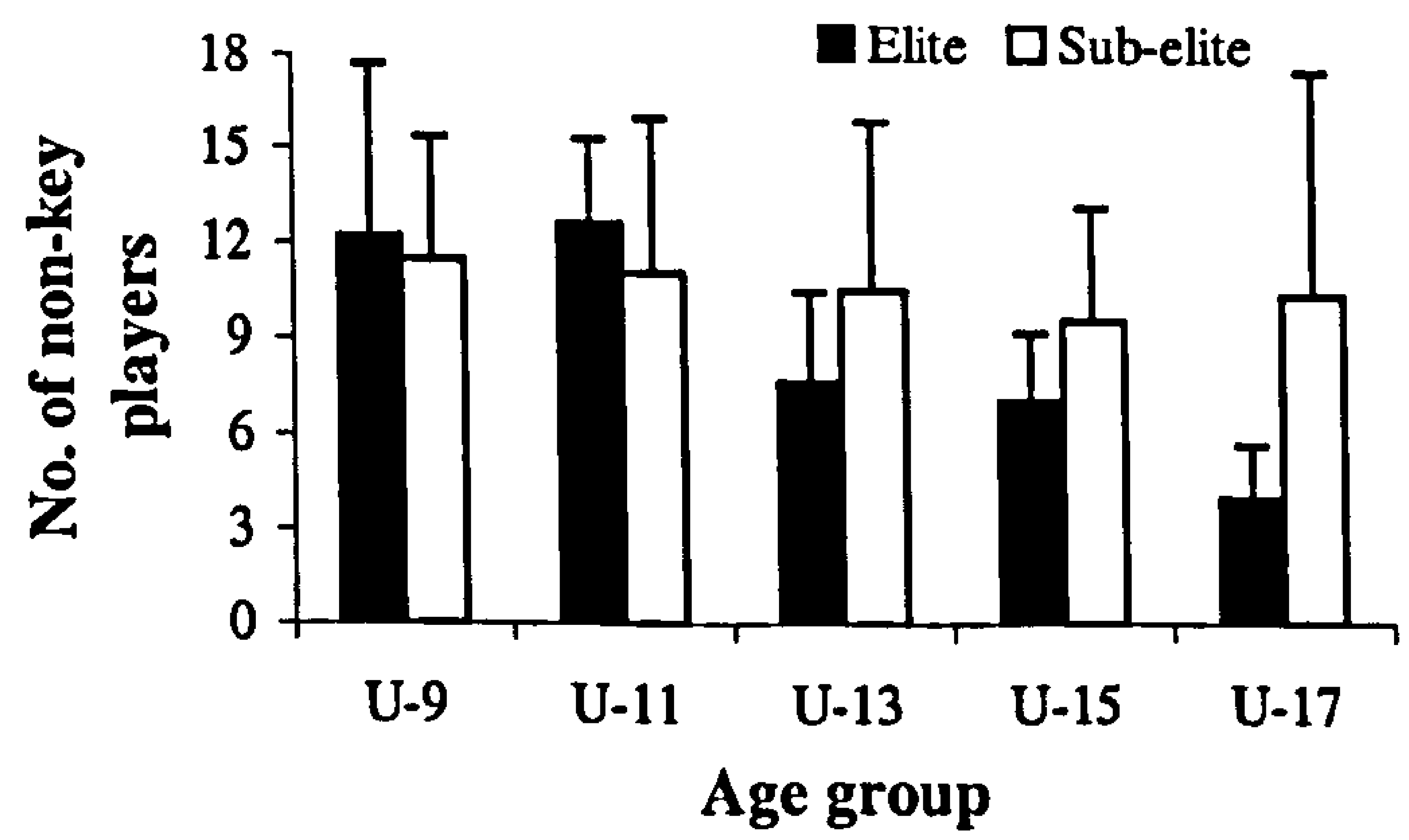


Figure 2.6. Total number of non-key players incorrectly highlighted across trials.

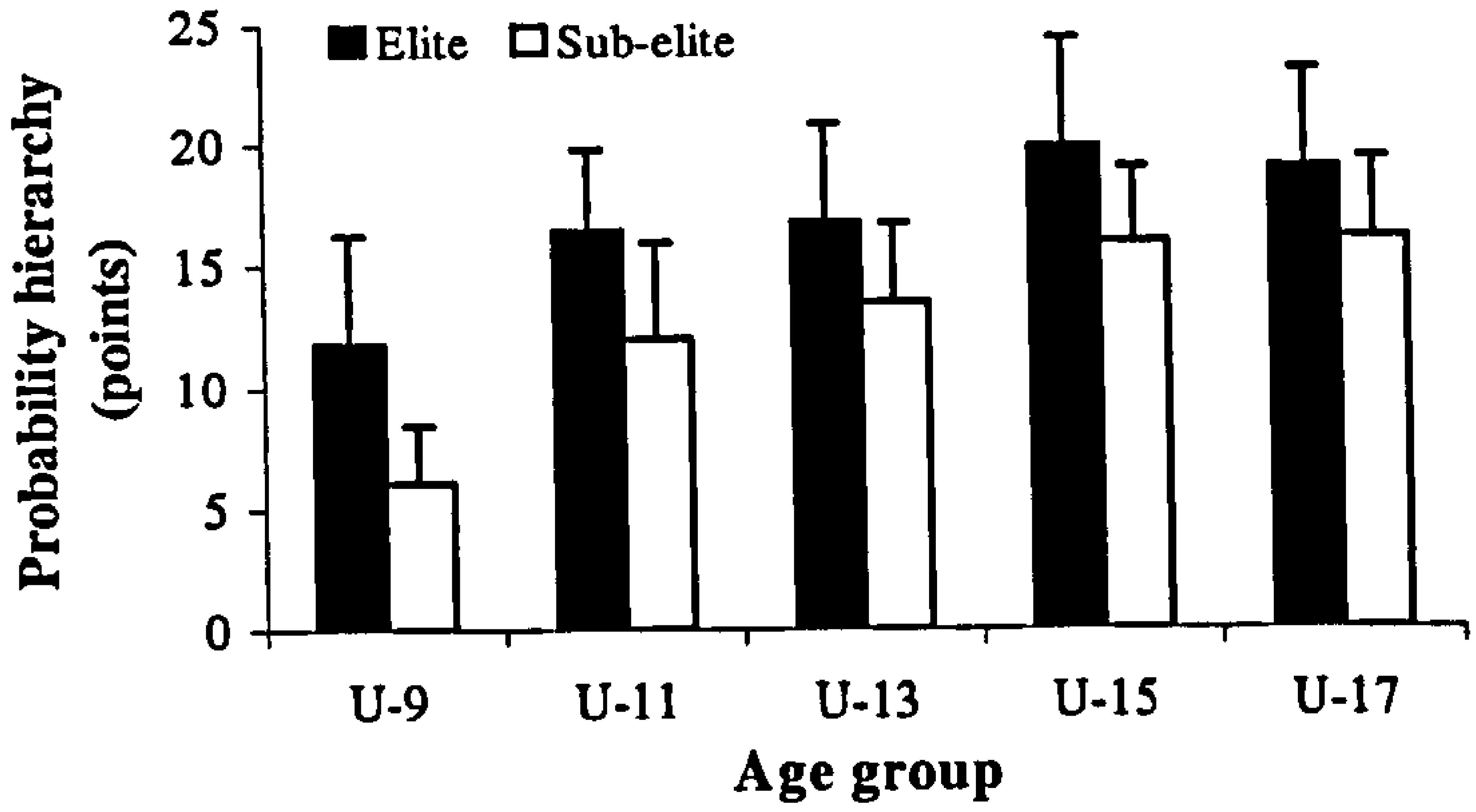


Figure 2.7. Probability hierarchy showing the correctness of response in assigning an appropriate probability value to the most important player(s).

Situational probabilities: Probability hierarchy. Main effects were found for age, F (4, 127) = 26.80, $p<.001$, and skill, F (1, 127) = 40.83, $p<.001$. When compared to sub-elite participants, elite players at every age were better at assigning a correct probability value to key players in the most threatening position (d = 0.59). Both groups improved similarly in their ability to perceive the importance of attacking players between 9 and 15 years of age, $p<.001$ (d = 1.99) (see Figure 2.7).

Predicting Performance in 9 to 17 Year Olds: Discriminant Analyses

Age. Four significant discriminant function variates were calculated with a combined χ^2 (16) = 160.78, $p<.001$. A strong association between predictors and groups remained when the first function was removed, χ^2 (9) = 30.517, $p<.001$. The remaining two functions did not significantly contribute to the model. The first two functions accounted for 87.8 and 6.9% of the between-group variability, respectively. Variables predicted by the model were significant at each of the first four steps (max. 24 steps), L (11) = 65.63 to 92.16, $p<.001$. The standardized canonical discriminant function co-efficients (β) indicated that structured memory recall was the greatest contributor to the first function and explained the greatest amount of variance ($\beta = .817$, $r^2 = .52$). The remaining variables entered in to the model at each step were peripheral awareness ($\beta = .483$), anticipation: 3 v 3 ($\beta = .299$), and situational probabilities: probability hierarchy ($\beta = -.291$). Each of these variables explained only an additional 5 to 6% of the true variance. Consistent with the effect size reported for memory recall, the greatest influence of this dimension occurred between 11 and 13 years of age (group centroids = 1.619, -1.112, respectively). The model accurately predicted 44.4 to 78.6% of age group membership. These values represent an improved prediction of 24.4 to 58.6% above chance levels.

Skill. The discriminant function variate calculated for skill was significant and accounted for the total between-group variability, χ^2 (2) = 40.75, $p<.001$. Variables predicted by the model were significant at the second step, L (11) = 35.53, $p<.001$ (max. 24 steps). Standardized canonical coefficients suggest that both anticipation in 11 v 11 game play situations ($\beta = .738$) and percentage of key players highlighted (situational probabilities) ($\beta = .633$) contributed similarly to the model ($r^2 = .19, .28$, respectively). The model accurately predicted skill group membership for 79.5% of the participants. Improved prediction was 29.0% beyond chance.

Discussion

This study examined the relative contribution of visual, perceptual, and cognitive skills to the development of expert performance using a multidimensional approach. A further aim was to determine which variables best discriminated between skill and age. The variables that were predictive of elite performance in the present study were perceptual or cognitive in nature. These findings are in agreement with earlier research using adult participants in snooker, soccer, and field hockey (Abernethy et al., 1994; Helsen & Starkes, 1999; Starkes, 1987). Perceptual and cognitive skill variables have been shown to account for a high proportion of the variance in soccer skill between adult groups (Helsen & Starkes, 1999). The amount of true variance between elite and sub-elite groups explained by perceptual and cognitive skill variables in the present study was 47%. These findings extend the current body of knowledge by demonstrating that perceptual and cognitive skills also reliably discriminate elite from sub-elite players between 9 and 17 years of age. Moreover, the perceptuo-cognitive skill model identified in this study was capable of accurately predicting elite status in approximately 80% of developing players.

As early as 9 years of age, elite players were superior at predicting key player involvement when observing attacking plays and more accurately assigned appropriate probability values to each key player. They were also able to use advance information available within emerging patterns of play and from postural cues more effectively. These findings suggest that 9 year old elite participants possess a comprehensive knowledge of the relationships between players, readily perceive the relative importance of each player, and can pick up on their intended actions to a greater extent when compared to sub-elite players. Although the use of adult type memory strategies (i.e., rehearsal and retrieval) have previously been demonstrated at 9 years of age (Gallagher & Thomas, 1984), skilled 8-10 year olds have generally been reported to possess inadequate problem representations and processing operations to facilitate an appropriate solution (French et al., 1996; Nevett & French, 1997). Extensive amounts of practice over several years (e.g., 10 year rule) may be necessary to fully acquire the knowledge and domain-specific memory skills underlying expert performance (Chase & Simon, 1973; Ericsson et al., 1993; Ericsson & Kintsch, 1995). However, the present study indicates that limited practice and high quality coaching can have a significant impact upon perceptual and cognitive skill acquisition at an early age.

The results from the situational probabilities paradigm suggest that elite players exhibited a greater degree of situational awareness from an earlier age. The number of key players highlighted was one of the most discriminating factors of skill. Irrespective of age, elite players were relatively accurate at picking up task relevant information while viewing each simulation and were able integrate this information with prior experiences to predict the best options available to the player in possession of the ball. Furthermore, between 9 and 15 years of age, elite players improved their ability to predict the next best move by assigning an appropriate probability hierarchy to the most important players thus improving certainty of an event's occurrence. That is, not only were elite players able to select key players in the game but, with increasing likelihood, were able to use the level of threat posed by each key player as a relative index of attention allocation.

The analysis of non-key players also indicates a meaningful contribution to the observed level of skill. Elite players improved their selectivity beyond that of sub-elite participants between 13 and 17 years of age, excluding more non-key players who did not pose an immediate potential threat within the impending attack (d = 0.53 to 1.27). Although sub-elite players improved their ability to identify key players between 9 and 13 years of age, elite players' reduction of task irrelevant information processing (i.e., non-key players) suggests that skill level as opposed to age had a greater contribution to the shift from an over-inclusive to a selective attention strategy (Ross, 1976). Through the use of a more refined selection strategy and probability hierarchy, developing elite players are able to decrease the decision threshold necessary to predict the likely outcome of a situation. Accurate prediction appears to be a consequence of integrating contextual information with situational probabilities or expectations stored in memory. With increasing age, elite players became more adept at predicting, and confirming or adapting their typical response (Williams, 2000). This is consistent with McPherson's (1999) 'current event profile' account of expert development. However, French and McPherson's (1999) suggestion that such memory adaptations are seldom developed prior to 15-16 years of age may be open to debate given that, in the present study, elite 9 year old soccer players were able to make relatively accurate and sophisticated predictions.

The results of the temporal occlusion paradigm partially support previous research that has employed a similar design to test anticipation (e.g., Williams et al., 1994). However, of the three game-play sequences used to assess anticipation, only 11 v 11 simulations were included in the discriminant analysis model for skill. The suggestion is that the complex patterns of play in the 11 v 11 simulations require more sophisticated knowledge structures and domain-specific memory skills to reach an appropriate solution. In comparison, in the 1 v 1 and 3 v 3 simulations fewer relations between players and possible outcomes need to be considered. The perceptual-cognitive skill model highlighted in this study suggests that both the ability to anticipate 'what happens next' (i.e., appropriate use of contextual information) and knowledge of 'what could potentially happen next' (i.e., integration of expectations stored in memory) in macro-states of play are vital components of expert performance.

The lack of skill-based differences in the ability to extract task-relevant information, such as postural cues, in micro-states of play (i.e., 3 v 3) provides partial support for Abernethy's (1988) findings in racket sports. However, skill-based differences in the 1 v 1 simulations indicate that 9 to 17 years old elite players are still able to anticipate effectively based on postural information, albeit to a lesser extent. In comparison to sub-elite players, elite players were approximately 12% more accurate in 11 v 11 simulations ($\underline{d} = 0.95$), yet only 6% more accurate in 1 v 1 simulations ($\underline{d} = 0.50$). Abernethy's claim that experts do not develop superior anticipatory skill until early adulthood is refuted given that elite players in the present study were able to anticipate opponents' intentions, particularly in 11 v 11 simulations, from 9 years of age. The present results suggest that anticipation based on the global relationships between players within emerging patterns of play may be of greater importance to early skill development in soccer than the ability to utilize more subtle postural information. Further research is required to verify this issue.

The ability to retrieve player positions from memory in attacking and defensive 11 v 11 simulations was examined in the recall paradigm. Although no significant Age or Skill interactions were reported, the large effect size suggests that there was a large improvement in elite and sub-elite players' ability to recall both structured and unstructured patterns of play between 11 and 13 years of age ($\underline{d} = 1.42$) (see Figure 2.4). Such increments in performance may be indicative of an age-related increase in available processing strategies, as identified by Chi (1977). The continued improvement by the elite players in structured recall between 15 and 17 years suggests that, at this age, they begin to develop a more organized and accessible, encoding and retrieval system compared to their sub-elite counterparts (d = 1.32). The results of the U-17 groups support previous work in soccer where experienced adults demonstrated less error in recalling key player positions from typical patterns of play when compared to inexperienced players (Williams et al., 1993). The U-17 results are also in agreement with Ericsson and Kintsch's (1995) and McPherson's (2001) propositions that domain-specific memory adaptations acquired through years of 'deliberate' practice contribute to the perceptual advantage.

In the present study, age was a stronger predictor of structured memory recall than skill. Similar findings have been noted in research using participants at the other end of the age spectrum (M age = 60.3 years) (Krampe & Ericsson, 1996). However, previous work on young adults (M age = 23.2 years) has found recall of patterns of play to be the most significant discriminator of expertise, and the most predictive of anticipatory skill (Williams & Davids, 1995). The lack of significance in the memory recall paradigm was potentially due to the large standard deviations observed. It is likely that the recall task used in this study was too complex for younger participants to consistently differentiate between skill groups. Moreover, instructions to recall specific player positions may have required participants to recall players that did not necessarily form part of the perceptual signature. Current research is underway within our laboratory to determine the nature of information encoded during viewing using a free recall paradigm. In accordance with de Groot's (1965) findings, the move-selection task used in the situational probabilities paradigm and anticipation of 11 v 11 simulations appear to have been better discriminators of skilled performance throughout development than the structured memory recall task used in this study.

Elite and sub-elite soccer players were not consistently or meaningfully discriminated based on their visual ability throughout late childhood, adolescence, and early adulthood. There was a general trend for static acuity, and in particular, peripheral awareness to improve up to around 13 years of age. This finding was confirmed by the inclusion of peripheral awareness in the discriminant analysis model for age and is consistent with research on perceptual-motor development (Williams, 1983). However, these improvements were not skill dependent. The skill-based differences observed in visual ability throughout the developmental age range were either highly variable, transient (e.g., superior peripheral awareness by elite players at U-11 and U-13 only), or equally favored sub-elite participants (e.g., stereoscopic depth sensitivity at U-11 and U-13). In previous studies using adult populations, the true variance explained by variables related to visual ability have demonstrated only a negligible contribution (3-5%) to skilled behavior (Abernethy et al., 1994; Helsen & Starkes, 1999). The exclusion of visual 'hardware' variables from the discriminant analysis model for skill illustrates their lack of contribution to elite performance throughout development. The optometric and physical properties of the visual system may well set limits on performance, but these do not appear to be skill dependent. No single variable related to visual ability consistently discriminates elite from sub-elite soccer players between 9 and 17 years of age.

In conclusion, the present research suggests that elite and sub-elite soccer players are not meaningfully discriminated on non-specific tests of visual ability throughout late childhood, adolescence, and early adulthood. Instead, elite players develop superior perceptual and cognitive skills that allow them to perform more successfully at each of the respective age groups. The perceptual-cognitive skill model indicates that from as early as 9 years of age, elite players can effectively utilize and integrate contextual information with expectations stored in memory in ways that systematically differ from their sub-elite counterparts.

The present study has important implications for training perceptual skill in sport. Previous guidelines have suggested that players should be amenable to perceptual training by 12 years of age (Grant & Williams, 1999). In light of the current findings there is a plausible argument for reducing this age recommendation. Indeed, McPherson and Thomas (1989) have demonstrated that 8-10 year old tennis players' decision-making skills could be improved following specific instruction. However, French and McPherson (1999) provide evidence to suggest that children may not develop task-specific cognitive or perceptual skills before the physical mastery of related technical skills. Moreover, the content and focus of practice sessions are likely not only to regulate motor skill development but also to produce different knowledge representations that affect how players 'read the game'. Therefore, a note of caution is made with respect to implementing perceptual skills training programs too early. In our view, the primary goal of instruction at an early age should be to develop key technical skills. When a sufficient level of mastery has been attained and the rules of the game understood, inclusion of perceptual and cognitive skills training that is relevant to the current strategies being implemented may provide a conducive environment for developing appropriate game reading skills.

Chapter 3

Underlying mechanisms of perceptual-cognitive expertise in soccer: An information processing perspective

Abstract

Performance and process data were collected to examine the mediating processes sub-serving perceptual-cognitive expertise in soccer. Elite and sub-elite adult players were assessed using a combined anticipation and situational probabilities task, adapted from Experiment 1 (see Chapter 2). Concurrent verbal reports were recorded while viewing film sequences of soccer action, and under free and cued recall conditions. Prior to data analysis, a formal task analysis was performed to define the general problem space. ANOVAs revealed that elite players were more accurate on all performance variables in both conditions compared to sub-elite players. Elite players were superior at picking up and encoding task relevant information, and made more effective use of retrieval cues to access more extensive retrieval structures stored in long-term memory. Verbal protocols suggested that elite players predominantly relied upon recognition processes and used forward, search-based processes to confirm initial perceptions via positive evaluation. Elite players' search was limited to one step in advance of the current action and was more extensive in width than sub-elite players' search. Sub-elite players predominantly relied upon limited forward search and less effective evaluation processes.

Key Words: Verbal Reports, Protocol Analysis, Task Analysis, Recognition, Search

Various methods have been employed to examine the mechanisms underlying perceptual-cognitive expertise using representative tasks. Research in the sports domain has typically focused upon process measures, such as eye-movement recording during task performance (for soccer-specific examples, see Helsen & Pauwels, 1993; Williams et al., 1999), with some exceptions examining EEG data, albeit in a limited range of tasks (e.g., Janelle, Hillman, Apparies, Murray, Meili, Fallon, & Hatfield, 2000). Verbal report techniques have also been used to elicit the nature of cognitions during task performance (e.g., McPherson, 1999a; 199b). However, verbal report research in sport has almost exclusively focused upon data collected *in situ*, rather than using reproducible film-based representations of performance. The focus of this experiment is to elicit the nature of thought processes that are reflective of expertise during representative performance via the use of verbal protocol analysis. The fundamental building blocks of this work are defined via the information-processing framework (see Newell & Simon, 1972; Ericsson & Simon, 1980; 1993). As such, the expertise approach to eliciting verbal reports within this framework is first detailed.

The Human as an Information Processor

The seminal work of Newell and Simon (1972), that defined the human problem solver in information processing terms, made vital contributions to our understanding of human cognition. These authors suggested that information processing was synonymous with symbolic representation and manipulation, where symbols were defined as elements (e.g., lists, attributes, and values) and connected by a set of relations into a symbol structure. Associated symbol structures were proposed to be constructed hierarchically and were likely to be embedded within existing structures to form tangled hierarchies (cf. Anderson, 1983). Memory was assumed to be capable of storing and retaining such symbol structures upon which, elementary information processes operate. Sequences of these elementary processes essentially define the behavior of the system (Newell & Simon, 1972). In sum, three component parts of an information processor were proposed by these authors: elementary information processes, a short-term memory (STM) to temporarily hold the input and output of such processing (also denoted as symbol structures), and a specifying component of the process (an interpreter) to provide integration (e.g., use of goal criteria).

Extending this approach to further examine the use of verbal reports as a valuable source of data, Ericsson and Simon (1980) suggested that a model of data interpretation should be as simple as possible. The model need not incorporate aspects that are theoretically contentious (e.g., elementary processes), though they must be robust so as to be compatible with alternative information processing assumptions (p.223). With this view in mind, Ericsson and Simon (1980) postulated that human cognition may be described as a sequence of states which are transformed by successive information processes. More specifically, the content of each 'information state' held in STM was proposed to represent the output of a previous process and the input to a future one. However, individuals' awareness would be restricted to the inputs and outputs of these processes only, and not of the actual process *per se*. Consistent with the known limitations of STM (cf. Miller, 1956), information entering STM may be replaced with new information, although pointers to operations, and to the symbols upon which these operations are performed, are likely to be temporarily present in STM and verbally accessible. Temporary information stored in STM can therefore, be 'heeded' (i.e., attended to) by an individual. The general model laid out by

Ericsson and Simon (1993) for eliciting verbal protocols suggests that verbalization of such information involves 'a direct encoding of the heeded thought and reflects its [cognitive] structure' (p.222).

In comparison to STM, long-term memory (LTM) requires that a retrieval process be invoked before stored information can be heeded. According to Ericsson and Simon (1993), retrieval is typically achieved through either an associative or recognition process. The recognition process occurs in milliseconds, stores pointers in STM to an associated pattern in LTM, and intermediate processes are unavailable to attention. In contrast, association is typically much slower, often storing intermediate sequences of heeded information in STM.

<u>The Problem Space and Analysis of the Task Environment</u>

Rational or adaptive behavior is typically directed toward a task-related goal(s) and is therefore deemed appropriate or plausible in the context of the problem or situation presented before an individual (Newell & Simon, 1972). As such, the task environment and problem space provide the appropriate means to delineate the problem solving process in more detail. Newell and Simon (1972) conceptualized the problem space as a number of alternative paths from an initial state to an end goal. All plausible alternative paths, in essence, the decision tree, constitute the total problem space. An individual's 'internal' problem space is defined with respect to an individual's initial knowledge state regarding the task environment. Attempts to reach a goal knowledge state and problem resolution are made via the application of various methods or heuristics to the internal problem space. Processes monitoring the applicability, or success of methods applied allow alternative methods to be chosen and the internal problem space reformulated until the task goal is achieved (Newell & Simon, 1972).

Ericsson and Simon (1993) suggest that a formal task analysis should permit the vocabulary and relations to be extracted in order to define both the problem space and operators that act upon it. Within the information-processing framework used for protocol analysis, the inputs for encoding processes are likely to be reflected in one or more units of the transcripts elicited through verbal report procedures. Moreover, the output must belong to an *a priori* explicitly given set of alternatives prior to accepting the inputs for encoding. Consequently, when performing a task analysis as much of the total problem space as possible should be derived independently of the problem spaces defined by each participant. By clearly defining this space through an inductive analysis of the task environment, the possible concepts, a set of problem configurations and goals, and the alternative solutions for solving the problem can be explicitly detailed (also see Newell & Simon, 1972). The task analysis conducted in this study is presented in the Appendix.

Examples from Chess

Very little research has been conducted in the sports domain that has adequately defined the problem space under investigation using formal task analysis methods. However, extensive research has been conducted in the domain of chess, which is somewhat analogous to the process of 'reading the game' in soccer. Much of the cognitive science research in chess has defined the problem space via the use of formal mechanisms, such as computer programs or production systems. The approach used has typically been similar to that defined by Shannon (1950) and can be broken down into three parts: Consider the alternative moves, evaluate the alternatives by some means of analysis, and decide upon the preferred move based upon the result of the evaluation. The second part of this process, the analysis, can be broken down further into a series of steps. First, searching the alternatives to some level of depth. Second, evaluating the positions reached at the end of the search in terms of their success, for instance, in achieving a specified goal. Next, combining evaluations at the end of each search into an effective value via a process called 'minimaxing' (i.e., where the 'best move' is assigned a maximum value for the participant's move and a minimum value for an opponent's move, and 'best' is a function of a player's assessment of their ability to win, lose, or tie each searched alternative). Finally, the analysis ends by choosing the alternative with the highest effective value, or that which is satisficing. That is, the alternative meets or surpasses some pre-determined threshold value, for instance, the decision threshold specified by Alain and Proteau (1980) in a racket sport context (e.g., 70% probability). In this manner, chess can be described as a process of forward search, where each step in forward search can be viewed as a branching process to more branches of alternative hypothetical future moves (Newell & Simon, 1972). By inferring effective values for each move, starting with the most terminal position at the end of a particular path and determining whether this will end in a win, tie, or loss, the most appropriate 'next' best move can be selected. Accordingly, the individual who can perceive each and every branch and determine the consequences of pursing each action is likely to be very successful (for more detail, see Newell & Simon, 1972).

De Groot's (1965) analysis of verbal protocols from Grand Master chess players suggests that highly skilled individuals demonstrate multiple examples of forward search through strategies such as progressive deepening, problem redefinition, and means-ends analysis. Participant evaluations in de Groot's study, however, were often extremely basic and experts did not always estimate the value of several positions simultaneously, before deriving a 'best' value. Moreover, participant protocols often implicated perceptual-recognition processes as a major contributor to skilled performance. The skilled chess players rapidly perceived or noticed the best move and then engaged in further activity in an attempt to reject or accept their initial perceptions, or to discover other new options via additional search. Arguably, perception and memory may be as important, if not more so, than searching future alternatives in skilled performance. Ericsson and Delaney (1999) point out that if chess experts merely functioned via a process of recognition of familiar patterns (i.e., chunks) alone, it would be an arduous task for participants to explore possible alternatives and evaluate the strengths and weaknesses of their early perceptual organization. In support of de Groot's (1965) findings, Charness, Reingold, Pomplun, and Strampe (2001) recently examined the eye movements of intermediate and expert chess players and gave a parsimonious explanation of their findings based upon more efficient encoding in larger chunks (p.15). In addition, they suggested that skilled encoding of this type facilitated rapid recognition and permitted participants to foveate on important areas of the board.

Examples from Sport

The majority of research using verbal reports in a sport context has been conducted by McPherson and colleagues (e.g., McPherson, 1994; 1999a; 199b; McPherson & Thomas, 1989). McPherson and Thomas (1989) originally developed a model of protocol structure for tennis and conceptualized verbalized concepts in production system terms, such as conditions, actions, and goals. Action concepts were later divided into regulatory and do concepts to reflect whether an action was performed, and how it was carried out, respectively

(McPherson, 1994). Using these concepts, and by identifying how verbal protocols were verbally linked together, the content and structure of players' problem representations could be examined. Findings from these studies suggested that experts encoded critical environmental cues, retrieved relevant goal concepts, detailed condition concepts, and forceful action concepts from long-term memory. In addition, McPherson (1999a; 1999b) suggested that expert problem representations included strategies for planning, monitoring (determined by frequency of concept and depth of analysis), and regulating game events in order to select, and where necessary, modify an appropriate response. The majority of this work focused upon the precursory processes proposed to mediate response execution, and consequently, was centered around the 'action' component, as opposed to more perceptual aspects of the task (e.g., 'reading the game'). Moreover, performance was examined under conditions considered to be non-standardized and lies outside of the remit specified by the expertise approach (cf. Ericsson & Smith, 1991). Regardless, McPherson's research is pioneering and is one of the few attempts at utilizing verbal report procedures to examine cognitive processes in sport.

Williams and Davids (1997) have provided one of the few attempts to record concurrent verbal reports in a representative soccer task. Participants' verbal reports were compared to eye-movement data from previous trials in 11 v 11 and 3 v 3 simulations as a method of verifying the area of the display to which participants were attending. The findings suggest that the verbal reports elicited from participants did not interfere with task performance, and provided a good index of selective attention, particularly in 11 v 11 scenarios. However, the data in this study were not analyzed with respect to a task analysis or problem space or did not allow a model of protocol structure to emerge and consequently, provides only limited insight into the mediating processes underlying performance. The available literature on visual search strategies in sport, however, has provided a wealth of information with respect to the perceptual strategies underpinning expert performance (e.g., Helsen & Pauwels, 1993; Williams et al., 1994). Experts have been cited to typically utilize a more efficient visual search strategy, with fewer fixations of longer duration than novices. However, the nature of visual search strategies is task dependent, and often the reverse is true (for a discussion, see Williams et al., 1999). These differences may in part be due to the difference between maximizing and optimizing tasks, where either time requirements or quality of response are emphasized, respectively (for a discussion, see Helsen & Starkes, 1999). Irrespective of the nature of the task, superior domain-specific knowledge and memory skills are typically assumed to underpin expert search behavior.

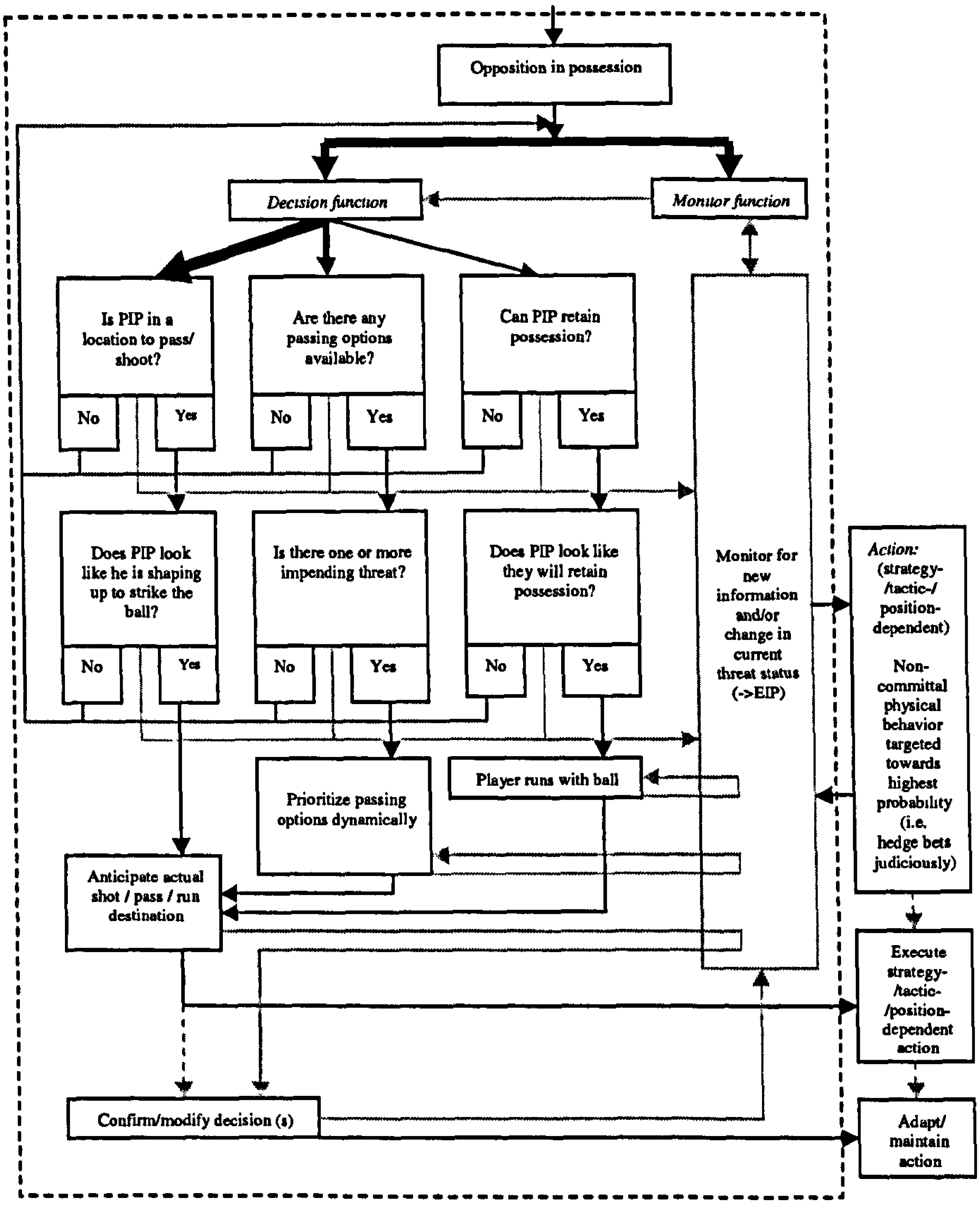
Defining the Task in Soccer

Although analogies have been made with respect to selecting the 'next best move' (see Chapter 2), there are a number of differences, as well as similarities, between 'reading the game' in soccer and playing chess, particularly when one begins to define the problem space. Adapting Shannon's (1950) description of the search process, and considering related evidence from the literature, assuming that there is an opposing player in possession of the ball, the game reading process in soccer can be defined in the following manner. First, consider the alternative options available to the player in possession (e.g., 'what he should do next' – shoot, pass, run/retain possession). Second, evaluate the available options by some means of analysis (e.g., minimaxing, satisficing, recognition, search), where priority in search is automatically given in order of threat (e.g., shoot, pass, run/retain possession, respectively). Third, each option is prioritized in order of likelihood based upon the evaluation process. Steps one to three need to be dynamically monitored and updated until some 'relatively deterministic information' is available to confirm or disconfirm option prioritization. Relatively deterministic information is perceived by (a) recognition of an opponent's action through some means of reference to previous experiences (e.g., proactive anticipation of future event based upon prior knowledge of the action, event, or opponent) and/or (b) observation of the actual action or event (e.g., reactive response to current situation). As a preliminary and general conceptualization, the goals (primarily expressed as questions) underlying these processes and the experimental task and are illustrated in Figure 3.1 as decision and monitoring functions.

While Newell and Simon (1972) point out that search explorations are unlikely to be deep enough to reach terminal end positions (e.g., check mate), the constraints placed on the chess player, even in speeded chess, are far less restrictive, both in terms of the time available to search, and the depth to which search can be employed. The static nature of the game and the finite number of permissible moves and locations to which one can move in chess (e.g., a total of 64 squares on the board) allows search to potentially go on for numerous moves in advance. However, there is no soccer analog for 'check mate in 10 moves!'

The search process in soccer is likely to involve forward search. When one includes the suggested recognition components, the problem becomes one of forward search in real-time where the search process, and the proceeding actions

Figure 3.1. A preliminary conceptualization of the goals directing the processes used in 'reading the game' in soccer.



Note. PIP = Player in possession. (The goals represented inside the dotted line are reflective of the perceptual-cognitive components of the task. The perceptual-motor components of the task reside outside the dotted line, are less well, specified and were not examined within the current experiment)

and anticipations, are confirmed or negated as the play unfolds. The speed of the game, its dynamic nature, and the unspecified future beyond that perceivable within the immediate present, largely precludes or negates any further extensive search or indeed, time for search. Consequently, in soccer, and particularly for the 'on-line' prioritization of best options, the problem space is likely to be limited to immediate forward search with respect to only one, or at most, two steps in advance of the current action. This process is likely to be juxtaposed by the recognition process (or its failure) where anticipation of future events becomes the overriding goal.

Eliciting Verbal Reports

Ericsson and Simon (1980) suggested that via the instruction to think aloud, heeded information in STM can either be verbalized directly (i.e., level one verbalization) or transformed from non-verbal information to verbal code (i.e., level two verbalization). Transformation of nonverbal information to verbal code may require additional processing (see Werner & Kaplan, 1963). However, when participants are instructed to concurrently verbalize using level one or two verbalizations, a direct trace of heeded thoughts and consequently, an indirect trace of the internal steps in cognitive processing can be elicited. Moreover, the additional transformation in level two verbalizations has been shown not to affect the contents of the report, instead the typical effect is to prolong the time taken to perform the task (see Ericsson & Simon, 1980). Where participants are asked to verbalize information that is not normally heeded (i.e., level three verbalizations), verbalization is likely to be an epiphenomenon of the verbal report procedure. Similarly, when participants are asked to summarize the thoughts they had during task performance or can only recall a limited number of thoughts from a previous activity, a subject may generalize across trials from the specific episodes they distinctly remember more than others, and offer generic strategies which may only partially resemble actual processing strategies used during the task (cf. Nisbett & Wilson, 1977). The current framework makes a clear distinction between verbal reports generated from immediately preceding processes and those used to provide general description or assumptions of personal task performance (Ericsson & Simon, 1980; 1993).

The aims of this experiment were to examine mediating mechanisms of expertise via recording performance data, and in particular, analyzing the content of elite and sub-elite soccer players' thoughts using concurrent verbal report procedures during perceptual-cognitive 'game-reading' tasks. The general or total problem space was defined *a priori* by means of task analyses, in line with the framework and assumptions detailed in the expertise approach. The representative task under investigation was designed as a product of Experiment 1 (see Chapter 2), by combining those variables which were most predictive of expertise (anticipation and situational probabilities tasks). An additional task manipulation was included (e.g., free and cued recall conditions) in the current experiment in an attempt to further elicit underlying processes. Elite players were expected to outperform sub-elite players on all performance measures. Elite players were also expected to demonstrate a greater degree of forward search evidenced by more planning and prediction statements regarding future options identified by the task analyses, and demonstrate superior recognition processes evidenced by the immediacy of their predictions regarding salient or effective options, compared to other less salient or effective options. In addition, elite players were expected to demonstrate more effective monitoring and prioritization behavior manifested in a greater number of cognitions related to specific features from the task analyses and more effective evaluations of statements.

Method

Participants

Elite and sub-elite, male soccer players (n=16) were selected as participants. Elite participants played at a semi-professional level and had been trained through the English Football Association Academy system. Three of the elite players had also played at a professional level. Sub-elite participants were amateur club players and had played only at a recreational level. The mean age of elite players was 26.04 (± 6.02 years), whereas the sub-elite players' mean age was 28.67 (± 4.22 years). Both groups commenced participation in soccer at similar ages (M age: elite = 5.75 ± 0.89, sub-elite = 5.63 ± 2.67 years of age). Informed consent was obtained prior to participation in the study.

Procedure

As in Experiment 1, film-based simulations were used to examine perceptual-cognitive skill. The offensive 11 v 11 action simulations were produced from professional and semi-professional matches shot from an elevated perspective behind the goal. Specifically, the sequences from the situational probabilities paradigm in Experiment 1 were re-edited to provide a viewing condition, followed by free and then cued recall conditions for each trial. In total, three practice trials and 18 test trials were presented.

Performance Data: Anticipation and Situational Probabilities Tasks

Viewing. Each action clip was presented on a large video screen. Prior to each clip, participants were oriented to the location of the ball and current play via the use of a pre-cue (e.g., a red box on a white background centered over the area of the screen where the action would be located). From the onset of action, each simulation lasted approximately 10s and was occluded 120 ms prior to the player in possession making either a discrete action (e.g., pass, shot on goal) or retaining possession and running with the ball. At the point of occlusion, the image changed to a black screen.

Free recall. Upon occlusion of the video, participants were presented with a line drawing of the pitch, replicating the same perspective as the final frame of action (27 x 40 cm, approx.). The replica was devoid of context, other than pitch markings, goal posts and the final position of the ball. Participants were instructed to recall the location of key players using 'X' to denote an attacking player (red) and 'O' to denote a defending player (white). However, the emphasis was not for participants to recall as many players as possible. An approach of this type may have changed the purpose for viewing the stimulus and are likely to elicit different cognitive processes than those required under normal performance conditions (see Decety & Grèzes, 1999). Instead, participants were instructed to recall the players to which they were attending at the end of the clip (e.g., perceptual signature) with the goal of completing the following tasks. The first task was to anticipate what the player in possession of the ball actually did next. Participants were given a choice of three response outcomes, shoot, pass, or retain possession (e.g., run with the ball). The second task was to determine which options were potentially threatening to the defence. Based upon their expectations of what should happen next, participants highlighted either, an option to shoot, the key players in a good position to receive or run on to the ball, or the option to retain possession. In addition, participants ranked each highlighted option in order of their perceived attacking importance (e.g., threat to the defence). These tasks were derived from the variables considered most predictive of expertise in Experiment 1. To increase the sensitivity of the probability hierarchy measure, and to add more weight to the points received for correctly ranking more threatening options, a weighted point system was devised as follows. A total of five points was awarded for correctly matching the assigned importance of the first ranked player, four points for the second ranked player, three for the third rank, and so on. In addition, one point was deducted for each rank away from the criterion previously determined by a panel of expert soccer coaches. The number of points for each trial was then divided by the total points available for that trial if answered correctly, and expressed as a value from 0 to 1. For instance, where the criterion rank for player A was 'first', and B was 'second', and where a participant marked A and B, 'second' and 'first', respectively, the total number of points received for that trial would be ((4 + 3) / (5 + 4)) 0.78. The maximum number of points across all test trials was therefore 18.

Cued recall. In the cued condition, the final frame of action was projected back on to the screen as a freeze frame and participants were given a photographic replica of the last frame (27 x 40cm approx.). Participants were requested to complete the same tasks as in the free recall condition, albeit without having to first recall player positions.

In the free recall condition, participants' responses were coded by two different experimenters (inter observer agreement = 92.4%) and where possible, verified by the verbal report data and video recording of the individuals' response. Key players correctly highlighted, non-key players selected, and the rankings of each option were measured against a panel of expert coaches (inter observer agreement = 90.4%).

Process Data: Concurrent Verbal Reports

Participants were requested to give a concurrent verbal report (i.e., think-aloud) while viewing the clip and performing the tasks in each of the conditions. Prior to commencing both practice and test trials, participants were instructed on how to think aloud. The instructions for verbal reports comprised of Ericsson and Kirk's (2001) adaptation of Ericsson and Simon's (1984, 1993, pp. 375-379) original instructions with an extended set of warm-up tasks. The training session included both instruction and practice on giving verbal reports in solving generic problems and more specifically, during video-based pre-practice and task completion. On average, the verbal report training session lasted approximately 1.25 to 1.5 hours. Verbal reports were recorded using a Panasonic professional video and external microphone.

On completion of the experiment, participants' verbal reports were first transcribed. To provide a more complete version of the transcripts, behavioral video analysis was used to identify ambiguous terms, for instance, 'this guy' or 'the red player over here'. Typically, participants traced the photograph or line drawing with their finger allowing unambiguous identification. Where identification was ambiguous, an 'x' was used to denote an unidentified player. The majority of these incidences occurred during the early stages of the dynamic viewing condition and so were less crucial in determining player positions/options within the free/cued recall tasks. Transcriptions were coded using a method of protocol analysis described by Ericsson and Simon (1993). Verbal reports were divided up to into segments using pauses, phrases, and other syntactical markers and an adapted notation system based upon predicate calculus was used to encode the data (e.g., relation [argument 1, argument 2]). Relations gave information regarding how the arguments were related. Various task-specific relations were used to code the data such as pass, shoot, retain, move, defend, attack, and possession. Arguments specified the nature of the elements (including options/areas of the pitch) or in some instances provided more description about the relation. As an example, if a participant verbalized a player (R5) running into to area C, this was notated as MOVE (R5, 'C', 'run'). The coding system was established primarily as a result of the inductive task analyses process.

The data were encoded on two separate occasions by the primary experimenter, and a random sample of the data was encoded on a third occasion by a third party. Agreement ranged from 87 to 95.5%. Consistent with the task and preliminary analyses, four different types of statements were encoded. These included cognitions, predictions, planning, and evaluations (cf. Ericsson, 1975, cited in Ericsson & Simon, 1993). Cognitions were all statements representing current action (C) or recalled statements about current events (R). Predictions were subdivided into anticipations of future events (A), and comments about potential next moves or options (O). Planning statements were those that detailed information about searching possible alternatives beyond the next move (including both offensive and defensive moves/options). Evaluations (E) were statements that made some form of assessment, typically in the form of positive (e.g., win, best, better, good) or negative appraisal (e.g., bad, worse, won't work) of a cognition, prediction or planning statement. Throughout the coding, items or statements that made reference to player positions or areas of the pitch identified in the task analysis were coded to indicate the options/areas to which they referred.

Data Analyses

Performance data. Separate two-way ANOVAs were used to analyze the number of decisions accurately anticipated (i.e., action only, action and direction only, action, direction, and player), the percentage of key players highlighted, the number of non-key players highlighted, and the probability hierarchy (e.g., option ranking). Skill level was the between-participant factor and recall condition (free, cued) was the within-participant factor.

Process data. In accordance with Ericsson and colleagues (Ericsson & Smith, 1991; Ericsson & Simon, 1993), to determine which trial showed the largest skill-based difference across all performance measures, and consequently, should be the subject of protocol analysis, an item analysis was conducted using a combined z score for each trial across all of the performance data. Trial 16 was identified as the most differentiating trial.

For each type of statement (e.g., cognition, prediction, planning, and evaluation), the total number of statements, the variety of relations, the total number of player/area options, and the variety of player/area options verbalized were analyzed using separate two-way ANOVAs. Skill level was the between-participant factor and condition was the within-participant factor. To determine whether relevant information was gleaned by participants from viewing the clip, viewing condition was included as an additional level of the within-participant factor, condition, for cognition statements only. Participants verbalized too few other statement types in the viewing condition to be considered for analysis (see Results section). Scheffe post hoc tests were used to follow up significant effects, where appropriate. In addition, the total number of positive and negative evaluations was analyzed using separate two-way ANOVAs. The planning data was not subjected to statistical analyses as too few protocols included such statements.

Data were checked for normality and sphericity with no violations observed. Effect size (Cohen's d) was calculated for each between group comparison of performance and process measures using pooled standard deviation (see Thomas, Salazar, & Landers, 1991). An estimated magnitude of effect, expressed as a percentage, was calculated for within group comparisons (see Thomas & Nelson, 1996).

Results

Performance Data

Anticipation. The analysis for anticipation of the action only (i.e., shoot, pass, retain) revealed main effects for skill, F (1, 14) = 14.71, $p<.01$, and condition, F (1, 14) = 7.04, $p<.05$. Elite players more accurately anticipated the majority of actions performed by the player in possession in both the free and cued conditions (d = 1.42 and 1.07 respectively). The results are presented in Table 3.2. Similarly, players anticipation of the direction of the pass revealed main effects for skill, F (1, 14) = 11.31, $p<.01$, and condition, F (1, 14) = 24.83, $p<.01$. Whilst both groups did not perform to the same standard when compared to the analysis of action only, the elite players still outperformed sub-elite players on both free and cued conditions (d = 1.57 and 1.65 respectively). The analysis of anticipated pass destination revealed similar results. Main effects were observed for skill, F (1, 14) = 57.38, $p<.01$, and condition, F (1, 14) = 21.48, $p<.01$. Elite players anticipated more pass destinations than sub-elite players in both free (d = 2.27) and cued conditions (d = 2.12). In all three dependent measures, both groups performed significantly better in the cued compared to the free recall condition. The estimated magnitude of effect suggest that elite players improved their performance by 9, 22, and 33% for each of the three dependent variables, respectively, whereas, sub-elite players increased performance by 28, 60, and 125%, respectively.

Table 3.2. Mean (SD) anticipation scores for elite and sub-elite players

	Action only		Action & direction		Action, direction, & player destination	
Group	Free	Cued	Free	Cued	Free	Cued
Elite	15.13 (2.42)	16.50 (1.41)	8.50 (2.77)	10.38 (2.19)	6.35 (1.76)	8.50 (1.19)
Sub-elite	10.25 (4.23)	13.14 (4.22)	3.75 (3.24)	6.00 (3.02)	2.00 (2.07)	4.5 (2.39)

Situational probabilities.

Percentage of key players. Main effects were observed for skill, F (1, 14) = 26.22, p<.01, and condition, F (1, 14) = 35.39, p<.01. When compared to sub-elite counterparts, elite participants highlighted a greater percentage of key players in both free and cued recall conditions (d = 2.11 and 2.17 respectively) (see Figure 3.3). Moreover, the estimated magnitude of effect revealed a 30% increase in performance by both groups when moving to the cued condition

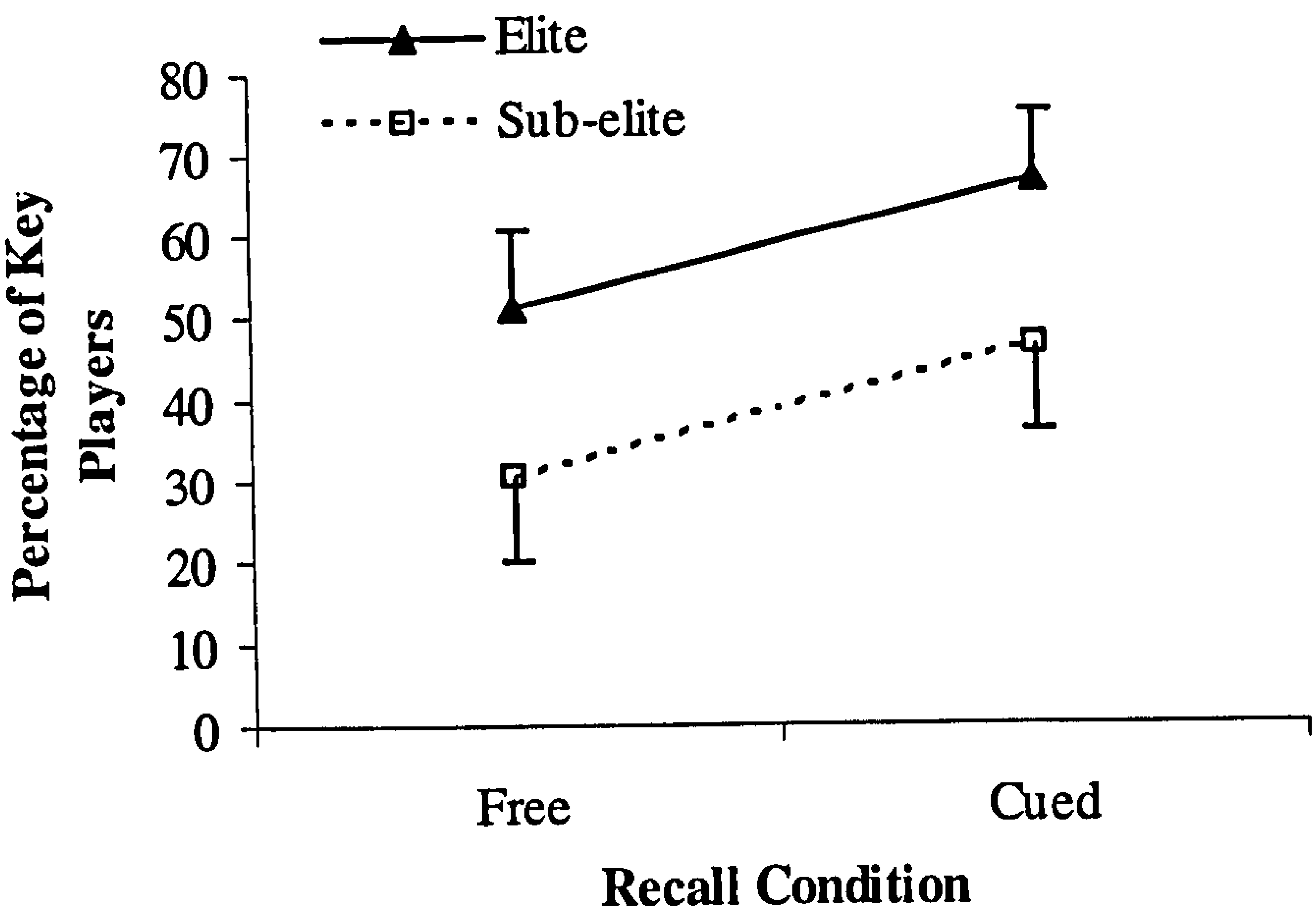


Figure 3.3. Mean (± SD) percentage of key players highlighted by elite and sub-elite players

Number of non-key players. There was no significant main effect or interaction for the selection of non-key players. The mean number of non-key players highlighted by each player across all trials was 14.81 (± 6.70). However, effect size analysis suggested that the mean difference between skill groups was relatively meaningful (d = 0.50). Elite players highlighted four fewer non-key players than sub-elite players in both conditions, F (1, 14) = 1.31, p = 0.27.

Probability hierarchy. Significant differences were found between skill groups in the ability to assign an appropriate rank to highlighted options. Elite players demonstrated superior performance in ranking key players when compared to sub-elite participants under both free and cued recall conditions, F (1, 14) = 31.34, p<.01 (d = 2.32 and 2.40 respectively). Both groups demonstrated a 32% improvement in performance when moving from the free to the cued condition, F (1, 14) = 45.53, p<.01 (see Figure 3.4).

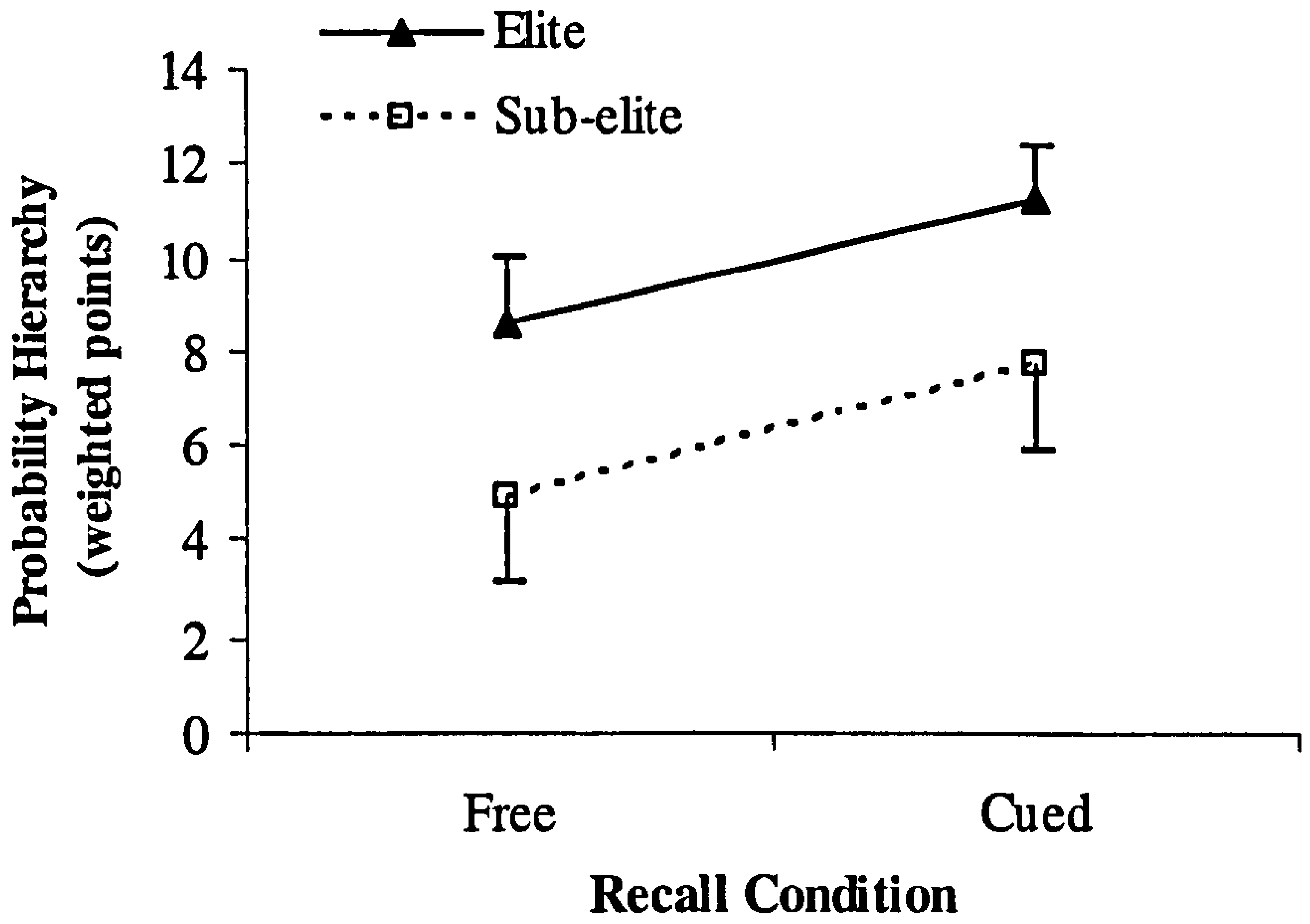


Figure 3.4. Mean (SD) probability hierarchy by elite and sub-elite players showing the correctness of response in assigning an appropriate probability value to the most important player(s)

Trial 16

To provide context to the subsequent protocol analysis performed on the most discriminating trial, a summary description of the results from trial 16 is provided. In the free recall condition, six out of eight elite participants accurately anticipated the actual passing option taken by the player in possession of the ball. In the cued condition, all elite participants anticipated the outcome of the pass correctly. In comparison, only three sub-elite players anticipated the actual shot destination during free recall, and four correctly anticipated the outcome of the pass in the cued condition. For the situational probabilities task, under free recall conditions, six of the elite players agreed with the criterion determined by the expert judges for the best option, and two agreed with the criterion ranked second best. The remaining elite participants were, on average, one rank away from the criterion. In the cued recall condition, all elite players agreed with the expert criterion for the best option, and five agreed with the second ranked option. There was agreement between only two sub-elite players and the criterion best option under free recall conditions. None of the sub-elite players agreed with the second ranked option under free recall conditions. In the cued condition, five sub-elite players agreed with the criterion for best option and only one agreed with the second best option. On the whole, the elite group was approximately 100% more accurate in their response than the sub-elite group on this trial across both anticipation and situational probability tasks, and under both free and cued recall conditions.

Process Data

No differences were observed between skill groups in the number of words articulated during the entire concurrent report for trial 16. The average number of words verbalized by elite and sub-elite players was 283.3 (± 70.4).

Cognitions.

Total number of cognitions. No skill-based differences were observed in the total number of cognitions across viewing, free, and cued recall conditions. However, there was a significant effect for condition, F (2, 28) = 17.06, $p<.01$. Both groups verbalized 35% fewer cognitions during viewing ($M = 4.9 \pm 1.7$) than in the free recall condition ($M = 3.2 \pm 2.0$) ($p<.01$). Fewer cognitions (e.g., 50%) were also verbalized in the cued ($M = 1.6 \pm 1.4$) compared to free recall conditions ($p<.05$).

Variety of relations. A main effect for condition was observed for the variety of relations verbalized during cognition statements, F (2, 28) = 30.31, $p<.01$. All participants reduced the number of different relations verbalized during cognitions by 72% when moving from viewing ($\underline{M}$ = 3.9 ± 0.9), to both free and cued recall conditions ($\underline{M}$ = 1.3 ± 1.0) ($\underline{p}$<.05).

Options. There were no significant differences between skill groups or across conditions regarding the total number or variety of options verbalized during cognition statements. The data are presented in Table 3.5.

Table 3.5. Mean (SD) number and variety of options verbalized by elite and sub-elite participants for each type of statement

	Elite		Sub elite	
Option Statement	Free	Cued	Free	Cued
Cognitions				
Total	2.6 (2.5)	2.8 (3.0)	2.6 (2.1)	2.1 (2.7)
Variety	2.4 (2.4)	2.3 (2.1)	2.3 (1.7)	2.1 (2.7)
Predictions				
Total	3.8 (1.0)	3.3 (0.9)	2.9 (1.6)	2.9 (1.0)
Variety	3.0 (0.8)	2.9 (0.8)	1.9 (1.0)	2.0 (0.5)
Evaluations				
Total	3.0 (1.5)	3.0 (0.8)	1.5 (1.3)	1.6 (1.2)
Variety	2.5 (1.1)	2.8 (0.7)	1.3 (1.3)	1.6 (1.2)

Table 3.6. Summary table of the sub-elite participants' predictions for trial 16.

	Viewing			Free			Cued		
Participant	Type	Relation	Option/argument	Type	Relation	Option/argument	Type	Relation	Option/argument
1				A	PASS	R5-C	A	PASS	R5-C
				A-COPY	PASS	R5-C	A-COPY	PASS	R5-C
				O	RETAIN	R2	O	RETAIN	R2
				O-COPY	RETAIN	R2	O-COPY	RETAIN	R2
2				A	RETAIN	R2	A	RETAIN	R2
				O	PASS	R3-F	O	PASS	R3-F
				A	RETAIN	R2	A-COPY	RETAIN	R2
							O	PASS	R5-C
							A-COPY	RETAIN	R2
3				A	PASS	R5-C	A	MOVE	R5-C
							A	PASS	C
							A	PASS	R5-C
4				A	MOVE	R5-C	A	PASS	R5-C
				A	PASS	R5-C			
5				A	PASS	R1-B	O	PASS	R1-B
				O	PASS	R5-C	O	PASS	R5-C
				A-COPY	PASS	R1-B	A	PASS	R1-B
6				O	PASS	R5-G	O	PASS	G
				A	RETAIN	R2	O	RETAIN	R2

					A	RETAIN	R2
7		A	MOVE	x	A	PASS	R1-B
		A	RETAIN	R2	O	PASS	R1-A
		A-COPY	RETAIN	R2			
		A	MOVE	R5-C + phantom			
		O	PASS	C			
		A-COPY	MOVE	R5-C + phantom			
8		O	PASS	'don't know'	A	PASS	C
		O-COPY	PASS	'don't know'	O	PASS	D
		A	PASS	G	A	PASS	R5-C
		A-COPY	PASS	G	A-COPY	PASS	R5-C

Note. The best and second ranked options chosen by the expert judges were R5-C and R1-B, respectively. A = anticipation of future event, O = prediction about future option, A/O-COPY = semantic/literal copy of anticipation/option statements. Relation refers to how options or arguments were related. The contents of the option/argument column refer to the options/areas of the pitch defined in the task analyses (see appendix).

Table 3.7. Summary table of the elite participants' predictions for trial 16.

	Viewing			Free			Cued		
Participant	Type	Relation	Option/argument	Type	Relation	Option/argument	Type	Relation	Option/argument
9				A	PASS	R5-C	A	PASS	R5-C
				O	PASS	R1-A	O	PASS	R1-B
				O	PASS	R3-A			
10				A	BSHAPE	W4, W5 - channel	A	PASS	R5-C
				A	MOVE	R5-C, run	O	RETAIN	R2
				O	PASS	G	O	RETAIN + PASS	R2 + ?
							O	PASS	G
11				O	PASS	R1-B	A	PASS	R5-C
				O	PASS	R5-C	A	MOVE, across	W4
				O	RETAIN	G	O	PASS	R1-B
				A	RETAIN	G			
12	A	ATTACK	[RED]	A	MOVE	R5-C, run	A	PASS	R5-C
				A	PASS	R5-C	O	RETAIN	R2
				O	PASS	R1-B	O	PASS	R1-B
				O	RETAIN	R2-C	O	PASS	R11-E
				O	PASS	R11-E			
13				A	PASS	R5-C	A	PASS	R5-C
				A	MOVE	R5-C, run	O	RETAIN	R2
				A-COPY	PASS	R5-C	O-COPY	RETAIN	R2

				O	PASS	D/È	A-COPY	RETAIN	R5-C
				O	RETAIN	R2			
14	O	PASS		A	PASS	R5-C	A	PASS	R5-C
				O	RETAIN	R2	O	PASS	R1-B
15	A	PASS	forward	A	PASS	R5-C	A	MOVE	R5-C, run
				O	RETAIN	R2	A	BSHAPE	R2-C
				A-COPY	RETAIN	R5-C	A	PASS	C
16				O	PASS	R1-B	O	MOVE	R5-C
				O	PASS	C/J	A	PASS	R5-C
				O-COPY	PASS	R1-B	O	PASS	R1-B
				A	PASS	x	O	RETAIN	R2
				O	PASS	R5-C			

Note. The best and second ranked options chosen by the expert judges were R5-C and R1-B, respectively. A = anticipation of future event, O = prediction about future option, A/O-COPY = semantic/literal copy of anticipation/option statements. Relation refers to how options or arguments were related. The contents of the option/argument column refer to the options/areas of the pitch defined in the task analyses (see appendix).

Predictions. Elite and sub-elite players verbalized very few predictions during the viewing phase of the experiment. Specifically, the elite participants verbalized a total of three predictions, and none of the sub-elite participants made any predictions while viewing. Consequently, the viewing condition was excluded from the statistical analyses. When verbalizing predictions, some participants tended to re-state (i.e., produce a literal/semantic copy of) previously verbalized predictions (for a summary of predictions, see Table 3.6 and 3.7). These statements were removed prior to analysis to avoid bias from duplication. This procedure did not significantly affect the analysis.

Number of predictions. No significant effect was found for condition, or for the Skill x Condition interaction. The skill main effect only approached significance, F (1, 14) = 3.94, p=.067. Analysis of effect size between skill groups revealed medium and small effects for the free and cued recall conditions, respectively (d = 0.51, 0.05). On average, elite players made more predictions (M = 3.3 ± 1.0) than sub-elite players (M = 2.5 ± 0.9).

Variety of relations. Participants did not statistically differ in the variety of relations verbalized during prediction under free or cued recall. All participants verbalized 1.9 (± 0.8) different relations in each condition.

Options. A skill main effect was observed for the variety of options verbalized during prediction, F (1, 14) = 9.43, p<.01. Elite participants made predictions about a more varied range of options than sub-elite participants in both free (d = .42) and cued recall conditions (d = 0.57) (see Table 3.5). No differences were found between groups or across conditions in the total number of options verbalized (M = 3.2 ± 1.1).

Evaluations. Due to the small number of sub-elite participants ($\underline{n}$ = 2) engaging in any form of evaluation during viewing compared to elite participants ($\underline{n}$ = 6), the viewing condition was excluded from the analysis of evaluations.

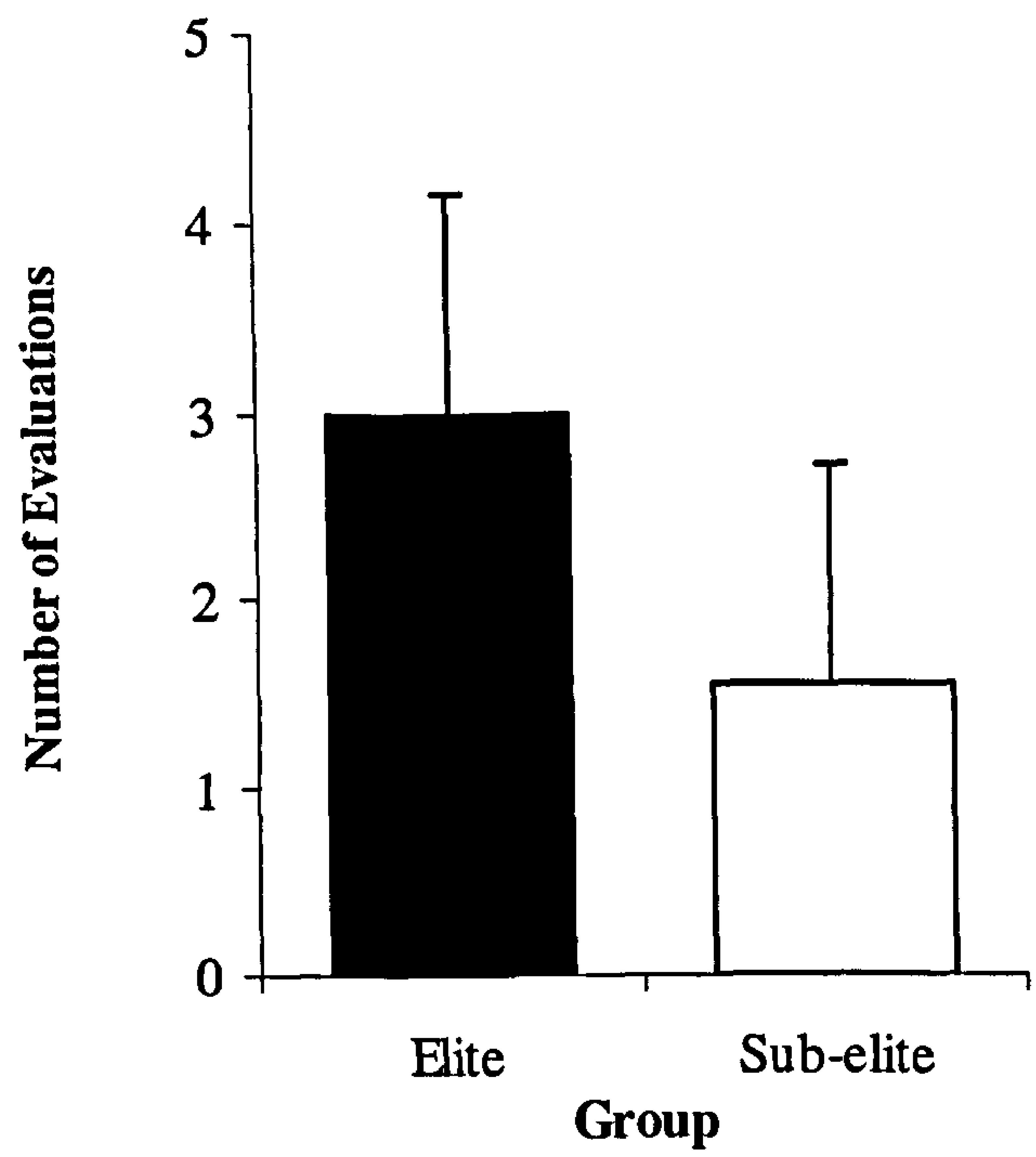


Figure 3.8. Mean (SD) number of evaluations verbalized by elite and sub-elite participants combined across free and cued recall conditions.

Number of evaluations. A significant main effect was found for skill, $\underline{F}$ (1, 14) = 8.14, $\underline{p}$<.01. Subsequent analysis suggested that there was a medium effect size for the difference between elite and sub-elite participants in both free and cued recall conditions ($\underline{d}$ = 0.42 and 0.47 respectively). Figure 3.8 shows that, on average, elite players verbalized one more evaluation per condition than the sub-elite players.

Variety of relations. No differences were observed between elite and sub-elite players, or across recall conditions, in the variety of relations verbalized during evaluation statements. The skill main effect approached significance, however, the effects were only small to medium, F (1, 14) = 7.12, p = .076 (d = 0.13, 0.35). On average, elite participants verbalized 2.0 (± 1.0) different relations compared to 1.3 (± 1.0) verbalized by the sub-elite group.

Options. Skill main effects were observed both for the total number of options, F = (1, 14) = 7.60, p<.01, and the variety of options verbalized during evaluation, F (1, 14) = 7.12, p<.01. Elite participants evaluated twice as many options in total compared to the sub-elite participants across both free and cued recall conditions (d = 0.41 and 0.43 respectively) and similarly, evaluated a broader range of options than their sub-elite counterparts in both conditions (d = 0.36 and 0.35 respectively) (see Table 3.5).

Positive and negative evaluations. A skill main effect was revealed for the analysis of positive evaluations, F (1, 14) = 19.802, p<.01. Elite participants verbalized 2.1 (± 1.0) positive evaluations compared to 0.7 (± 0.7) verbalized by sub-elite participants across both free (d = 0.63) and cued (d = 0.77) recall conditions. In comparison, a significant main effect or interaction was not found for the analysis of negative evaluations. The mean number of negative evaluations across both conditions and skill groups was 0.7 (± 0.8).

Discussion

The aim of this experiment was to examine the mediating mechanisms of perceptual-cognitive expertise in a soccer 'game reading' task. Elite participants were expected to perform significantly better on all tasks and in both free and cued recall conditions than sub-elite players due to superior encoding and memory skills. It was anticipated that elite players would demonstrate superior recognition and search processes in order to quickly identify and prioritize the likely options available to the player in possession and anticipate the next best move. The alternative available options were detailed in the task analysis (see Appendix).

Performance data

The pattern of performance data was similar across three of the four performance variables (i.e., anticipation, key players highlighted, probability hierarchy). Elite players significantly outperformed sub-elite players in both conditions, although both groups increased their performance to a similar extent in the cued recall condition compared to the free condition. While a significant effect was not observed for the fourth performance variable, the effect size suggested that elite players may have been more selective in their omission of non-key players ($d = 0.51$). The similar results to those obtained in Experiment 1 suggests that the task was both representative and reliable, and construct validity was retained.

Elite players' superior performance in the free recall condition on each of the aforementioned variables suggests that these players possess knowledge and/or memory skills which allow them to 'pick up' and encode a greater degree of task-relevant information during viewing (cf. Abernethy & Russell, 1987; Williams & Burwitz, 1993; Williams & Davids, 1998), and could rely upon encoded information to make relatively accurate predictions regarding future options in the absence of any contextual information. In comparison, sub-elite players were unable to extract similar information while viewing and were approximately 30% less accurate under free recall conditions across all variables. In the cued condition, both participants supplemented their initial performance to a relatively similar extent. However, while the skill-based difference remained comparable across conditions, the higher scores achieved by the elite group suggest that this supplementation was available from a richer source. The elite data is consistent with using the contextual stimulus as a retrieval cue, or pointer to a more detailed structure of task-relevant information stored in long-term memory (cf. Chase & Ericsson, 1982; Ericsson & Delaney, 1999). In contrast, sub-elite participants are likely to have extracted their responses mainly from the contextual information available within the photograph, or from less well-defined and more superficial memory structures.

An interesting facet of performance data observed in both groups was the decline in prediction skills as participants 'mentally' anticipated further into the future. Where participants attempted to anticipate beyond the immediate situation (e.g., anticipation of action only) to future events (e.g., anticipation of pass destination/pass recipient), a decrement in accuracy was found across all trials and both conditions (see Table 3.2). The actual and estimated magnitude of effect calculations indicated that this decrement was far greater for sub-elite players. The prediction of action, in anticipation terms, may solely be a product of perceptual recognition-based processing that is restricted to within the current move (i.e., action only, pick up of postural cues). In contrast, prediction of pass destination/recipient may be more of a combined function of pattern recognition and search-based processing (cf., de Groot, 1978; Newell & Simon, 1972). The necessity to encode the recipient of the ball may, therefore, not be absolute and may largely be determined by the relative ease with which this information can be perceived. Rather, as the situational probabilities data suggest, anticipation of pass recipient may occur in more relative terms where one merely needs to be aware of an opponents potential impact upon the game should they receive the ball (e.g., prioritization of options). The analysis in Experiment 1, examining anticipation in macro- and micro-game simulations supports the view that determining the destination of the pass (e.g., 11 v 11 situations) is a more difficult task and more discriminating of expertise than determining the outcome of action information only (e.g., information available from postural cues in 1 v 1 situations).

The performance data from trial 16 highlighted that subtle differences may often differentiate elite from sub-elite players. Even the most differentiating trial did not reveal perfect and completely imperfect performance from elite and sub-elite players, respectively. Instead, the differences appear to be a matter of degree. According to those authors who advocate the expertise approach, these subtle differences are acquired in the form of superior domain-specific knowledge and memory skills over years of training (e.g., Simon & Chase, 1972; Ericsson et al., 1993; Ericsson & Kintsch, 1995). Research in the domain of soccer clearly supports this argument (see Helsen, Starkes, & Hodges, 1998).

Process measures

Cognitions. The significant reduction in the number of cognition statements and the variety of relations, verbalized during viewing, and both free and cued recall conditions suggests that the mode of cognitive processing changed in line with the task requirements (i.e., from attending to information to predicting the outcome). Rather than being an epiphenomenon of the task (cf., Nisbett & Wilson, 1977), it is arguable that the main reason for this change in statement type was that, until the end of the clip, an incident had not occurred which required participants to 'read' an impending attack for the purposes of predicting best options or anticipating future actions. In addition, under game-like time pressure (e.g., when viewing), it may be difficult to verbalize each and every thought, particularly level two verbalizations, at the rate determined by the pace of the game (cf., Ericsson & Simon, 1980; 1993).

Contrary to expectations, there were no skill-based differences in the number of cognition statements, variety of relations, or in the number and variety of options verbalized during any of the conditions. These data provided no preliminary support for more substantive monitoring during the game (e.g., multiple verbalizations of an attended stimulus, see McPherson, 1999) to allow alternative methods to be selected an applied (see also, Newell & Simon, 1972). However, the conceptualization of monitoring in soccer may be somewhat different to that used by McPherson (1999) in tennis where players attend to only one individual. Instead, monitoring in soccer, may not only be reflected in the depth of analysis about changes in the general state of play over time, but also in the width of analysis, for example, in a greater number of evaluations of verbalized cognitions (and predictions), to determine whether re-prioritization is required.

Predictions. While no significant effect was found for the Skill x Condition interaction, the skill effect approached significance ($p = .067$). In addition, there was a medium effect size under free recall, suggesting that the difference between elite and sub-elite players was meaningful. The data provide tentative support for elite participants' possessing superior skill in encoding and retaining more information in STM pertaining to predictions about potential options during free recall. Although the difference related to only one prediction approximately, the appropriate evaluation of this information, and the additional options considered ($p < .01$), may have been sufficient to formulate an effective strategy. Memory skills involving the use of prediction and evaluation have been proposed to be reflective of expertise in a range of contexts (e.g., Ericsson & Delaney, 1999; McPherson, 1999a, 199b, McPherson & French, 1999).

The higher number of predictions regarding a greater variety of options in both conditions suggests that elite players were drawing from a more relevant and extensive store of information than sub-elite players. This data supports previous assumptions regarding the extensive knowledge base underlying elite soccer performance (cf. Helsen & Starkes, 1999; Williams et al., 1999). Moreover, the order of prediction statements offers considerable evidence for the use of recognition processes to access this knowledge base (see Figure 3.6 & 3.7). The verbal protocols indicated that, in the free recall condition, six of the eight elite participants verbalized predictions about the criterion best option (i.e., R5-C, see Appendix) immediately upon presentation of the blank response sheet, or first verbalized predictions regarding the defenders covering the criterion player before accurately anticipating the best option (e.g., participant #10, see Figure 3.7). The two elite participants that did not immediately verbalize the criterion either, considered both second and best options successively within the first two predictions but evaluated the latter incorrectly (i.e., # 11), or discovered the option only after searching the second ranked option, amongst other areas of the field, and committing to a weaker alternative (e.g., # 16). The immediate verbalization of the second ranked criterion option by the latter two players suggests that similar recognition processes were used to identify this option in the free recall condition. Only three of the eight sub-elite participants recognized the criterion best option immediately in the free recall condition. The remaining sub-elite players first searched other options, and only mentioned it after considerable deliberation of either the second ranked (e.g., # 5), or an alternative option (e.g., # 7).

In the cued condition, similar results were observed. All of the elite participants immediately recognized the criterion best option. In comparison, two additional sub-elite players discovered this option in time via a process of search, and one removed the option from his prediction statements. This data support de Groot's (1965) and Charness et al.'s (2001) findings and suggest that recognition processes that rely mainly upon perception and memory may be more vital to understanding expertise differences than more search-oriented processes in this context.

Planning. Across more than 600 protocol statements that were coded, a total of two planning statements were verbalized by all sub-elite players, and six by elite players. None of the participants verbalized more than one planning statement and all of them where articulated in the cued condition. Consistent with the description of the task adapted from Shannon (1950), the soccer players did not plan ahead more than one step in advance of the current move, presumably due to the task constraints imposed. Although this does not mean that participants do not engage in overt search processing beyond the superficial depth of the next move, it is likely that any search behavior is restricted to immediate forward search, where the width of relevant options is variable and dependent upon the associated task constraints. Eye movement data from 11 v 11 studies support these findings. Elite players were shown to scan back and forth from the player in possession to peripheral areas of the display in order to search for time constraints and opportunities available within the immediate future (Williams & Davids, 1998). Inclusion of all planning statements in the cued condition only, may suggest that planning activity is heavily dependent upon the availability of contextual information (cf. Vincente & Wang, 1998). However, due to the insufficient number of planning statements verbalized in this experiment, future research is needed to clarify this issue.

Evaluations. The evaluation data are consistent with the prediction data. On average, elite players demonstrated one more evaluation regarding twice as many, and a greater variety of options highlighted in the task analysis, than sub-elite players. These data provide evidence that elite participants' width of search is greater than their sub-elite counterparts and that elite players engage in more extensive monitoring and evaluation of a broader range of options (cf. McPherson, 1999a; 1999b, Ericsson & Simon, 1980; 1993). Moreover, search was restricted to depth evaluations based upon only one step into the future (i.e., possible next moves) without evaluation beyond the next step. However, all of the evaluations observed were overly simple in nature compared to those expressed in computational models of chess (see Newell & Simon, 1972). Evaluations were restricted to statements such as 'that's better', and 'that's a good option'. This is consistent with de Groot's (1965) analysis of human chess behavior suggesting that, in reality, a comparable minimaxing-type process during evaluation in soccer 'game reading' is implemented using only very elementary, albeit effective comparisons.

The analysis of positive and negative evaluations suggests that search is used for different purposes. Where elite players spend more of their time focusing upon positive evaluations (e.g., WIN outcomes, see Appendix), sub-elite players' assessment is spread equally across both positive and negative evaluations. The implication is that elite players generally use search as a confirmatory processes for recognized options, whereas sub-elite players use the search process to work out the more effective option before deciding upon a course of action. The performance data suggest that the former is a more effective strategy.

In summary, the performance data indicate that the elite players possess greater skill in ‘picking up’ and encoding a greater degree of task-relevant information during viewing, and in turn are able to use these retrieval cues as pointers to more extensive retrieval structures stored in long-term memory. The verbal report data suggest that elite participants rely mainly upon recognition-type processes to highlight those predictions likely to be considered best options, and then confirm the initial perceptions via predominantly positive evaluation (i.e., search-based processing). The use of both recognition and search-based processing in this manner supports prior analyses of Grand Master chess players' verbal protocols (see de Groot, 1978; Newell & Simon, 1972). The elite players' search behavior, necessary to allow evaluations to take place (cf. Ericsson & Delaney, 1999), however, appears to be limited to immediate forward search considering only one step in advance, albeit, is more extensive in width than sub-elite participants' search. On average, sub-elite players' performance was inferior to elite players and generally more dependent upon limited forward search and less effective evaluation.

Chapter 4

The Road to Excellence in Soccer: A Quasi-Longitudinal Approach to Deliberate Practice

Abstract

This study examined the relative contribution of sport-specific and non sport-specific activities to the development of elite performance using a quasi-longitudinal design. Elite and sub-elite soccer players (n = 203) between 9 and 18 years of age completed a practice history questionnaire. Skill-based differences in hours per week and accumulated hours spent in soccer team practice were observed in all age cohorts from nine years of age ($p<.001$). Observed differences in perceptual-cognitive skill can, in part, be attributed to spending significantly more time in team practice and, specifically tactical and strategic decision making activities. No skill effects were found for time spent in soccer-related playful activities directly opposing Cote et al.'s (2001) endorsement of an early investment in deliberate play. While engaging in playful activities, sporting diversity and later specialization may be functional for skill development, skill groups were not differentiated on any of these issues. The suggestion that deliberate play is an important factor in expertise development was not supported. The notion of higher levels of motivation being a pre-requisite for elite performance was supported. The quasi-longitudinal design used to collect data appears to provide a robust estimate of time spent in each activity and a useful methodology for future research.

Key Words: Expertise, Skill Acquisition, Skill Development, Motivation, Research Design.

Many authors adhere to the notion that talented or gifted individuals are more likely to achieve exceptional levels of performance than those who merely start early or work hard. However, universal definitions of talent or giftedness have not prevailed. Winner (1996) defined individuals as those who show precocity toward mastery and early learning, learn in qualitatively different ways, and engage in novel problem solving methods. Such individuals typically show greater 'quantity, speed and complexity of cognition' and transfer common strategies to new contexts more effectively (Robinson & Clinkenbeard, 1998). Not only do these individuals demonstrate giftedness in their approach to learning and problem solving but they are also characterized by a 'rage to master'. Those with such precocity for learning classically possess high levels of intrinsic motivation and an intense, and often obsessive interest within their domain of expertise.

In an attempt to differentiate between giftedness and talent, Gagné (1985, 1991) suggested that the former was related to above average levels of aptitude or competence such as intellectual or creative ability, whereas the latter was related to higher than average domain-specific performance. While sport, games, and performance have been considered as talent domains, as opposed to domains of creativity (Simonton, 2000) it is arguable that elite performers across a breadth of fields require skill, talent, creativity, dedication, motivation and persistence, not to mention quality instruction and vast amounts of practice to succeed, albeit in varying degrees. Few would deny that the pathways to attaining skilful and exceptional levels of performance are composite in nature (see Helsen & Starkes, 1999; Ward & Williams, in press). For instance, Renzulli (1986) suggested that those individuals whose performance is attributed to giftedness is not merely a reflection of cognitive or intellectual characteristics but is likely to be a consequence of the interaction between intellectual ability, creativity, and task commitment.

From a skill acquisition perspective, our intention is not to raise the debate of the potential interaction or co-variation between *g* and *e*, that is, the relative importance of nature and nurture (see Sternberg, 1998). Rather, our aim is to elucidate those acquirable and/or pre-dispositional factors that can guide an individual towards skilled levels of performance, and ultimately toward the attainment of expertise. Important questions concern the processes by which expertise can be acquired and whether the activities of elite performers accurately reflect such acquisition. The underlying motives for participation and the way in which participation is measured are of equal interest. Both issues have been considered contentious in recent applied research (e.g., Helsen, Starkes, & Hodges, 1998; Deakin & Cobley, 2002).

Those that have concerned themselves with these questions have primarily taken an environmental stance on expertise development (e.g., Ericsson, Krampe & Tesch-Römer, 1993; Howe, Davidson, & Sloboda, 1998), or have tended to focus upon the social environment in which 'gifted' individuals are nurtured (e.g., Csikszentmihalyi & Robinson, 1986; Csikszentmihalyi, Rathunde, & Whalen, 1993). For instance, in affirmation of Galton's work, Roe (1951) concluded that the capacity to endure hard work and sustain concentration and commitment were more predictive of outstanding achievements than intellectual ability. The suggestion is that both high levels of ability and persistence within a domain are needed to achieve exceptional or eminent levels of performance. Chase and Simon (1973) originally highlighted the importance of extensive involvement within a domain before expert levels of performance could be achieved (i.e., 10 year rule).

In line with this claim, and as a result of assessing talented artists, musicians, athletes, mathematicians and scientists, Bloom (1985) demonstrated that long and intensive periods of training were a precursor to the attainment of expertise. This doctrine has received considerable support across various domains (e.g., Charness, Krampe, & Mayr, 1996; Starkes, Deakin, Allard, Hodges, & Hayes, 1996). Specifically, attention has been focused upon the deliberate nature of practice activities in which skilled performers repeatedly engage (Ericsson et al., 1993).

Ericsson et al. (1993) suggested that deliberate practice was monotonically related to the attainment of expertise and predicted that previous amounts of deliberate practice would be directly related to current levels of performance. According to this viewpoint, the greatest improvements in performance are likely to be associated with the largest weekly amounts of deliberate practice. Therefore, those performers who have accumulated the largest number of practice hours throughout their career and consistently and deliberately engaged in high levels of practice for sustainable periods are more likely to attain expert status. The theory of deliberate practice does not completely rule out a role for talent, nor does it necessarily show causal relations between measured attributes and expertise (see Winner, 1996; Sternberg, 1996). However, and perhaps more importantly, this approach provides a useful structured and empirical mechanism for quantifying practice and predicting expertise.

The concept of deliberate practice has in the past decade pervaded the expertise literature. The original research attempted to account for differences in achieving expert levels of performance in music and chess (for a review, see Ericsson, 1998). While much support has been gleaned from these domains, a considerable amount of interest has been shown in sport with support being rallied in favour of the original proposals, albeit with some qualification and extension to the original theory. For example, Ericsson et al. (1993) initially indicated that participation in deliberate practice activities was particularly effortful. However, some physically effortful activities do not require high levels of concentration which was also a primary constituent of deliberate practice (see Starkes et al., 1996; Hodges & Starkes, 1996). Deliberate practice research in music generally indicated that practice alone or individual practice with a teacher was the activity most likely to reflect deliberate mastery attempts and improve performance (see Ericsson et al., 1993; Howe, Davidson, & Sloboda, 1998; Sloboda 2000). Yet, research in sport shows that time spent in team and group practice more appropriately explained expert-novice differences (e.g., Helsen et al., 1998). Given the competitive nature of many performance-related activities, Singer and Janelle (1999) recently suggested that experience in match-play, or practice-like match-play may be an appropriate predictor of performance and an important constituent of optimal practice environments. Despite these discrepancies, the influence and application of the deliberate practice framework has been demonstrated in fields as diverse as clinical psychology training (Rosenberg, 2000), teacher education (Dunn & Schriner, 1999), imagery skill development (Cumming & Hall, 2002), and with insurance agents (Sonnetag & Kleine, 2000).

The majority of researchers using the deliberate practice framework have relied upon retrospective reports of practice history profiles over the career span. These methods have provided a somewhat gross approximation of the type of practice in which participants engage and a relatively inadequate reflection of the microstructure of practice (Deakin, 2001; Deakin & Cobley, 2002). Although the reliability of questionnaire data has repeatedly been demonstrated, what participants actually report doing and what they actually do cannot necessarily be equated, particularly as they are required to retrospect over numerous years. One way to circumvent such limitations would be to utilize historical practice diaries that extend over a performer's entire career. However, to gain access to such records would be an impressive feat, almost as admirable as the extent of the performer's practice and its documentation. The few researchers that have managed to obtain these career participation diaries have been unable to differentiate expert from novice performance both on the amount and type of practice activities and the microstructure of practice (e.g., Young & Samela, 2001).

An alternative method of gaining a truer reflection of participation history would be to collect cross-sectional data across a variety of age groups or to employ a longitudinal approach. To our knowledge, only a handful of studies have summarized the practice habits of expert performers by adopting either one of these approaches (see Horgan & Morgan, 1990; Schneider Bos & Reider., 1993; Van Rossum, 2000; Weir, Kerr, Hodges, Mckay & Starkes, 2002). Schneider et al. (1993, translated in Schneider, 1997) performed a regression analysis on a sample of 14 year old exceptional tennis players over a five year period. The amount and intensity of practice and tennis specific skills explained most of the variance in tennis ranking attained several years later. Parental support during earlier years was also predictive of performance ranking. Whilst some individual differences in general motor ability were apparent, this study provided support for Ericsson et al.'s (1993) model that deliberate practice was important in developing expertise.

Using a cross sectional design, Van Rossum (2000) assessed the number of hours per week spent in field hockey (i.e., time spent in games and practice combined) by male and female, youth, national and international players aged between 6 and 25 years. Elite youth players retrospectively reported spending 4.1 (under-15) and 4.9 (under-16) hours per week in field hockey, whereas national players (under-18) and national league club champions (18+ years old) both reported spending 7.6 and 10.1 hours per week, respectively. Rather than collect retrospective estimates over the careers of each participant, Van Rossum (2000) extrapolated data from two to six month retrospective reports to provide an estimate of accumulated hours for each year at each of the respective age groups. The data suggested that the adult international and national players had spent approximately 4,600 and 4,100 hours participating in field hockey, respectively. These data included time spent in match-play and did not include individual practice and consequently these amounts do not provide a true reflection of 'deliberate practice'. More importantly, inclusion of the accumulated hours data from the same 'youth' group in both national and international players' estimates did not allow skill-based differences in practice habits prior to 13 years of age to emerge. Furthermore, no reliability data was provided. These limitations could account for the relatively conservative estimates compared to the 10,000 hours recommended by Ericsson et al. (1993). Whether this data constitutes mere repetition of learned activities, maintenance-type activities, or activities deliberately designed to improve performance is questionable. In the absence of sufficient longitudinal data, clearly there is scope for new and innovative methodologies to overcome these issues.

Recent work in applied contexts suggests that environmental factors other than deliberate practice may be equally important in facilitating the progression toward expertise. In an adaptation of Bloom's (1985) work on talent, Côté and colleagues (Côté, 1999; Côté, Baker & Abernethy, 2001; Côté & Hay 2002) proposed that 'deliberate play' during the early or sampling years (6-12 years) was crucial for developing fundamental skills, and ultimately for achieving expertise, specifically in sport. Emphasis was placed upon fun and enjoyment within these activities, upholding Scanlan, Carpenter, Schmidt, and Keeler's (1993) claim that enjoyment plays a crucial role in activity commitment. To examine the extent to which deliberate play activities played a vital role in the development of expertise, Côté and colleagues conducted participant interviews across a range of team sports. Expert and world-class athletes engaged in considerably more 'deliberate play' early on in their careers than non-experts (Baker, Côté & Abernethy, in press; Côté et al., 2001). Ericsson and colleagues (1993, 1996, 1998) contested whether play is particularly productive for developing expert performance. As a foundation to skilled performance, however, physical activities engaged in for the purposes of play may be fundamental for learning initial cognitive and movement skills and may allow preliminary mental representations necessary for expert performance to be established (Beamer, Côté, & Ericsson, 1999; Ericsson, 1998). In the long term, engaging in intrinsically motivating behaviors (i.e., deliberate play) during the early stages of participation increases an individual's eagerness to pursue more externally controlled activities (i.e., deliberate practice) (Deci & Ryan; 1985; Ryan & Deci, 2000).

The 'sampling years' were proposed to be a period where diversity was both encouraged and beneficial to the development of skilled performance (Côté, 1999). A significant negative correlation was found between the number of sports in which participants engaged during the early years and the number of hours spent in sport specific training ($r = -.74$, $p < .01$) (Baker et al., in press). Those world-class team players who demonstrated greater diversity across several domains accrued less practice hours than those who had participated in fewer physical activities. 'Functional fixedness', which may occur as a result of early specialization and lack of diversity, has been shown to hinder an individual's ability to find an appropriate solution during problem solving (Seifert, Meyer, Davidson, Patalano, & Yaniv, 1995). As a consequence, such behavior may inhibit the development of skilled cognitive performance in real world tasks. According to Simonton (2000), intellectual cross-training (i.e., diversity) may be advantageous in alleviating the negative effects of overtraining or excessive specialization and, therefore promote skill development.

There are also significant implications from this research for transfer of cognitive skills. Recent research within our laboratory (Smeeton, Ward, & Williams, 2002) suggests that benefits to perceptual-cognitive skill acquisition may only be gained from diversifying in those tasks that are structurally similar, sharing higher order relations and/or higher order predicates (i.e., tactical similarities) (see Gentner, 1983; Gentner, Ratterman, & Forbus, 1993). Given the qualitative nature of the research undertaken by Côté and colleagues, the external validity of their findings and the relationship between correlation and causality in this instance remain to be investigated.

While deliberate practice and potentially deliberate play provide a vehicle for attaining expert levels of performance, the development of expertise is reported to occur as an interaction between a number of elements. Meta-cognitive, learning, and thinking skills, as well as knowledge, motivation and their contextualization were recently identified as the six elements of the developing-expertise model (Sternberg, 2000). In particular, motivation was viewed as the pivotal and activating component within this interaction. This view is consistent with Ericsson et al.'s (1993) original conceptualization of expertise development. Ericsson and colleagues viewed motivation as a pre-requisite for sustained engagement in deliberate practice over days, years, and even decades. Those individuals who exhibit higher levels of intrinsic motivation are typically most committed to their domain of expertise (see Csikszentmihalyi et al, 1993). With respect to the development of expertise, an individual's commitment to deliberate practice is one of the factors that distinguish skilled participants from everyday individuals who may struggle to meet lesser practice demands (Ericsson et al., 1993).

To examine motives for participation, Scanlan et al. (1993a) developed a model of commitment specific to sport, developed largely from Rusbult's (1980) investment model of commitment. This model highlights five factors which impact the desire to sustain participation and includes enjoyment, involvement alternatives, personal investment, social constraints, and involvement opportunities. Scanlan et al.'s (1993a) model suggests that enjoyment is positively related to commitment which opposes Ericsson et al.'s (1993) conception of deliberate practice activities. Ericsson et al. suggested that the process of engaging in deliberate practice activities was not inherently enjoyable. Support for Scanlan et al.'s model was found by Starkes et al. (1996) and Helsen et al. (1998) in a variety of different sports (e.g., hockey, ice-skating, soccer, wrestling). Participants rated practice activities as extremely enjoyable questioning Ericsson et al.'s prediction, particularly within domains that involve a large perceptual-motor component. It is still debatable to what extent an individual's ratings of enjoyment are biased by outcome (i.e., product oriented) or truly reflect actual participation (i.e., process oriented). A shift from process- to product-based enjoyment with increased participation and/or success might lend support to both Ericsson et al.'s (1993) and Scanlan et al.'s (1993a) research. That is, enjoyment from actual participation during the early years might explain an individual's commitment. In later years, the enjoyment gained from an individual's assessment of the outcome (i.e., win/lose, observable skill improvement) says nothing about the inherent enjoyment of the practice process and may even bolster commitment further where a successful outcome is obtained.

In this paper the deliberate practice framework is employed as a mechanism for quantifying and predicting the development of expertise. A number of issues remain to be resolved in this regard. The relative contribution of practice and play to the development of elite levels of performance has not been fully examined, particularly in applied performance and developmental contexts. The microstructure of practice has also been under-researched and the relevance of diversity across tasks/domains and subsequent specialization has received very limited attention. Similarly, identifying underlying motivations for participation may highlight those prerequisite factors necessary to allow expertise to flourish. Only by focusing upon the important constituents of skill acquisition will progress be made in developing future experts. Although some relatively reliable data exists from purely retrospective methodologies, innovative designs may allow cross-validation of developmental data and provide a more robust assessment of the skill acquisition process. Each of these issues will be comprehensively addressed by examining the development of expertise using elite and sub-elite soccer players between 8 and 18 years of age.

Experiment 3: Soccer-Specific Participation

The primary aim in this experiment was to examine the relative contribution of team and individual practice, match-play and playful activities to the development of elite levels of performance. A novel methodology for assessing the process of skill acquisition using a quasi-longitudinal design was employed. This methodology allowed the retrospective data to be cross-validated by directly comparing each skill groups' data from the most recent year of participation, thereby providing a more accurate reflection of current practice habits. Further aims were to examine developmental ratings of domain-specific (e.g., soccer practice), domain-related (watching soccer) and non domain-specific activities (e.g., school work), and to examine the microstructure of practice. It was expected that deliberate 'team' practice would be the most discriminating variable between skill groups, particularly within older age groups and that individual practice (cf. Helsen et al., 1998), and potentially playful activities (cf. Baker et al., in press; Côté et al., 2001), would contribute to the skill development model in the earlier years. The activity ratings were partly exploratory. Previous domain-specific research suggests that skill-based differences would not emerge on soccer-specific activities and that these activities would be more relevant, effortful, require more concentration and be more enjoyable than the average rating for all activities (e.g., Helsen et al., 1998). However, whether perceptions of relevance, effort, concentration and enjoyment differ between skill groups as they emerge over a developmental time period has yet to be answered. Given the competitive nature, as well as the perceptual-motor and perceptual-cognitive demands of the domain of interest, skill groups were expected to be differentiated on time spent practicing technical skills, in supervised and unsupervised match-play, and in tactical and strategic decision making during a typical training session.

Method

Participants

Male soccer players (n=203) between 8 and 18 years of age were selected as participants. Elite players were recruited from three National level Academies accredited by the (English) Football Association. Sub-elite players were recruited from elementary and high schools, and Liverpool John Moores University. Elite players competed at the highest national level for their respective age groups, whereas sub-elite participants played at local amateur club or school level. An average of 11 participants was included in each sub- group. The groups were comprised of participants aged nine and under (U-9), U-10, U-11, U-12, U-13, U-14, U-15, U-17, and U-18. The mean age (± SD) of each participant group is presented in Table 4.1. Informed consent was gained prior to participation.

Procedure

Participants completed a sports participation questionnaire under supervision. The questionnaire was adapted from previous research (see Helsen et al., 1998; Hodges & Starkes, 1996; Hodges et al., 2002). First, biographical information was recorded for each participant. The ages at which players first engaged in soccer-related playful activities, individual or team practice, and match-play were reported. Playful activities were classified as fun games, or unstructured activities (i.e., 'kick- around' with friends) that were undertaken primarily for enjoyment.

Table 4.1. Biographic information for the elite and sub-elite players in each age group

			Mean (SD) start age			
	Age group	Mean (SD) age	Playful activities	Individual practice	Team practice	Match-play
Elite	U-9	9.29 (0.35)	4.30 (1.28)	4.53 (1.51)	5.33 (1.11)	4.93 (1.16)
	U-10	10.38 (0.28)	4.45 (1.13)	6.00 (1.61)	5.82 (0.75)	6.27 (1.01)
	U-11	11.53 (0.23)	4.42 (1.24)	4.75 (1.36)	5.75 (1.54)	5.75 (1.54)
	U-12	12.42 (0.39)	4.00 (1.29)	5.00 (2.52)	5.14 (0.69)	6.00 (2.24)
	U-13	13.54 (0.30)	5.47 (1.68)	6.53 (2.67)	7.20 (2.37)	7.27 (2.40)
	U-14	14.54 (0.30)	6.23 (2.20)	7.62 (2.69)	7.31 (1.60)	7.46 (1.51)
	U-15	15.70 (0.16)	5.56 (1.01)	8.22 (2.59)	7.33 (2.50)	7.11 (1.96)
	U-17	17.62 (0.23)	6.50 (1.93)	7.00 (2.00)	7.00 (2.07)	7.25 (2.12)
	U-18	18.57 (0.21)	7.58 (2.07)	7.58 (2.19)	7.67 (2.06)	7.67 (2.15)
Sub-elite	U-9	9.46 (0.25)	4.63 (1.30)	5.78 (1.31)	7.29 (1.33)	6.75 (1.36)
	U-10	10.47 (0.30)	4.85 (1.41)	6.08 (1.88)	6.30 (1.57)	6.70 (1.70)
	U-11	11.49 (0.33)	5.00 (0.74)	6.50 (2.20)	8.17 (1.83)	7.60 (2.55)

U-12	12.26 (0.30)	3.75 (1.04)	10.00 (2.45)	9.50 (3.51)	9.17 (3.31)
U-13	13.27 (0.22)	4.25 (0.89)	6.38 (2.33)	7.75 (1.50)	8.67 (2.07)
U-14	14.33 (0.28)	5.00 (1.34)	7.50 (2.98)	7.40 (1.52)	8.38 (2.39)
U-15	15.27 (0.23)	5.90 (1.60)	6.78 (2.17)	8.50 (2.07)	9.40 (2.88)
U-17	17.46 (0.24)	5.60 (0.84)	8.60 (2.22)	7.10 (1.79)	7.10 (1.29)
U-18	18.19 (0.22)	6.00 (1.63)	6.50 (1.35)	7.40 (1.90)	7.40 (1.90)

Individual or team practice activities were defined as those deliberately designed to improve rather than maintain performance, such as soccer-specific drills, technical, tactical and strategic skills, open- (e.g., phase-play, small-sided games) and set-play practices (e.g., corner, free kick). Match-play included time spent playing competitive matches against another team.

Second, players were asked to provide a history of soccer-specific participation. Information was requested regarding hours per week spent in team (i.e., number of sessions per week, time spent in each session) and individual practice, match-play and playful activities. This information was reported retrospectively for the present year, then on a yearly basis for the preceding three years of participation, and in three-year intervals until their first year of involvement in soccer. Players were also asked to record the number of weeks per year for which they had not participated in any soccer activities. This information was used to calculate accumulated practice hours for each year. In addition to the practice history information, using an 11-point Likert scale, players were asked to rate their involvement in soccer between 0 (play-oriented) and 10 (practice-oriented) both for the first and last year of participation.

Third, participants rated soccer- and non soccer-related activities based upon their perceived relevance to improving soccer performance, physical effort required to carry out each activity, level of concentration needed to perform the activity, enjoyment obtained from participation, and the specific source of enjoyment (i.e., enjoyment based upon actual participation, or on their appraisal of the outcome of each activity). Responses to the first four rating categories were given on a Likert scale (0 = extremely low, 10 = extremely high). A categorical response was used to measure the specific source of enjoyment (1 = outcome, 2 =

process). Finally, participants were asked to provide details regarding the microstructure of practice (e.g., warm up, unsupervised match-play). Participants reported an estimate of the amount of time spent in various activities during a typical practice session.

Cross-Validation and Reliability

One measure of validity and two measures of reliability were obtained. The retrospective soccer participation histories reported by each age group were cross-validated via comparison to the reports of previous years for older age groups within the same skill level. For example, retrospective estimates from each of the U-18 to U-10 groups at 9 years of age were compared to the U-9 group's estimate for the current year. Test-retest reliability was performed on a sample of players (n = 10). Players refilled in the participation history section of the questionnaire one week after initial completion. Reliability of retrospective information was also assessed using practice diaries completed over a period of seven days by a random selection of players (n = 16). Participants were asked to identify each physical activity in which they participated, the duration of each activity, and to rate them as per previous instructions. Players were requested to complete the diary as soon after the activity as possible, and no later than at the end of each day.

Data Analyses

Two-way ANOVA was performed on all biographical information including participants' age and their respective start age in individual and team practice, match-play, and playful activities. Age and skill were the between-participant factors. Participants' ratings of whether activities were play or practice oriented were analyzed using a three-way ANOVA. Time (i.e., first/last year) was the within-participant factor. To determine the relative contribution of each variable and to predict skill group membership, stepwise, forward discriminant function analyses were conducted for each age group on hours per week and accumulated hours spent in each of the above four activities. The criteria for entering and removing variables from the model were based upon the total number of variables analyzed (see Biddle, Markland, Gilbourne, & Sparkes, 2001).

For purposes of cross-validation, separate one-way ANOVAs were used to determine whether there were differences between information reported by one group for the current year (e.g., U-17 age group at 17 years of age) and older age groups at that same age (e.g., U-18 at 17 years of age). In addition, the original hours per week data were correlated with the re-test data collected one week later using Pearson's product moment coefficient. Players' ratings of relevance, physical effort, concentration, and enjoyment were initially analyzed using three-way ANOVA with activity as the within-participant factor. The intention was to determine whether any differences were apparent between each sub-group's activity ratings. As per Ericsson et al. (1993), our primary interest was to determine whether participants' ratings of each activity were significantly different from the overall mean rating across all activities ($\underline{n}$ = 13). Significant differences were examined using one-sample t-tests. Chi square was used to analyze the specific source of participants' enjoyment (i.e., process vs. outcome). Yates' correction for continuity was incorporated into calculation of the Chi square statistic. The alpha level was adjusted for all comparisons using the Bonferroni method ($\alpha = 0.001$).

Results

Biographic Information

Analysis of players' age in commencing playful activities revealed a main effect for age only, F (8, 185) = 8.21, $p<.001$. No skill main effect or interaction was observed. For each of the respective age groups, both elite and sub-elite participants commenced playful activities in soccer at a similar age. The mean ages at which players began engaging in each soccer activity are presented in Table 4.1. A main effect for age, F (8, 185) = 4.55, $p<.001$, and an Age x Skill interaction, F (8, 185) = 3.308, $p<.001$, were observed for participants' start age in individual practice activities. As age increased, participants tended to begin individual practice at a later age. Scheffe's post hoc analyses indicated that the U-17 to U-14, and U-12 age groups began individual practice at a later age than the U-9 age group did ($p<.001$). Similarly, U-17 age group started individual practice later than the U-10 group ($p<.001$). The U-12 sub-elite players' late start in individual practice was the primary contributor to the significant interaction effect ($p<.001$). A significant main effect for skill, F (1, 185) = 24.29, $p<.000$, and an Age x Skill interaction, F (8, 185) = 3.53, $p<.001$, were found for start age in team practice. Elite players typically commenced team practice earlier than sub-elite players. Again, the later start in team practice by the U-12 sub-elite group significantly contributed to the observed interaction ($p<.001$). Analyses of start age in match-play revealed significant main effects for age, F (8, 185) = 4.67, $p<.001$, and skill, F (1, 185) = 21.95, $p<.001$. The U-9 group engaged in match-play from an earlier age when compared to the U-13 to U-15 age groups ($p<.001$). Overall, elite players began participating in match-play at an earlier age than the sub-elite players ($p<.001$). No significant skill-based differences were observed in height or weight at each age.

Practice History in Soccer

The discriminant function analyses for both hours per week and hours accumulated in soccer activities are summarized in Tables 4.2 and 4.3. Quasi-longitudinal data (i.e., data from the current year for each age group) for hours per week and total hours accumulated in all activities are presented in Figures 4.4 to 4.7. With few exceptions, team practice in the most recent year of participation was the largest, and often sole, contributor to the significant variate. Moreover, team practice was the only variable to consistently discriminate between skill groups at each age. The mean squared canonical correlation (r^2) for the U-9 to U-11 groups was 0.56. The model accurately predicted group membership for 85.3% of U-9 to U-11 players (35.3% improved beyond chance levels of prediction). A higher proportion of the true variance was accounted for in the U-12 to U-18 players ($r^2 = 0.76$). The mean prediction capacity of the model also increased with age, accurately predicting 94.9% of group membership for the older age groups (>U-12) (44.9% above chance).

Table 4.2. Summary of variables predicted by the discriminant function for hours per week spent in all activities.

Age Group	Discriminant function variate statistics	Canonical correlation (r)	Accuracy of group membership prediction (%)	Variables predicted by the model at each step. (Age at which each variable was predictive).	Standardized canonical discriminant function coefficient (β)	Stepwise statistics
U-9	χ^2 (2) = 22.54, p<.001	.719	82.4	Step 1: Team practice (8)	0.668	Wilks' λ = .602, F (1, 32) = 21.15, p<.001
				Step 2: Match-play (7)	0.629	Wilks' λ = .483, F (2, 31) = 16.57, p<.001
U-10	χ^2 (1) = 16.64, p<.001	.734	79.2	Step 1: Team practice (10)	1.000	Wilks' λ = .461, F (1, 22) = 25.71, p<.001
U-11	χ^2 (1) = 17.02, p<.001	.740	95.8	Step 1: Team practice (11)	1.000	Wilks' λ = .453, F (1, 22) = 26.56, p<.001
U-12	χ^2 (1) = 15.82, p<.001	.847	93.3	Step 1: Match-play (10)	1.000	Wilks' λ = .282, F (1, 12) = 33.07, p<.001
U-13	χ^2 (1) = 21.39, p<.001	.815	91.3	Step 1: Team practice (13)	1.000	Wilks' λ = .335, F (1, 21) = 12.05, p=.002
U-14	χ^2 (2) = 51.81, p<.001	.957	100.0	Step 1: Team practice (14)	1.150	Wilks' λ = .128, F (1, 22) = 150.15, p<.001
				Step 2: Playful activities (9)	0.702	Wilks' λ = .085, F (2, 21) = 113.29, p<.001
U-15	χ^2 (1) = 18.77, p<.001	.824	94.7	Step 1: Team practice (15)	1.000	Wilks' λ = .321, F (1, 17) = 36.03, p<.001
U-17	χ^2 (1) = 19.29, p<.001	.844	94.4	Step 1: Team practice (17)	1.000	Wilks' λ = .288, F (1, 17) = 39.54, p<.001
U-18	χ^2 (2) = 28.27, p<.001	.880	95.5	Step 1: Team practice (17)	-0.705	Wilks' λ = .364, F (1, 20) = 34.92, p<.001
				Step 2: Playful activities (17)	0.790	Wilks' λ = .226, F (2, 19) = 32.57, p<.001

Table 4.3. Summary of variables predicted by the discriminant function model for accumulated hours spent in all activities.

Age Group	Discriminant function variate statistics	Canonical correlation (r)	Accuracy of group membership prediction (%)	Variables predicted by the model at each step (Age at which each variable was predictive)	Standardized canonical discriminant function coefficient (β)	Stepwise statistics
U-9	χ^2 (1) = 22.52, $p<.001$	.715	79.4	Step 1: Team practice (9)	1.000	Wilks' λ = .489, F (1, 32) = 33.39, $p<.001$
U-10	χ^2 (1) = 12.15, $p<.001$	.657	79.2	Step 1: Team practice (10)	1.000	Wilks' λ = .568, F (1, 22) = 16.72, $p<.001$
U-11	χ^2 (4) = 32.87, $p<.001$	.898	95.8	Step 1: Team practice (11)	7.310	Wilks' λ = .661, F (1, 22) = 11.26, $p<.001$
				Step 2: Team practice (9)	-1.091	Wilks' λ = .408, F (2, 21) = 15.26, $p<.001$
				Step 3: Individual practice (8)	-6.586	Wilks' λ = .281, F (3, 20) = 17.08, $p<.001$
				Step 4: Match-play (11)	1.084	Wilks' λ = .193, F (4, 19) = 19.82, $p<.001$
U-12	χ^2 (1) = 14.26, $p<.001$	.825	93.3	Step 1: Team practice (12)	1.000	Wilks' λ = .320, F (1, 13) = 27.67, $p<.001$
U-13	χ^2 (1) = 21.39, $p<.001$	.815	91.3	Step 1: Team practice (13)	1.000	Wilks' λ = .436, F (1, 21) = 9.75, p=.005
U-14	χ^2 (2) = 45.46, $p<.001$	.941	100.0	Step 1: Team practice (14)	9.073	Wilks' λ = .466, F (1, 22) = 25.17, $p<.001$
				Step 2: Team practice (13)	-8.737	Wilks' λ = .115, F (2, 21) = 80.96, $p<.001$
U-15	χ^2 (2) = 23.30, $p<.001$	.876	94.7	Step 1: Team practice (15)	4.768	Wilks' λ = .678, F (1, 17) = 8.06, p=.01
				Step 2: Team practice (13)	-4.484	Wilks' λ = .233, F (2, 16) = 26.32, $p<.001$
U-17	χ^2 (3) = 25.18, $p<.001$	.908	94.4	Step 1: Team practice (17)	-12.146	Wilks' λ = .782, F (1, 17) = 4.46, p=.05

				Step 2: Team practice (16)	12.103	Wilks' λ = .227, F (2, 16) = 25.57, p<.001
				Step 3: Playful activities (10)	0.626	Wilks' λ = .176, F (3, 15) = 21.83, p<.001
U-18	χ^2 (5) = 27.49, p<.001	.889	95.5	Step 1: Individual practice (13)	-3.448	Wilks' λ = .817, F (1, 20) = 4.48, p=.047
				Step 2: Individual practice (18)	3.134	Wilks' λ = .580, F (2, 19) = 6.89, p=.006
				Step 3: Match-play (18)	0.638	Wilks' λ = .423, F (3, 18) = 8.17, p<.001
				Step 4: Team practice (18)	-2.930	Wilks' λ = .341, F (4, 17) = 8.21, p<.001
				Step 5: Team practice (16)	2.704	Wilks' λ = .209, F (5, 16) = 12.12, p<.001

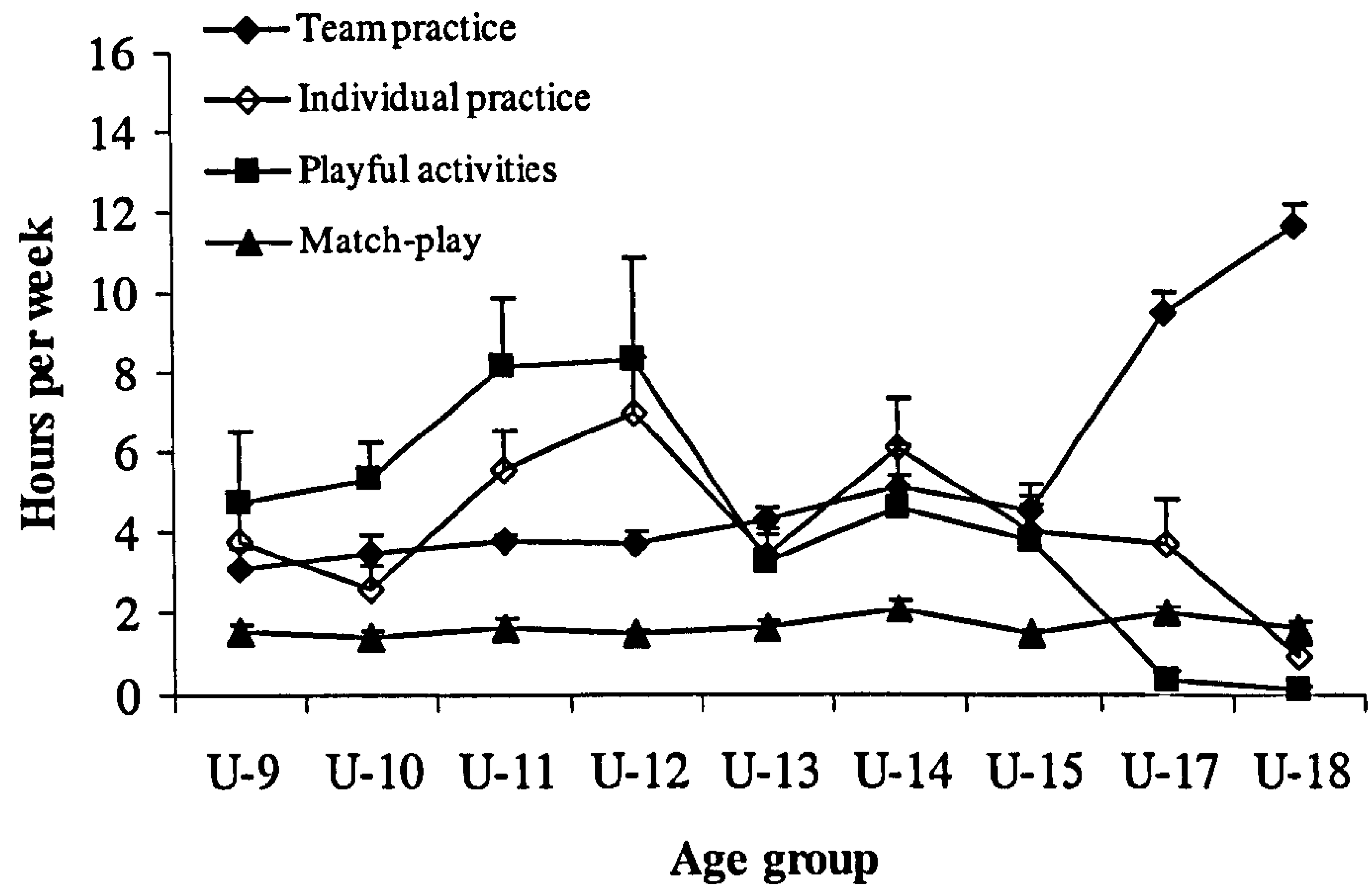


Figure 4.4. Hours per week (SD) spent in team practice, individual practice, match-play, and playful activities in soccer for elite players.

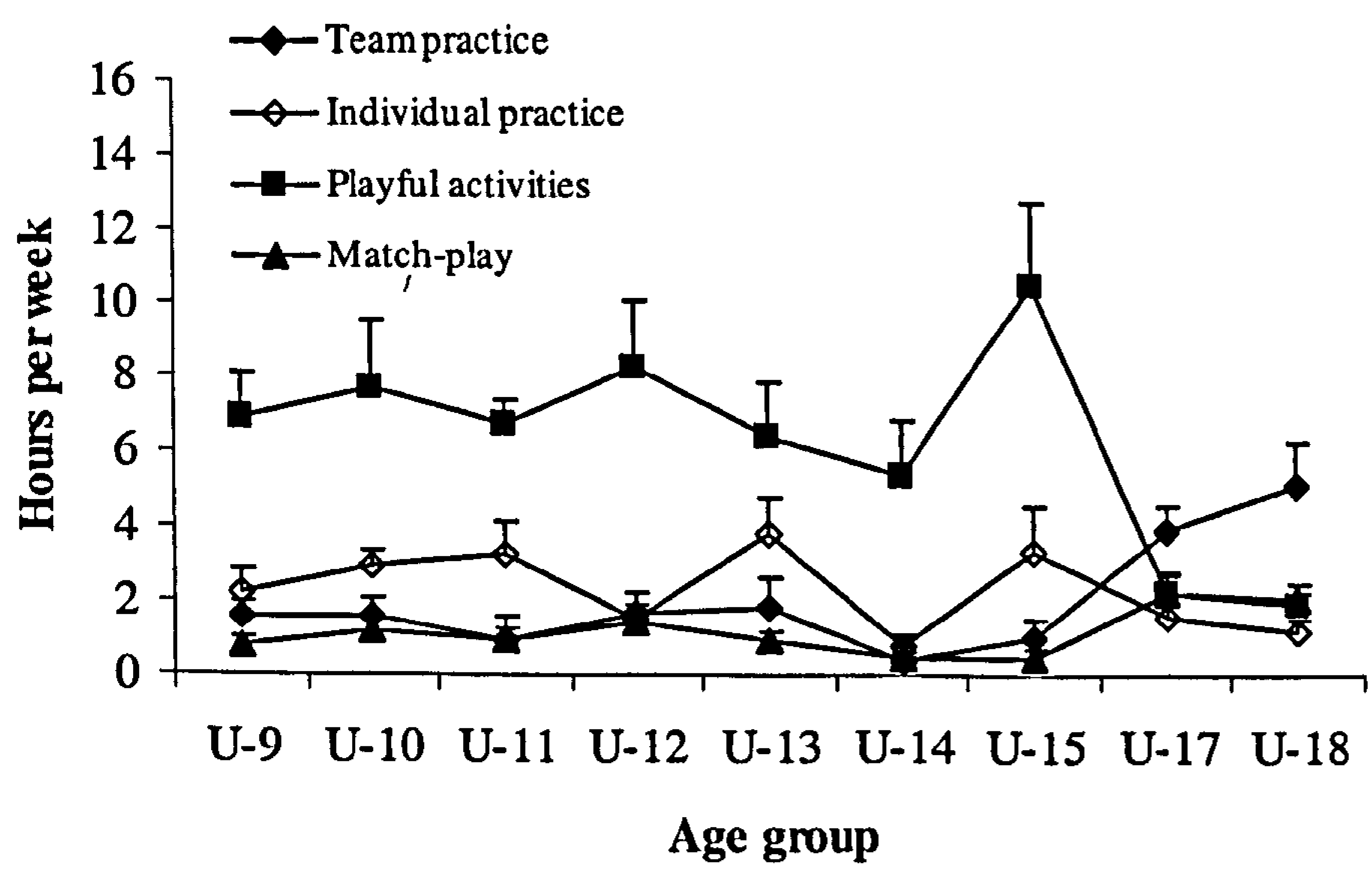


Figure 4.5. Hours per week (SD) spent in team practice, individual practice, match-play, and playful activities in soccer for sub-elite players.

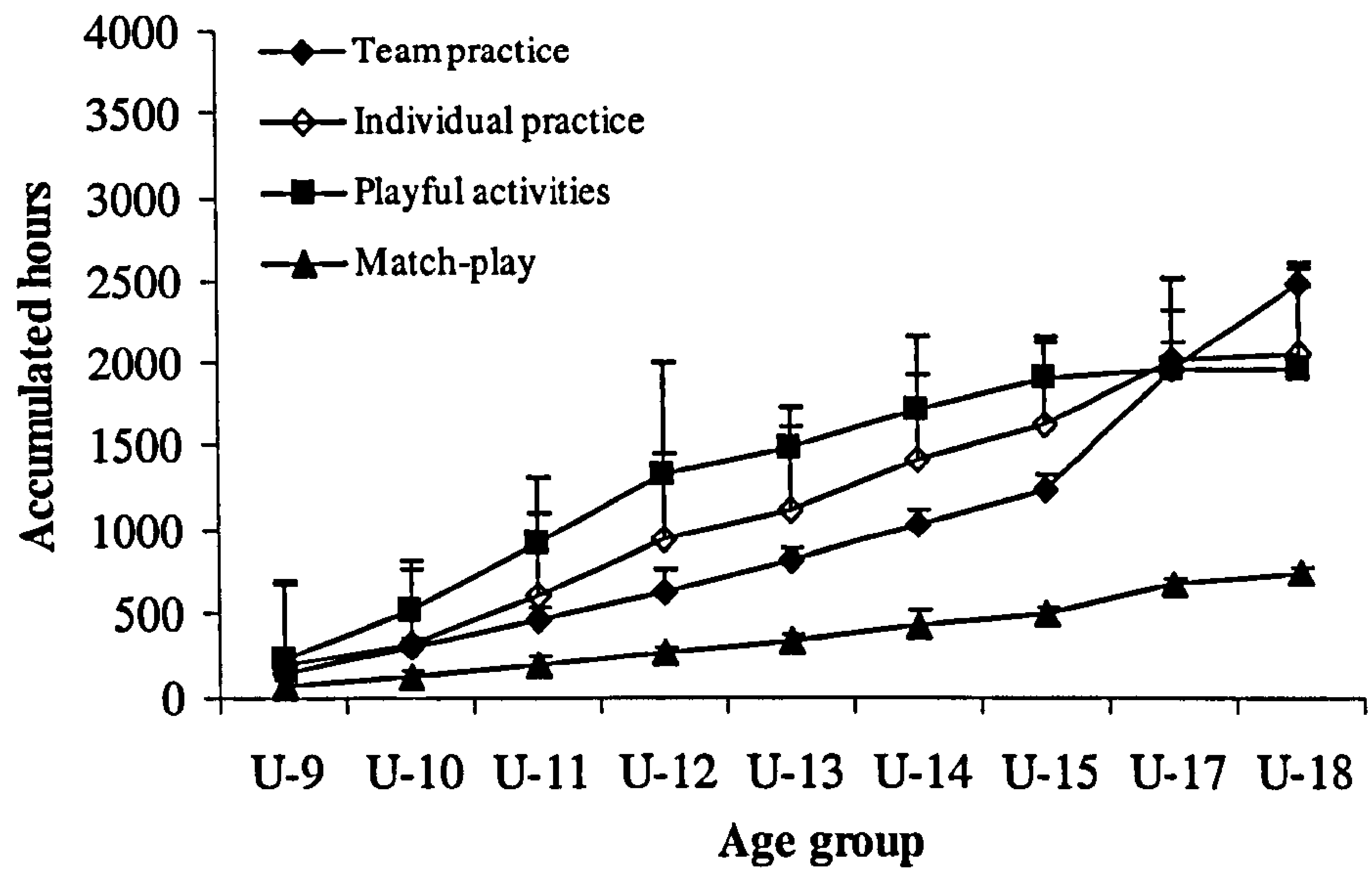


Figure 4.6. Total number of hours accumulated (SD) in team practice, individual practice, match-play, and playful activities in soccer for elite players.

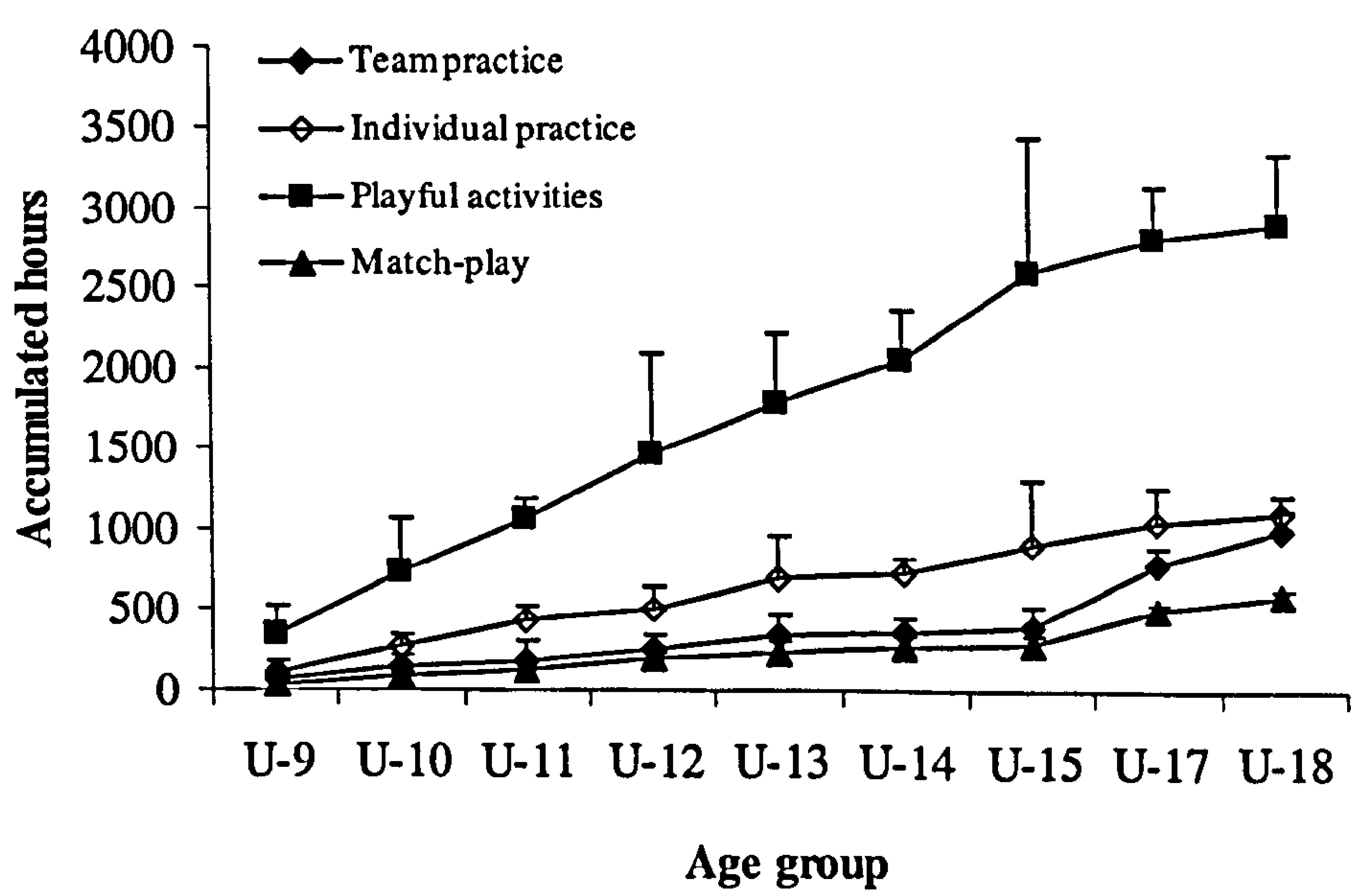


Figure 4.7. Total number of hours accumulated (SD) in team practice, individual practice, match-play, and playful activities in soccer for sub-elite players

Cross-validation. For every year of retrospective data, separate analyses were performed to determine whether there were significant differences between older players' retrospective estimates and younger players' estimate from the current year. No significant differences in retrospective reports were found for the number of hours per week reported in playful activities, individual practice, and match-play across all age groups. The only significant age effects were found in the number of hours spent in team practice at 9, 10, and 11 years of age, F (8, 93) = 8.13, $p<.001$, F (7, 79) = 9.27, $p<.001$, and, F (6, 69) = 6.55, $p<.001$, respectively. At 9 years of age, the U-9 group reported spending significantly more time in team practice compared to the U-13 and older age groups' retrospective estimates ($p<.001$). Similarly, at 10 years of age, the U-10 group reported more hours for team practice than the U-13 and older age groups ($p<.001$). At 11 years of age, the U-11 group's estimates for the current year were higher than the U-14 and older age groups ($p<.001$). To maintain a conservative estimate of team practice, U-9, U-10, and U-11 data points in Figure 4.6 were derived from the U-12 to U-18 age groups' mean scores. This data provides a more accurate and reliable reflection of the number of hours accumulated by the older age groups.

Reliability. Significant positive correlations were found between participants' test and re-test retrospective reports for their last five years of estimation (r = .952 to .914). Retrospective estimates beyond this period were generally not as strong and were non-significant (r = .684 to .621, p = .05). A weak correlation between test and re-test estimates of hours per week spent in soccer activities was found for only one year of retrospective recall (i.e., six years prior to current year) (r = .14). Interestingly, only three participants' estimates of the time spent practicing six years ago (re-test) were different from their first estimate for this period (test). Furthermore, the mean difference between test and re-test retrospective estimates of practice some six years previous was minimal (M = 0.5 ± 0.7 hours).

No significant or meaningful correlations were found for the diary analyses suggesting that the week for which activities were reported was atypical. Correlations ranged from .085 to .357 ($p>.05$). However, mean comparisons indicate that the diary and questionnaire data were similar though somewhat more variable, particularly for time spent in team practice (M = 4.70 ± 4.26 vs. 4.69 ± 1.27 hours, respectively) and match-play (M = 1.65 ± 1.14 vs.1.65 ± 0.56 hours, respectively). Only the mean time spent in other sports differed dramatically between diary and questionnaire reports (M = 0.93 ± 2.31 vs. 4.10 ± 4.51 hours, respectively).

Ratings of Activities

Ratings of enjoyment are presented in Table 4.8. The analysis of enjoyment ratings revealed a significant violation of the sphericity assumption for repeated measures ANOVA, χ^2 (77) = 334.45, $p<.001$ ($\varepsilon = .88$). The Huynh-Feldt correction factor was used to adjust the degrees of freedom accordingly. Significant activity, F (10.57, 1701.67) = 41.10, $p<.001$, and group, F (8, 161) = 4.43, $p<.001$ main effects were highlighted, in addition to Activity x Skill, F (10.57, 1701.67) = 2.87, $p<.001$, and Activity x Group interactions, F (84.55, 1701.67) = 1.99, $p<.001$. Post hoc analyses did not reveal the source of the interactions. However, ratings of 'being coached' approached significance indicating a trend towards elite players taking more enjoyment in this activity in comparison to their sub-elite counterparts (p = 009). As age increased, there was a general trend for enjoyment on all activities to decrease, except on ratings of technical skill, being coached, match-play, and sleep. These activities remained comparatively high across each age group. As per Ericsson et al. (1993), further comparisons were made to determine whether ratings of activities for enjoyment were significantly higher or lower than the mean rating for each activity.

In addition to the ratings based upon the level of inherent enjoyment gained from participation, each player provided a second categorical measure (1 = outcome, 2 = process) of the specific source of enjoyment for each of the 13 activities. Chi square revealed significant age-related differences between observed and expected scores for all activities, except education and sleep, χ^2 (8) = 30.19 to 50.44, $p<.001$. At an early age, players typically gained enjoyment from actual participation in the activity itself (M ratings for all activities at U-9 = 1.66 to 1.92). As age increased, the general trend was for players to shift their emphasis toward appraising the outcome of the activity, particularly in soccer-skill specific or physical soccer-training related activities (M rating at U-18 = 1.32). No significant differences were found between skill groups.

ANOVA did not reveal any skill-based differences between activity ratings for relevance, physical effort, and concentration. Comparisons to determine whether activity ratings for these categories were significantly different from the overall mean for each activity were, therefore, carried out irrespective of skill or age group. The data are presented in Table 4.9.

Table 4.8. Mean ratings (out of 10) of activities per skill and age group for enjoyment gained from participating in each activity

Group / Activity	U-9	U-10	U-11	U-12	U-13	U-14	U-15	U-17	U-18
	Age Group								
Elite									
Practical soccer skill-specific:									
Technical skills	9.40[H]	9.09	9.50	9.71[H]	9.14[H]	9.46[H]	8.44	8.75	8.92[H]
Tactical & strategic skills	8.73	8.82	8.58	9.57	8.64	6.85	6.67	7.38	8.08
Being coached	9.60[H]	8.18	9.33	9.71[H]	9.21[H]	8.92[H]	8.56	8.13	8.58[H]
Match-play	9.93[H]	10.00[H]	9.91[H]	10.00[H]	9.50[H]	10.00[H]	9.44[H]	9.63[H]	9.50[H]
Physical soccer-training:									
Strength, power, & speed	7.80	9.18	9.92[H]	8.57	8.36	8.08	7.22	7.25	5.83
Flexibility	6.53	4.45	8.75	5.43	6.43	4.85	5.11	4.75	4.42
Endurance	7.20	9.27	7.75	7.71	7.36	6.38	6.88	6.75	5.38
Soccer related:									
Watching others play soccer	8.73	8.73	9.28	9.71[H]	9.00	8.83[H]	5.78	8.50	7.55
Talking generally about soccer with coach, players, managers, or parents	6.80	5.82	8.00	9.33	7.62	7.33	6.89	7.00	7.00
Non-soccer related:									
Active leisure	8.64	7.27	6.83	8.17	7.71	6.83	6.13	4.75	5.18
Non-active leisure	9.29[H]	9.09	7.00	7.57	7.00	8.75[H]	6.75	7.63	7.91
Education	7.27	7.82	4.75	4.57	6.08	4.00	1.75	4.38	3.82
Sleep	8.53	9.27	9.17	7.00	7.62	9.46[H]	7.75	7.25	7.73

(cont.)				Age Group					
Group / Activity	U-9	U-10	U-11	U-12	U-13	U-14	U-15	U-17	U-18
Sub-elite									
Practical soccer-skill specific:									
Technical skills	7.84	9.31	7.89	8.50	8.86	7.50	9.30H	9.00H	9.30H
Tactical & strategic skills	8.11	8.62	8.89	8.13	8.43	7.44	8.70	7.60	6.30
Being coached	7.21	8.62	7.89	6.25	6.57	6.90	8.20	7.60	8.40
Match-play	8.63	9.54	9.33	9.25	8.14	7.11	9.30H	8.60	8.50
Physical soccer-training:									
Strength, power, & speed	8.47	8.62	8.89	5.50	8.29	7.30	8.30	6.80	6.00
Flexibility	8.16	7.62	8.44	7.75	6.86	5.30	6.70	4.40	4.20
Endurance	7.84	9.23	8.00	4.88	7.00	6.20	8.10	5.20	4.00
Soccer related:									
Watching others play soccer	7.84	9.38	8.44	8.38	7.71	7.89	9.40H	8.80	8.20
Talking generally about soccer with coach, players, managers, or parents	7.42	8.54	6.75	7.00	6.14	6.25	6.56	7.40	6.30
Non-soccer related:									
Active leisure	8.58	8.62	7.11	7.75	7.29	5.33	6.50	4.70	4.90
Non-active leisure	8.21	8.08	7.33	6.75	6.67	5.78	8.30	7.60	8.20
Education	5.37	5.15	3.67	4.63	6.71	4.33	4.80L	3.00	4.90L
Sleep	6.53	7.38	6.67	8.63	7.57	7.56	8.90	7.70	8.40

Note. H denotes that the mean score was significantly higher than the overall mean for that rating category. L denotes that the mean score was significantly lower than the overall mean.

Table 4.9. Mean ratings of activities for relevance for improving performance, physical effort and concentration required to perform the activity

Activity	Relevance	Physical effort	Concentration
Practical soccer-skill specific:			
Technical skills	9.21^{H}	8.38^{H}	9.07^{H}
Tactical & strategic skills	8.99^{H}	7.27^{H}	8.96^{H}
Being coached	8.90^{H}	8.01^{H}	8.75^{H}
Match-play	9.29^{H}	9.39^{H}	9.42^{H}
Physical soccer-training:			
Strength, power, & speed	8.32^{H}	8.51^{H}	7.63^{H}
Flexibility	8.23	6.81^{H}	6.92
Endurance	8.25^{H}	8.51^{H}	7.19
Soccer related:			
Watching others play soccer	8.34^{H}	1.85^{L}	7.10
Talking generally about soccer with coach, players, managers, or parents	7.80	2.63^{L}	7.41
Non-soccer related:			
Active leisure	5.18^{L}	5.94	5.19^{L}
Non-active leisure	2.36^{L}	1.45^{L}	4.12^{L}
Education	6.47^{L}	4.60^{L}	8.53^{H}
Sleep	8.76^{H}	0.81^{L}	1.47^{L}

Note. ^{H} denotes that the mean score is significantly higher than the overall mean for that rating category. ^{L} denotes that the mean score is significantly lower than the overall mean.

Microstructure of practice

Approximately 38% of the sub-elite participants were not currently participating in a structured training program or did not report a breakdown of their current activities. Consequently, analyses on the microstructure of practice were carried out irrespective of age group. A significant violation of the sphericity assumption was reported, χ^2 (35) = 239.71, $p<.001$ (ε = 0.77). The Huynh-Feldt correction factor was used to correct the degrees of freedom. A significant main effect for activity, F (6.15, 996.46) = 43.06, $p<.001$, and a Skill x Activity interaction were revealed, F (6.15, 996.46) = 3.72, $p<.001$. The results are presented in Figure 4.10. All participants spent more time practicing technical skills compared to any other activity. Participants spent less time in set plays and tactical and strategic decision making activities compared to supervised match-play. In addition, participants spent less time resting and in cross training activities compared to all other activities ($p<.001$). Moreover, elite players spent more time in tactical and strategic decision making activities when compared to sub-elite players ($p<.001$).

Discussion

The quasi-longitudinal approach used in this experiment provides a useful methodological tool for collecting current practice data from individuals at the highest age-related skill level. The discriminant analyses suggest that reports from the most recent year of participation are more likely to accurately reflect actual practice schedules for each respective age than their retrospective reports since the onset of participation. The cross validation analyses, the test-retest reliability data,

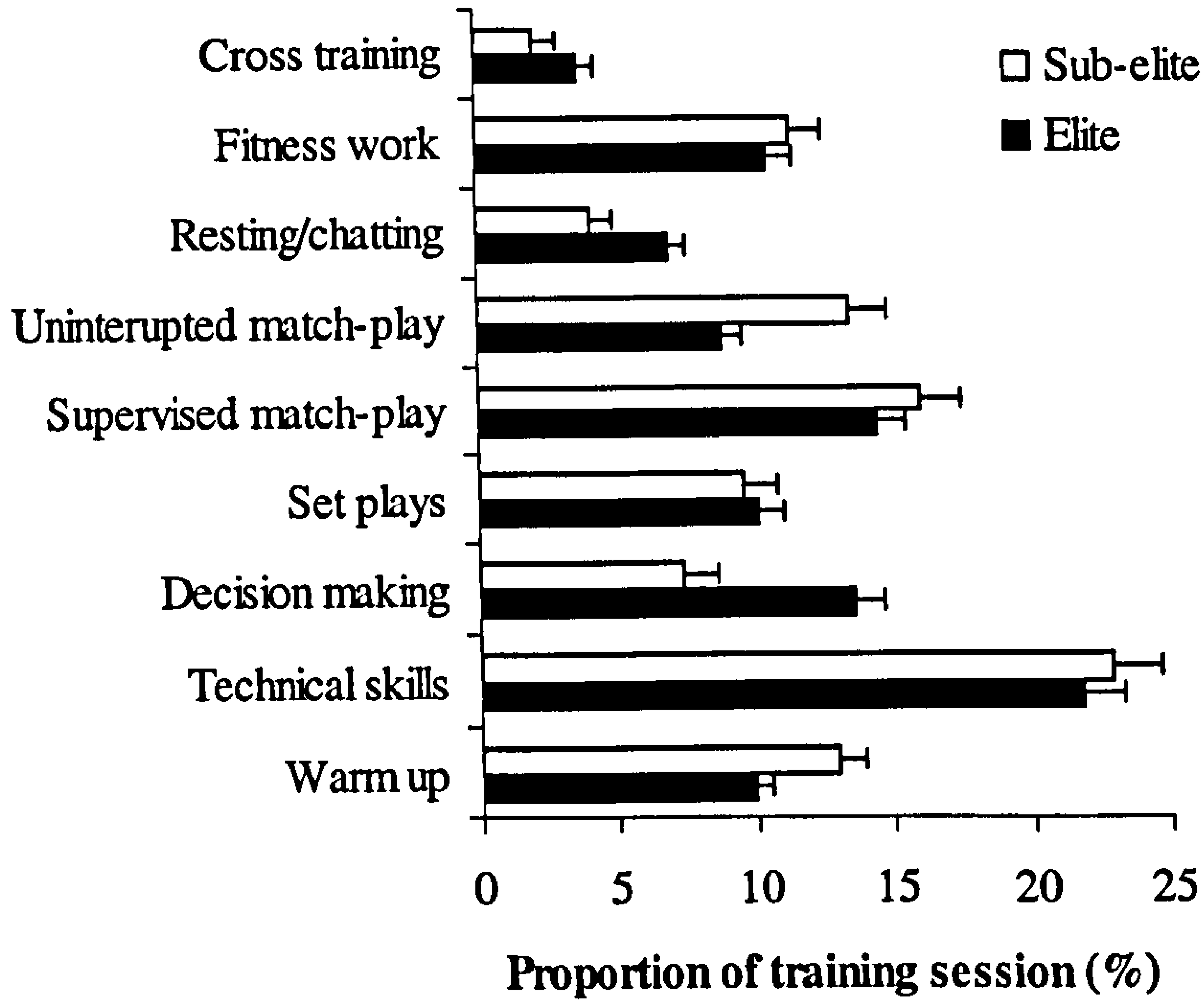


Figure 4.10. Proportion of time (SD) spent in each activity during a typical training session.

and to some extent the diary analyses, provide a reliable reflection of a typical week and support the fact that relevant data is accurately captured, at least, over the last five to six years of participation using retrospective reports.

Both skill groups reported participating in soccer (M age = 5.38 ± 1.77 years) and individual practice (M age = 6.61 ± 2.49 years) at a similar age. The earlier start in systematic 'team' training by elite players compared to their sub-elite counterparts (M age = 6.53 ± 1.93 and 7.60 ± 1.75, respectively) is consistent with previous research in swimming (Kalinowski, 1985), gymnastics (Kaminski, Mayer, & Ruoff, 1984), and music (Sonsiak, 1985). Within the current framework, a young starting age merely provides a head start and does not necessarily provide a good indicator of attained performance level. A head start needs to be proceeded by sustained and increasing amounts of deliberate practice (Ericsson, Tesch Römer, & Krampe, 1990).

As predicted, team practice in the most recent year of participation was the most consistent discriminator between skill groups and explained the majority of variance in skill. This finding is consistent with previous research in a team sport context (e.g., Helsen et al., 1998). When compared to previous research, the estimates of number of hours accumulated in practice activities are somewhat low. This is particularly evident when contrasted with Ericsson et al's (1993) suggestion that individuals require the 10,000 hours of deliberate practice before reaching expert levels of performance. Specifically, after 13 years of participation, including 12 years of systematic training, the U-18 elite group had accumulated 4542 hours in combined team and individual practice (of which 2484 were from team practice only) compared to 2100 hours accumulated by sub-elite players. After 13 years into their career, the international, national and provincial level soccer players examined by Helsen et al. (1998) had accrued approximately 6200, 5000 and 3900 hours respectively, in combined estimates of team and individual practice at 18 years of age. However, Helsen et al. (1998) included both maintenance- and improvement-type activities in their calculations suggesting that time spent in actual 'deliberate' practice may have been over-estimated. Moreover, more recent research suggests that elite and world class performance levels can be attained in as little as 3000 to 4000 hours of deliberate practice (see Baker et al., in press; Cote et al., 2002).

Although other variables made a significant contribution to the model, the highest standardized coefficient was typically reported for team practice. However, for the hours per week data, match-play, and playful activities were also significant contributors to the model. Where these variables played a role in predicting performance (see Table 4.2), elite players typically spent more time in match-play and less time in playful activities compared to sub-elite players. Time spent in individual practice was also intermittently included in the model for the accumulated hours data (see Table 4.3). In addition, no skill-based differences were evident in growth characteristics such as height and weight. Taken together, these findings lead to the suggestion that consistently spending time in team practice throughout development, together with some early experiences in match-play, provides an appropriate vehicle for skill progression. The sporadic contribution from individual practice suggests that this variable may enhance skill development for some participants, but it is not the sole or main contributor to the development of expertise in team-oriented domains. The quasi-longitudinal data suggest that, in line with data from Helsen et al. (1998), the number of hours per week spent in individual practice reduced as the number hours spent in team practice increased between 15 and 17 years of age. However, this effect was largely influenced by the results of the U-18 elite group and the remaining age groups did not typically reduce the number of individual practice hours in which they engaged. Rather a monotonic increase was generally observed across all of the elite age groups (except U-18). These findings may reflect the increasing awareness by the Academy system of the value of individual practice to the development of elite players.

While both skill groups engaged in substantial amounts of play during childhood and adolescence (see Figures 4.6 and 4.7), participation in these activities did not directly contribute to the attainment of elite performance or, at least, these activities did not discriminate between skill groups during the sampling years (7 to 12 years) as suggested by Côté and colleagues (2001). Conversely, those individuals who have accumulated, or currently spend less time in playful activities between 14 and 18 years of age are more likely to achieve elite status. This effect could credibly be a by-product of resource constraints. The effective time allocation to practice activities by elite players, or alternatively, a greater opportunity to engage in practice, as opposed to concentrating upon playful activities appeared to contribute to the skill difference. For example, the U-18 sub-elite players accumulated 2890 hours in playful, soccer-related activities, whereas only 998 and 1102 hours were invested in team and individual practice, respectively. In contrast, U-18 elite players spent only 1971 hours in playful activities compared to a much greater investment in team (2484 hours) and individual (2058 hours) practice. Other resource constraints (i.e., time spent in non domain-related activities) and motivational factors which could potentially impact the distribution of time spent in each activity are examined in Experiments 4 and 5.

The developmental assessment of activity ratings highlights the necessity to consider the differences between elite and sub-elite players at each age. Previous retrospective research using adult participants has found ratings of activities to be similar across skill groups (e.g., Ericsson et al., 1993; Helsen et al., 1998). However, the current experiment suggests that ratings of enjoyment are contingent upon both skill level and age. In particular, enjoyment ratings appear to be biased by outcome of the activity (i.e., win, score, perform well) as age increases, especially when rating improvement- (i.e., practical, soccer-skill specific) and maintenance-type activities (i.e., physical, soccer-training).

Tactical and strategic skills were the only activities that were rated by participants in a manner consistent with the original definition of deliberate practice activities (see Ericsson et al., 1993). That is, they were considered by the elite group to be highly relevant, physically effortful, and required high levels of concentration. Importantly, participants did not score these areas as highly on ratings of enjoyment. Starkes and colleagues (1996; Helsen et al., 1998; Hodges & Starkes, 1996) indicated that in physical performance-related domains such as sport, not only do individuals rate practice as enjoyable, they are more likely to persist within the activity as a direct result of such experience. Activities such as technical skills, being coached and match-play each fit into Starkes and colleagues' reclassification of deliberate practice activities (i.e., highly enjoyable) in varying degrees, although this is dependent upon age. Match-play was the only variable to score higher than average on enjoyment across *all* age groups. While the finding that this variable was perceived to be the most enjoyable activity by elite players is consistent with Starkes and colleagues' (1996) classification, and is potentially crucial to skill development (Singer & Janelle, 1999), this variable is not consistent with the original deliberate practice criteria (Ericsson et al., 1993). Ericsson and colleagues differentiated between work/competition, play and practice. In competitive environments (i.e., match-play), individuals are likely to continue to use currently effective yet potentially sub-optimal strategies as opposed to invest in learning new or refining old methods. The career participation history data (i.e., hours spent in each activity) indicate that investment in this activity, while potentially important, is not as crucial for the development of expertise as engaging in activities specifically designed to improve performance such as those highlighted by the ratings data (i.e., technical skills, being coached, tactical and strategic skills).

Conclusions from the activity ratings data is supported in part by the analysis of the microstructure of practice. These data indicate that during a typical training session all players invest more time in technical skills. The mere fact that elite players have spent more time in practice, particularly in a team environment, and hence more overall time in technical skills than sub-elite players, is testament to their current skill level. High proportions of time spent in supervised match-play (i.e., being coached) by all players (and hence more time spent in this activity by elite players as a consequence of a greater amounts of accumulated practice), and the greater amount of time spent practicing tactical and strategic decision making skills by elite players suggests that this group should be more advanced in each performance index. While the expected monotonic relationship is difficult to specifically test, the elite players' selection and continuance in the Academies and the superior performance of age-matched elite players on anticipation, decision-making, and game-related problem solving tasks compared to sub-elite players supports this assumption (see Chapter 2).

Experiment 4: General Participation in Sports, Games, and Other Physical Activities

The aims of this experiment were to examine the participation history of elite and sub-elite soccer players in physical activities other than soccer and to determine whether skill groups could be differentiated on activities such as practice, play, and match-play in other sports and games, and the onset and cessation of participation in each domain. The primary aim was to examine differences in sporting diversity and its influence upon skilled behavior within the specialist domain (i.e., soccer). Although previous research findings are not mutually exclusive, conflict arises as to the most effective nature of participation during early skill development. On the one hand, some authors suggest that an earlier start to domain-specific practice is more likely to lead to earlier attainment of elite level performance than those who start late (for a review, see Ericsson et al., 1993). Ericsson and colleagues' monotonic benefits assumption suggests that engaging in deliberate practice from an early age would lead to associated increases in performance within the domain of expertise. On the other hand, later specialization within a specific domain has recently been proposed to facilitate perceptual-motor development in general, and ultimately the development of expertise through increased diversity across tasks/domains (for a review, see Côté, et al., 2002). Extra-domain diversity (i.e., intellectual cross-training) has been shown to facilitate acquisition and transfer of cognitive skill (see Simonton, 2000). According to Côté et al. (2002), the facilitatory transfer mechanism is most likely to occur at a perceptual-motor level through the development of fundamental skills or movement schema which underpin more specialized or parameter-specific movements (see Gallahue & Ozmun, 1995). Accordingly, experience of those movements, tasks or domains which share identical elements with the specialist domain are likely to facilitate skill development in the latter (e.g., Osgood, 1949). Alternatively, transfer could occur at a perceptual-cognitive level, where performance on tasks that share similar attributions, higher-order relations, and higher-order predicates (i.e., tactical similarities) are likely to benefit performance in the specialist domain (for a review, see Reiss & Weisberg, 1997; also see Gentner1993). While the argument for diversity and transfer is conceptually appealing, the available empirical evidence in applied, physical or competitive contexts is sparse.

Resource constraints (e.g., available time/finances) are also likely to be a major factor limiting the number of activities in which individuals engage. Given that participants in this experiment were from the same socio-economic/socio-cultural population, it was expected that no differences would emerge in time spent in other activities, whether in practice, match-play or playful settings. However, we anticipated that elite players would spend a greater amount of time in structurally similar team sports, rather than dissimilar team or individual sports, games or activities.

Method

Participants

The participants used in this study were identical to those used in Experiment 3. Table 4.1 shows the mean age (± SD) of each group as a function of skill.

Procedure

As in Experiment 3, participants completed a questionnaire under supervision. Participants were requested to list all sports, games, and physical activities in which they had participated on a regular, weekly basis, over and above their mandatory involvement in physical education classes. Biographical information was then recorded regarding the age of entry into each activity, when regular practice began and when participation ceased (if applicable). Participants were also asked whether they considered each activity to be their main, or one of the main activities in which they engaged. The same participation history format as in Experiment 3 was used to examine the number of hours per week and accumulated hours spent in practice (i.e., team and/or individual), match-play, and playful activities across all activities. As in soccer, players were asked to rate activities on an 11-point Likert scale as to whether each activity was judged to be extremely playful in nature (0) or extremely practice oriented (10). Ratings of play/practice were requested for the first and final year of participation in each activity. To gain an additional measure of reliability to those gleaned from Experiment 3, questions pertaining to the onset of participation in soccer were rephrased and asked in this experiment.

Data Analyses

Two-way ANOVA was performed on the number of activities in which participants engaged with age and skill as the between-participant factors. Similar analyses were employed on the mean start age in other activities (excluding soccer), mean start age in regular practice activities in other activities, and the age at which the highest level was attained. The categorical variable 'highest level attained in other activities' was analyzed via a non-parametric rank-order technique using Puri and Sen's (1985) L statistic. Similarly, due to the diverse number of other activities in which participants engaged and the varied nature of onset and cessation of participation (which were non-normal in their distribution), the total number of accumulated hours spent in practice, match-play, and playful activities for all other activities was analyzed using the same non-parametric technique. Further descriptive analyses were performed on the activity type (i.e., similar team, dissimilar team, and individual) for each skill group. Team sports and/or activities were classified as similar or dissimilar based upon an a priori task analysis (see Smeeton et al., 2002). A three-way ANOVA was performed on ratings of play/practice with time (first/last year) as the within-participants factor. The start age in playful soccer activities reported in Experiment 1 was correlated with the age at which players commenced participation in soccer reported in this experiment using Pearson's product moment coefficient.

Results

Biographical Information for Others Sports

Only an age main effect was found for the number of activities in which participants engaged, F (8, 185) = 3.37, $p<.001$. On average, participants engaged in approximately three activities (including soccer) ($M = 2.97 \pm 1.32$), however, the U-17 group engaged in more activities ($M = 3.94 \pm 0.82$) compared to participants in the U-15 group ($M = 2.11 \pm 1.15$). In total, 78.2% of elite players engaged in activities other than soccer, compared to 82.4% of sub-elite players.

The analysis of participants' start age in other activities revealed a significant main effect for age, F (8, 163) = 15.68, $p<.001$. The U-9 ($M = 6.47 \pm 1.13$ years) and U-10 ($M = 7.45 \pm 1.18$ years) groups started participating in other activities at an earlier age than the U-14 (M = 9.83 ± 1.87 years) and older age groups ($p<.001$). Similar age-related trends were found for the age at which practice commenced in other activities, F (8, 163) = 19.93, $p<.001$. The U-9 group began practice earlier than all other groups (M = 7.02, SD = 1.26 years) ($p<.001$). The U-10 group also started practicing other activities earlier than the U-14 and older age groups (M = 7.80 ± 1.12; M = 10.35 ± 1.52 years, respectively) ($p<.001$). No skill-based differences were found for start age in practice or playful 'other' activities.

Elite participants attained a higher level in other activities when compared to sub-elite players, L (1) = 41.15, $p<.001$ (Elite M = 1.74 ± 0.52; Sub-elite M = 1.39 ± 0.49). However, this difference was minimal (1= recreational, 2 = school/amateur level). An age effect was also found for attained level, L (8) = 40.44, $p<.001$. There was a trend for the older groups to have attained a higher level (e.g., U-18 M = 1.90 ± 0.62) when compared to the younger groups (e.g., U-9 M = 1.36 ± 0.41). Again, this difference was marginal. Not surprisingly, the age at which participants attained their highest level increased with age, F (8, 163) = 34.17, $p<.001$ (M age = 6.98 to 12.92 for U-9 and U-18 age groups respectively). Participation in other sports continued for all groups until the present year, except for the U-17 and U-18 age groups, F (8, 163) = 363.79, $p<.001$. The U-17 and U-18 groups ceased participation in other activities at 16.02 (± 0.97) and 16.29 (± 1.37) years of age, respectively. There were no skill-based differences in the age at which players stopped participating in other sports.

Reliability. A significant positive correlation was found between the start age in playful activities (Experiment 3) and onset of soccer participation (Experiment 4) ($r = 0.96$).

Practice History in Other Activities (excluding soccer)

Figures 4.11 and 4.12 highlight the total number of accumulated hours in which elite and sub-elite participants respectively engaged in playful activities, practice, and match-play in other sports, games and physical activities (excluding soccer). A significant age main effect was found for the amount of accumulated time spent in practice only, L (8) = 51.25, p<.001. Irrespective of skill group, both the U-17 and U-18 groups participated in more non-soccer related practice compared to their younger counterparts. A Skill x Age interaction was not found for the number of accumulated hours of practice in other activities. Similarly, no significant differences were found for the amount of time spent in playful activities or match-play within other sports or activities. There were no significant differences between groups even when the total time accumulated in all other sporting activities was combined.

Given the possible differences in the amount of time spent in different types of other activities, further analysis of the data was performed based upon whether participants engaged in similar team, dissimilar team or individual activities. This preliminary descriptive analysis suggests that on average, the sub-elite participants accumulated approximately three times the amount of time in play, practice, and match-play activities in similar team sports and double the amount of time in playful activities in dissimilar team and individual activities than the elite players (see Table 4.13).

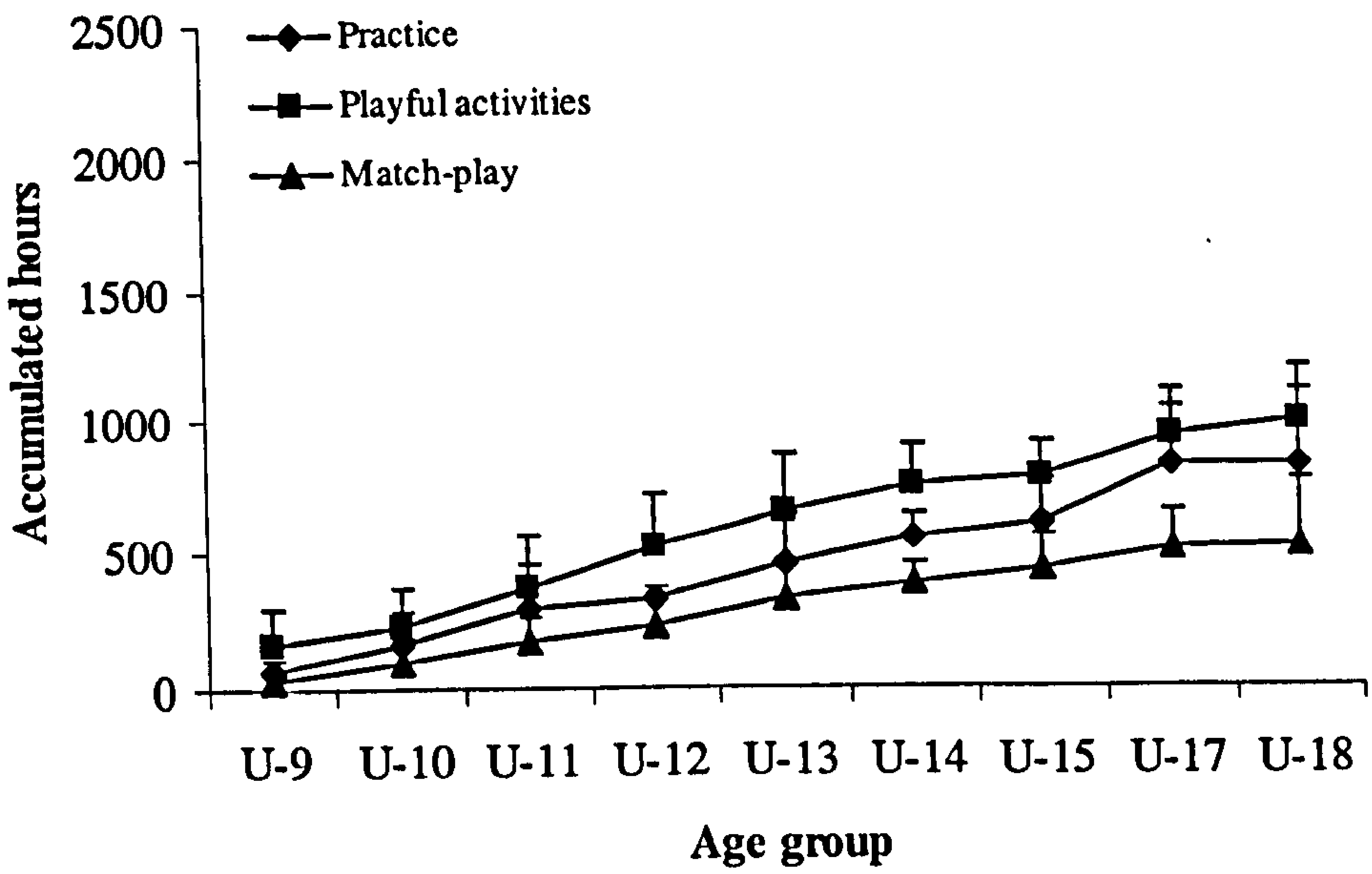


Figure 4.11. Total number of hours accumulated (SD) in playful activities, practice and match-play in other sports for elite players.

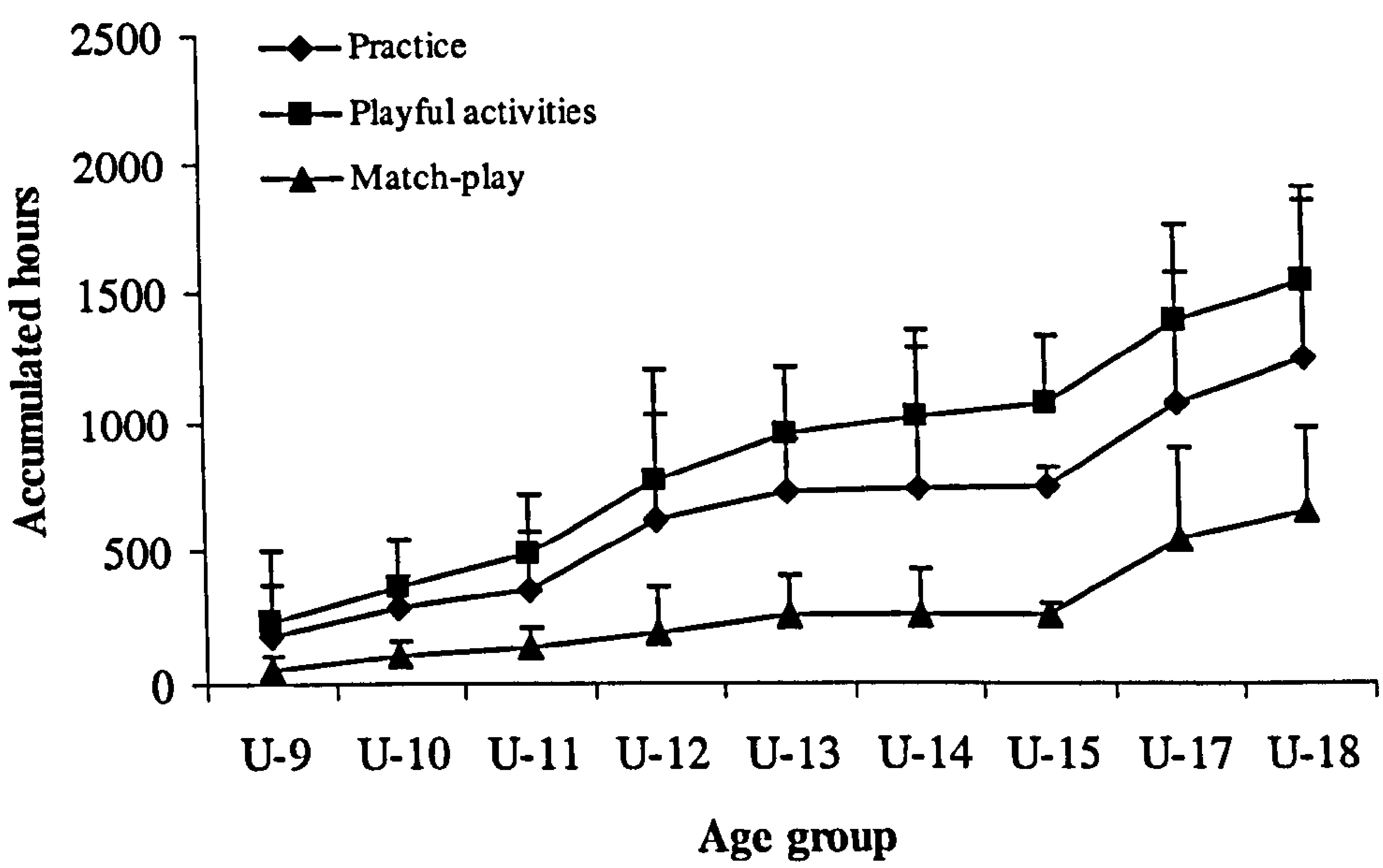


Figure 4.12. Total number of hours accumulated (SD) in playful activities, practice and match-play in other sports for sub-elite players.

Table 4.13. Mean number of accumulated play, practice, and match-play hours in other similar and dissimilar team sports and individual sports for each skill group

		Elite	Sub-elite
Similar team sports	Play	295.57	856.83
	Practice	241.31	1113.06
	Match-play	196.26	695.02
		(n = 11)	(n = 15)
Dissimilar team ports	Play	312.38	728.65
	Practice	503.16	539.00
	Match-play	426.63	650.84
		(n = 9)	(n = 31)
Individual sports	Play	599.39	851.17
	Practice	511.05	682.27
	Match-play	316.91	347.25
		(n = 60)	(n = 39)

Lastly, no differences were found between participants' ratings of activities as being either play or practice oriented in their first and last year. The Skill x Time interaction approached significance suggesting that there may be a trend for sub-elite players to engage in slightly more playful non-soccer activities during their last year of participation, F (1, 163) = 7.189, p = .007. Although the difference between groups was again marginal, elite players ratings were relatively stable over time (M = 5.12 ± 2.98; M = 5.32 ± 2.76, first and last year respectively) when compared to sub-elite players (M = 5.38 ± 2.78; M = 4.49 ± 2.59, respectively).

Discussion

As expected there was no advantage to either skill group in the range and extent to which participants engaged in other activities. Elite and sub-elite players began participating in other activities (M age = 8.67 ± 2.18 years) and commenced practice (M age = 9.19 ± 2.07 years) in these activities at similar ages. They participated in approximately three activities (including soccer) and both skill groups played at a comparable level. Consequently, the differences in diversity in terms of the number sports played and relative exposure in years appears to negligible, if at all apparent, contradicting Côté et al.'s (2002) claim that expert participants typically demonstrate greater diversity.

The analyses of accumulated hours spent in other activities allowed a more detailed examination of the diversity issue. While no meaningful differences emerged in the level and number of sports in which participants engaged, the amount of time spent in each activity could potentially elucidate greater diversity for either skill group. Skill-based differences were not observed in the time spent in practice, match-play, and playful 'other' activities, even when these activities were combined. The implication is that elite players are no more diverse in their pursuit of other activities than sub-elite players and consequently, gain no additional benefit from engaging in these activities. The descriptive assessment of time spent in similar and dissimilar team as well as individual activities showed that contrary to expectation, sub-elite rather than elite players spent greater amounts of time participating in similar team sports (i.e., similar to soccer). According to Côté (1999; Côté & Hay, 2002), children in the sampling years should benefit in their future domain of specialization from the amount of time spent 'deliberately playing' (i.e., in rule-based 'play', which is primarily determined by the participant's age), particularly where those activities share identical motor elements, or common procedural elements in more perceptual-cognitive tasks. However, the current standard of sub-elite players in all activities and lack of skill progression as age increased indicates that diversity, and in particular, playful activities in other sports did not necessarily contribute to expertise development within the domain of interest (i.e., soccer). It is likely that the type of practice in which participants engaged in other activities was not 'deliberate' or of the kind where relative improvements could have facilitated performance in another domain. The differences obtained in this experiment compared with Cote and colleagues' results may be partially due to cultural biases in the sample used and differences in the seasonal nature of activities in which participants engage.

Without the deliberate intention to improve, performance in the specialist domain is unlikely to be facilitated by time spent in other activities. Consequently, any benefits from diversity across a range of activities may be in general motor proficiency rather than in domain- or skill-specific improvements. Simonton (2000) argued that intellectual cross-training or diversity across domains may alleviate functional fixedness caused by excessive specialization. However, to date there has been no empirical verification of this doctrine in an applied setting beyond Cote and colleagues' research efforts. Recent research efforts within our laboratory which have examined related issues suggests that transfer from one sport to the next occurs only when tasks share tactical and structural similarity, or when participants could adapt or modify an established and appropriate strategy (i.e., strategy contained usable relational rules) to a new domain (see Smeeton, Ward, & Williams, 2002). However, the research by Smeeton et al. (2002)

examined only issues of transfer between similar and dissimilar sports and did not directly test those individuals who had experience of cross training in multiple domains compared to those who specialized early. Future research is needed to test such hypotheses.

With regards to specialization, few players ceased participating in any activity prior to, or in the current year of participation except for the U-17 and U-18 groups. Both skill groups at these ages demonstrated a shift towards concentrating on soccer at around 16 years of age, a timeframe which replicates the findings of Helsen et al. (1998). Specialization at 16 coincides with graduation from (mandatory) high school, where individuals have access to a number of activities, and then progress to other educational or vocational pursuits, or to full-time acceptance in a soccer Academy where contractual obligation necessitates specialization. By default, both skill groups specialize in only one activity (i.e., soccer) however, the reasons for specialization are completely divergent. Elite players invest and build on their experiences and practice to date, whereas sub-elite players find consolation in recreation (cf. Bloom, 1985; Côté, 1999).

Experiment 5: Motivations for Participation

The aim of the final experiment was to examine underlying motivations for participation in soccer and other activities. The original expertise framework emphasized the ability to sustain engagement in deliberate practice. An individual's commitment to such deliberate investment was considered one of the most distinguishing factors of skilled performance. Our primary aim was to examine participants' commitment to their domain of expertise and, given the discrepancies in previous research (see Starkes et al., 1996), to examine participants ratings of enjoyment at the onset and during the current year of participation.

Continued participation beyond recreational levels of performance and sustained commitment within an achievement domain throughout development is closely related to an individual's level of intrinsic motivation and perceived competence. Moreover, perceptions of competence are intrinsically motivating (Deci & Ryan, 1985; Ryan & Deci, 2000). When an individual can expect to master a challenging task they invest considerably more effort and are far more motivated than when engaging in a non-challenging task or have a low perception of self-competence (Lens & Rand, 2000). Lens and Rand (2000) suggested that "individuals like to do things they are good at and they also become good at things they like to do" (p.199). Accordingly, it was our aim to examine participants' ratings of perceived competence from first to last year of involvement.

Personal motives for participation were also examined. It was expected that elite players would invest more time and effort, be more dedicated, get more enjoyment from participation, and perceive themselves to be more competent in soccer activities than sub-elite players. Moreover, elite players would demonstrate more enjoyment and perceived competence in both the first and last year of participation in comparison to sub-elite counterparts. Differences in enjoyment and perceived competence were not expected in non-soccer related activities. Given the open-ended nature of the questions, ratings of personal motives were partly exploratory. However, elite players were expected to emphasize greater parental support during their career, and focus upon more intrinsic (e.g., self determination, skill improvement) and practice-related factors as opposed to external (e.g., to win) and solely enjoyment related factors.

Method

Participants

The same participants used in Experiment 3 were also used for this experiment. Biographical data are presented in Table 4.1.

Procedure

As per Experiments 3 and 4, participants completed a questionnaire under supervision. Motivations for participation in physical activity, and soccer in particular, were examined. Questions pertaining to player motivations in soccer were adapted from the Sport Commitment Model (Carpenter, Scanlan, Simons, & Lobel, 1993; Scanlan et al., 1993a, 1993b) and the Perceived Competence Scale (Harter, 1981). An 11-point Likert scale was used to assess players' ratings of both perceived competence and general levels of enjoyment from participating in each activity (including soccer) during their first and final year of participation. Using a similar Likert scale, time and effort (i.e., personal investment) spent in soccer practice, and the level of dedication (i.e., commitment) towards playing soccer were assessed. A scenario-specific (i.e., involvement alternative) question was used to assess participants' dedication to soccer by asking participants to choose between playing soccer and engaging in their most favorite other activity (i.e., 10 = other activity only, 0 = soccer only). In addition, participants reported the most influential person in their career, the most important factor perceived necessary for success in soccer, and the main reason for playing soccer during the last year of participation.

Data Analyses

Time/effort was assessed using a two-way ANOVA with skill and age as between-participant factors. Dedication, enjoyment, and competence were assessed using separate three-way ANOVAs. Situation (general/situation-specific dedication) was the within-participant factor for dedication, and time (first/last year) was the within-participant factor for both enjoyment and competence. Remaining variables were analyzed descriptively and reported as percentages.

Results

Motivations in Soccer

Participants' mean ratings of time/effort, dedication, competence, and general enjoyment are presented in Table 4.14. A significant skill main effect indicated that elite players (M rating = 9.58 ± 0.62) invested more time/effort in soccer when compared to sub-elite (M = 7.72 ± 2.48) players, F (1, 185) = 63.178, p<.001. Significant main effects for dedication were observed for skill, F (1, 185) = 85.37, p<.001, and situation, F (1, 185) = 35.24, p<.001. Elite players (M = 9.13 ± 1.99) rated their level of dedication higher than sub-elite (M = 6.58 ± 2.98) players. However, all participants' ratings of dedication decreased when specifically asked to choose between playing soccer (M = 8.56 ± 2.41) and their

Table 4.14. Mean motivational ratings for participation in soccer for each skill and age group

		Time/effort	Dedication		Competence		Enjoyment	
Skill	Age		General	Specific	First year	Last year	First year	Last year
Elite	U-9	9.40	9.93	7.33	5.33	8.53	10.00	9.47
	U-10	9.82	10.00	9.82	7.18	9.36	9.91	9.91
	U-11	9.83	10.00	9.67	7.25	8.88	10.00	9.92
	U-12	9.71	10.00	9.14	4.29	8.29	10.00	10.00
	U-13	9.47	9.80	7.71	5.60	8.80	9.73	9.47
	U-14	9.67	9.83	9.42	4.77	8.38	9.92	9.77
	U-15	9.61	10.00	6.67	4.22	7.78	9.44	9.67
	U-17	9.13	9.13	9.25	7.00	8.38	9.63	9.50
	U-18	9.58	9.67	7.50	4.25	7.42	9.83	8.67
Sub-elite	U-9	9.05	8.00	4.84	5.42	7.11	9.26	9.21
	U-10	8.54	8.54	7.08	4.23	7.23	8.35	8.92

U-11	7.10	6.70	6.90	4.33	7.83	9.83	9.58
U-12	7.13	5.88	5.63	5.25	6.00	8.38	8.38
U-13	7.86	6.57	7.14	3.88	5.75	8.88	8.75
U-14	5.45	4.91	4.27	3.45	5.27	7.91	8.09
U-15	8.00	7.70	6.10	4.10	7.30	9.10	8.90
U-17	7.70	7.80	6.10	6.60	8.10	9.70	9.10
U-18	7.50	7.90	6.20	6.00	8.20	9.90	9.50

other most favorite activity (M = 7.18 ± 3.02). A skill main effect was also observed for general levels of enjoyment in soccer, F (1, 185) = 19.96, $p<.001$. Elite players (M = 9.71 ± 0.67) rated soccer as slightly more enjoyable compared to the ratings of sub-elite players (M = 9.01 ± 1.82), although the difference between groups was small.

Analyses of competence revealed main effects for skill, F (1, 185) = 18.34, $p<.001$, and time, F (1, 185) = 181.98, $p<.001$. Elite players (M = 7.01 ± 2.48) perceived themselves to be more competent at soccer than the sub-elite players (M = 5.94 ± 2.75), although both groups' perceptions of competence increased from their first (M = 5.20 ± 2.52) to last (M = 7.75 ± 2.18) year of involvement. The Age x Skill interaction also approached significance, F (8, 185) = 2.89, $p = .005$. There was a trend for the elite players' ratings of competence to be higher at the younger age groups only (U9 to U-14 elite M = 7.40 ± 2.44; sub-elite M = 5.83 ± 3.15).

Altogether, 84.2% of elite players rated their parents as the most influencing person in their career compared to 43.6% of sub-elite players. The coach or teacher was attributed to be the most influential person by 10.8% and 9.7% of elite and sub-elite players, respectively. A total of 43.6% of sub-elite players attributed other people such as friends, or family members (e.g., uncle, cousin), as being the most influential person in their career compared to 5.1% of elite players. Elite players generally considered practice and high levels of motivation to be the primary factors necessary for success, whereas sub-elite players perceived practice, skill, and team-work to be most important (see Table 4.15). Moreover, elite players' main reason for playing in the current year was to improve their skill level, whereas, the majority of sub-elite players primarily focused upon enjoyment (see Table 4.16).

Table 4.15. The most important factors rated as necessary for attaining success by elite and sub-elite players expressed as a percentage (%)

Factor	Elite	Sub-elite
Motivation (i.e., desire to win, attitude, dedication, determination)	26.61	11.88
Skill	9.17	25.74
Practice	36.70	23.76
Talent	5.50	6.94
Coaching	5.50	4.95
Teamwork	2.75	20.79
Hard work, physical effort	3.67	2.97
Enjoyment	8.26	2.97
Luck	0.92	4.95
Other	0.92	0.99

Motivations in Other Sports

No significant effects were found for participants' enjoyment in other sports. The mean rating of enjoyment in sports other than soccer across all players was 7.97 (± 1.71). A main effect for time only was found for competence, F (1, 163) = 29.82, $p<.001$. All players increased their perceived competence from first (M = 5.65 ± 2.07) to last (M = 6.74 ± 2.06) year of participation.

Table 4.16. Elite and sub-elite players' main reason for playing in the current year expressed as a percentage (%)

Reason	Elite	Sub-elite
Current team selection	5.45	0.91
Play at a higher level	20.00	10.00
Improve skill level	40.90	20.90
Win	10.91	17.27
Enjoyment	28.18	46.36
Competition	2.73	1.82
Physical training	0.00	2.73
Job	0.91	0.00

Discussion

As anticipated, elite players invested more time/effort in, and were more dedicated to, their specialist domain than the age-matched sub-elite players. The current data also suggest that ratings of dedication may be inflated unless participants are given a situation specific example to work with. Elite players gained more enjoyment from participation than sub-elite players, however, differences were minimal. While the greatest skill-based differences were apparent in variables directly reflecting commitment (i.e., dedication) or personal investment (time/effort), enjoyment received the highest rating by both groups. The present findings are consistent with Scanlan et al.'s (1993a) model of commitment suggesting that enjoyment is an important construct in motivating youth players into continued participation. In examining elite performance, Scanlan and Simons (1992) highlighted that enjoyment was also a principal factor in distinguishing between skill groups. However, the current data suggest that the appreciable differences in dedication and time/effort between skill-groups may reveal a more promising distinction between groups. While enjoyment may be a crucial antecedent of commitment, a player's dedication and the time/effort (deliberately) invested in an activity may play a greater role in accounting for differences in the development of expertise (cf. Ericsson et al., 1993). Further more although the consequences of commitment are not necessarily well represented in Scanlan et al.'s (1993a) commitment model, these factors may provide some initial insight in this regard. Further research is needed to clarify these issues.

The perceived competence data highlight important motivational differences between elite and sub-elite players and provide some explanation of the differences in time/effort invested in soccer. Elite players perceived themselves to be more competent than sub-elite participants and are therefore more likely to invest time in challenging tasks. Where deliberate efforts to improve are made in this regard, progression toward skilled behavior should be made. As mastery attempts turn into actual competence, increases in perceived competence are likely to occur (Harter, 1982). This effect was seen in both groups as perceived competence increased with age. While marginally non-significant ($p = .005$), the observed trend for younger elite players to be more competent than sub-elite players between 9 and 14 years of age indicates the potential for greater success and improvement by the elite group in the earlier stages of participation than the sub-elite group. The lack of differences in perceived competence in other sports is likely to reflect the similar performance level attained and similar amount of accumulated experience across skill groups in these activities.

The different ways of perceiving competence and success typically manifest themselves in a player's task or ego goal orientation. Those individuals who are more task oriented are often likely to stay motivated even under adverse conditions. Similarly, when successful, ego oriented individuals are likely to exhibit comparable behavior. However, if unsuccessful, the latter may be more prone to withdraw from the situation, reduce on-task effort, or engage in negative behavior to preserve their perceived ability. Multidisciplinary research using 15-16 year old soccer players suggests that ego-orientation was amongst the most predictive factors of elite performance (Reilly, Williams, Nevill, & Franks, 2000). However, at a younger age, the promotion of task orientation may well avoid less mature children experiencing negative perceptions of competence or ability. Moreover, a motivational climate which meets the needs of both task and ego oriented individuals is most likely to maximize the chances of increased perceived competence (see Duda, 1995; Roberts, Treasure, & Kavussanu, 1996).

Elite players nominated their parents as the greatest influence on their career, thereby providing support for the notion that nurturing social environments, and particularly, parental support and encouragement in the early years, are likely to facilitate performance and skill acquisition throughout development (Bloom, 1985; Côté, 1999; Csikzentmihalyi et al., 1993; Schneider et al., 1993). When compared to the sub-elite participants, elite players considered high levels of motivation and practice to be factors which were vital for success in soccer. Their greater focus upon (deliberately) improving skill level provides an adequate reflection of the necessary requirements for attaining expertise.

Chapter 4: General Discussion

The aims of this chapter were to examine the relative contribution of domain-specific, deliberate team and individual practice, deliberate play, and match-play to the development of expertise, the role of diversity across domains and subsequent specialization, and the underlying motivations for commitment to the domain and ultimately for attaining elite levels of performance. In addition, a novel methodology was proposed for collecting career participation history data allowing cross-validation of retrospective reports across each successive age group.

An important finding was the consistent contribution of team practice from the most recent year of participation (e.g., hours per week and accumulated hours) to the difference in attainted performance between skill groups. Consistent with previous research in team sports, the data indicate that team practice may be the most useful participation variable to discriminate elite from sub-elite players (cf. Helsen et al., 1998). According to the present research, those who primarily invest more time and effort in to this activity are more likely to progress toward expertise. Even at very early stages of participation, elite players could be discriminated from sub-elite individuals on time spent in team practice. Examination of the U-9 group, for instance, suggests that participants were differentiated from as early as 8 and 9 years of age on hours per week and the total number of hours accumulated in team practice, respectively. This difference was apparent even though the U-9 elite group had accrued only an additional 70 hours in team practice and participated for an additional 1.5 hours per week at 9 years of age than the sub-elite group. Although the current data indicate that this age group can hardly be classified as experts (e.g., approximately 4 years in domain, 3 years in systematic practice), the continued investment in team practice beyond their sub-elite counterparts clearly demonstrates marked differences in the acquisition process along the road to excellence. An interesting observation in this regard is the gradual and continued increase in hours per week spent in team practice compared to other activities. Time spent in deliberate 'team' practice by elite players increased slowly from 3.14 to 11.67 hours per week, with an exponential rise between 15 and 17 years of age. Ericsson et al. (1993; Ericsson, 1996) pointed out that the adaptation process necessary to habituate oneself to extensive amounts of deliberate practice may be relatively slow. The necessity of gradual and continued increments in the amount of time spent in deliberate practice per day in order for expertise to be attained was supported by Starkes et al. (1996). For instance, these authors noted that individuals in sporting domains spent between 15 and 30 minutes in the first year to 4.5 hours per day after 10 years. Although time spent in team practice is principally controlled by the Academy, our data suggest that the training system currently employed may be effective in allowing players to adapt to the continued demand of deliberate practice activities.

Compared to previous literature, estimates of accumulated hours in deliberate (team) practice are relatively low, particularly when contrasted with the 10,000 hours benchmark approximated by Ericsson et al. (1993). After 13 years of participation, including 12 years of systematic training, the U-18 elite group had accumulated 4542 hours in combined team and individual practice (of which 2484 were from team practice only) compared to 2100 hours accumulated by sub-elite players. After 13 years into their career, the international, national and provincial level soccer players examined by Helsen et al. (1998) had accrued approximately 6200, 5000 and 3900 hours respectively, in combined estimates of team and individual practice at 18 years of age. However, Helsen et al. (1998) included both maintenance- and improvement-type activities in their calculations suggesting that time spent in actual 'deliberate' practice may have been over-estimated. More recently, Soberlak (2001 cited in Côté, Baker & Abernethy, 2002) and Baker et al. (in press) reported similar amounts of accumulated practice to the findings presented in this paper. These authors highlighted that professional and world class elite athletes had accrued only 3072 and 4000 hours respectively, after investing 13 and 14 years in sport-specific deliberate practice.

Figure 4.6 and 4.7 indicate that time accumulated in soccer-related playful activities appears to be a dominant activity in which all individuals engage during skill development. While time spent in deliberate play is potentially functional for perceptual-motor and perceptual-cognitive skill development, elite and sub-elite players were not consistently differentiated on this activity. Where groups could be discriminated on this variable, elite players invested less time compared to sub-elite players. Consequently, the suggestion that deliberate play was an important contributor to expertise development, particularly during the early years, was not supported (cf. Baker et al., in press; Côté & Hay, 2002; Côté et al., 2001, 2002). In the absence of sufficient team practice, those participants who invested time in playful activities (i.e., sub-elite group) attained only recreational levels of performance. The true contribution of this variable cannot be fully examined without examining individuals that did not engage in playful activities yet engaged in practice and attained elite levels of performance.

The issue of diversity and transfer of skill from one activity to the next is an important one in this regard. Participating in a greater number of activities at an early age is assumed to reduce the number of practice hours necessary to attain expertise within a specialist domain (see Baker et al., in press). However, the current data do not support this doctrine. No differences were found in the number of sports in which participants engaged and the amount of time spent in practice, match-play or playful activities related to other domains. Moreover, descriptive analyses of the data indicate that sub-elite players may even spend more time in similar team sports than elite players. It appears that without the deliberate intention to improve (assumed here through the lack of progression or relatively low standard at which all players participated in other activities) no amount of time spent in other activities would facilitate performance within the specialist domain. Consequently, any benefits from diversity across a range of activities may be in general motor proficiency rather than in domain- or skill-specific improvements. In addition, one has to ask the question whether intentional and deliberate practice within other activities (i.e., diversity) would facilitate performance within the domain as much as actual domain-specific performance? Simonton (2000) argued that intellectual cross-training or diversity across domains may alleviate functional fixedness caused by excessive specialization. However, this proposal remains to be empirically tested. In an applied memory recognition task recently conducted within our lab, transfer occurred only when tasks shared tactical and structural similarity, or when participants could adapt or modify an established and appropriate strategy (i.e., strategy contained usable relational rules) to a new domain (see Smeeton et al., 2002).

The higher ratings of time/effort and dedication from the onset of participation suggest that elite players develop a ‘rage to master’ from an early age. Higher levels of perceived competence from an early age suggest that this construct is acquired, potentially as a consequence of successful mastery attempts in the early stages of learning. When a task is challenging and successful mastery is achieved, the increased intrinsic motivation that accompanies greater perceived competence is likely to mobilize commitment toward the domain, where opportunity for, and engagement in, deliberate practice monotonically affects performance. As indicated by Ericsson et al. (1993), high levels of motivation and commitment to deliberate practice appear to be a pre-requisite for sustained improvement and attainment of expertise. Without its presence, the contributory factors to the development of expertise are likely to remain dormant (Sternberg, 2000).

At first glance, high ratings of enjoyment may serve to reinforce Scanlan et al.'s commitment model. As Starkes et al. (1996) suggested, individuals who excel in physically oriented domains are more likely to rate participation in such activities as enjoyable. However, unless ratings of enjoyment can be validated either via a behavioral index or by determining whether enjoyment is gained from actual participation or its outcome, only limited information can be determined from such ratings. The present data suggests that there is a shift in enjoyment rating from being process- to product-focused as age increases, indicating that both Scanlan et al.'s (1993a) view of enjoyment in commitment terms, and Ericsson's view of enjoyment as it relates to deliberate practice can both be supported. At an older age, individuals may gain enjoyment from the activity, albeit based upon the outcome (e.g., good performance) or result (e.g., win), though may not find actual practice inherently enjoyable as they progress toward expert levels of performance. This perception could also be fostered by a coach who may become more outcome-driven or ego-oriented with older age groups.

The methodology employed in this paper provides a tool for comprehensively assessing the skill acquisition process and the development of expertise. Not only does the current design allow retrospective reports to be recorded at each age in the developmental process, but also allows cross-validation of retrospective estimates from older individuals with reports from younger individuals' current year of participation. Consequently, the data provides both a synopsis of each individual's participation history at each age and level of expertise and a reliability check to determine the accuracy of the most recent and previous reports. One has to assume, that the current learning model (i.e., progression through the Academy) accurately reflects the 'usual route' that an individual would follow to become an expert within that domain. Appraisal of current domain-specific experts suggests that with few exceptions those who reach the highest level progress through the current system from an early age. It is our contention that the present data provides a more complete picture of expertise development than previously presented, in terms of quantifying practice variables which promote skill acquisition and identifying when such variables contribute to skill development. The current model also provides an excellent method for predicting group membership based on participation. For example, the discriminant analysis model in this study accurately predicted skill group membership for between 85 and 95% of individuals, dependent upon age. Moreover, between 56 and 76% of the variance was explained by the current model indicating that this was a powerful tool for quantifying and predicting expertise development.

In summary, the quasi-longitudinal approach used in this program of work offers a valuable method of quantifying and predicting elite performance and a useful methodology for future research in various domains. Moreover, this approach provides a robust estimate of time spent in each activity. Of all the activities assessed, only team practice in soccer consistently discriminated between skill groups. Although participants engaged in a large amount of playful activities during the early years of participation, this activity did not discriminate between skill groups and consequently, did not appear to directly contribute to the development of expertise in the current sample. The data also indicate that diversity without specific intention to improve performance through deliberate practice may be of little use in contributing to the expertise effect in another, albeit similar domain. Elite players' higher levels of motivation, commitment, and enjoyment suggest that from the onset of participation elite players possess or develop the prerequisite characteristics necessary for success within the domain of soccer.

Chapter 5

Epilogue

Attaining the dizzy heights of expertise is the ambition of many an individual across a host of performance domains. However, few athletes, artists, musicians and other performers manage to scale such pinnacles of success. Researchers have deliberated about how elite levels of performance are achieved for centuries, and the components of expertise have all but been left to the mystique that the notion of talent has to offer. Consistent with this doctrine, many psychologists ascribe to the view that basic abilities are sufficient to explain expert performance (see Sternberg & Wagner, 1999). However, deviating from this assumption, Ericsson and colleagues (Ericsson 1996; Ericsson & Charness, 1994; Ericsson & Lehmann, 1996) advocated that, not only is expert performance a product of domain-specific knowledge and skill, but the structure and acquisition of expertise are fundamentally different than originally considered. The three step approach to studying expertise was conceived to empirically examine these issues (Ericsson & Smith, 1991). While previous research in sport, and particularly in soccer, has adopted one, or at best, two of these steps as independent entities (e.g., Helsen & Starkes, 1999; Helsen, Starkes, & Hodges, 1998), to date, there has been no integrated attempt to examine pertinent issues by examining each step within a single program of work. The aim of this thesis was to pursue this goal. Specifically, the focus was on perceptual-cognitive expertise and the ability to 'read the game' successfully. Only by considering each step of the expertise approach in the context of the larger framework can the structure and acquisition of expertise be fully understood (Ericsson, 2001).

The Expertise Approach - Step One

The first step of the expertise approach suggests that under standardized conditions, the characteristics of expert performance should be examined via the design of representative laboratory-based tasks. However, in order for the essence of expertise in each task to be elucidated, not only should representative tasks differentiate across skill groups, but the defining components of the task need to be explicitly identified (Ericsson & Smith, 1991). In chess, for instance, expert memory may be assessed by asking individuals to recall the positions of chess pieces, however, the best task for capturing expert chess performance is to ask players to select the next best move (de Groot, 1978, Ericsson & Kintsch, 2000). This approach is relatively uncontroversial, however, examines performance specifically as a function of task constraints as opposed to an otherwise independent construct.

Previous research has successfully characterized skilled perceptual-cognitive expertise in soccer using both unidimensional (e.g., Williams & Burwitz, 1993) and multidimensional approaches (e.g., Helsen & Starkes, 1999). However, rarely in sport, or in other domains, has the development of perceptual-cognitive expertise been characterized using a multidimensional approach. These issues were examined in Experiment 1 using elite and sub-elite soccer players between 9 and 18 years of age. As a secondary aim, the issue of whether developing experts could be more accurately characterized by basic visual abilities or task-specific skills was also examined. While comparisons have been made on adult populations (e.g., Abernethy et al., 1994; Helsen & Starkes, 1999; Starkes

1987), the question of which variables are most discriminating of expertise during its development have yet to be answered. The findings of this experiment suggest that developing elite and sub-elite players were generally not differentiated by basic visual abilities and these variables did not significantly contribute to the discriminant analysis model. Rather, as early as nine years of age, elite soccer players could be discriminated on perceptual-cognitive factors of expertise such as anticipating an opponents' actions and identifying key player involvement in an attack against the defensive goal. Participants' performance typically increased with age and elite players generally outperformed sub-elite participants on most tasks. While recall did not contribute to the discriminant model for skill, elite participants' significant increase in recall performance between 15 and 17 years of age, beyond sub-elites, suggested that elite players had started to develop a more organized and accessible, encoding and retrieval system compared to their sub-elite counterparts. The general pattern of data across all variables suggested that elite players can effectively utilize and integrate contextual information with expectations stored in memory in ways that systematically differ from their sub-elite counterparts. This description is consistent with previous explanations of skilled performance in soccer (e.g., Williams, 2000), sport (e.g., French & McPherson, 1999), and expertise in general (e.g., Ericsson, 1998), and extends current findings to the development of perceptual-cognitive expertise in soccer. Moreover, this explanation is consistent with contemporary theoretical viewpoints. For instance, in their theory of long-term working memory, Ericsson and Kintsch (1995) suggested that experts acquire skills that promote both rapid encoding of information in long-term memory and allow selective access to this information when required. From this perspective, with extensive practice, experts are proposed to index information in such a way that they can successfully anticipate future retrieval demands and use pointers or retrieval cues in short-term memory to facilitate access. These flexible representations acquired by elite participants allow adaptation to the changing situational demands in scenarios such as those presented during Experiment 1.

The Expertise Approach – Step Two

Theoretical credibility for this viewpoint is evident from related empirical work (e.g., Ericsson & Polson, 1988), however, appending a plausible explanation *a posteriori* assumes that the hypothesized mechanisms and processes reflect actual task performance in soccer without first subjecting such hypotheses to empirical falsification. The aim of Experiment 2 was to examine the nature of processes underlying elite soccer performance using the methods detailed in the second step of the expertise approach. Research focusing upon process measures, particularly visual search in soccer, has attempted to answer related questions (e.g., Helsen & Pauwels, 1993; Williams & Davids, 1998). This research has primarily highlighted characteristic perceptual strategies adopted by elite players that have been assumed to reflect both the extraction of task-related information for purposes of perceptual decision-making, and the processing demands placed upon an individual (see Abernethy, 1985). The inequality between the locus of fixation and attention indicates that this approach may not provide specific detail regarding the exact nature of information scrutinized and may need to be supplemented with a richer source of data to fully express the potential that eye-movement registration techniques can offer (Abernethy, 1988; Davids, 1984; Williams, Davids, Burwitz, & Williams, 1993). Williams and Davids (1997) supported this conclusion and suggested that eye movement data should ideally be collected in conjunction with verbal reports, particularly when examining tasks which require the use of peripheral vision to extract task relevant information. Moreover, these measures alone may provide a more substantive, albeit indirect, examination of the perceptual-cognitive processes underlying elite performance (see Ericsson & Simon, 1980; 1993).

Much debate preceded the acceptance of verbal reports as data. A suggestion was that introspective methods were unnecessary and should be superceded by behavioral observation (Watson, 1913). More recently, verbal reports have been proposed to be largely epiphenomenon of the task (Nisbett & Wilson, 1977). While these objections were made, often in line with current trends in scientific inquiry, in his 50th aphorism, Sir Francis Bacon (1620), an advocate of an inductive method of modern science, highlighted that:

> "...by far the greatest impediment and aberration of human understanding arises from the dullness and inadequacy and deceptions of the senses, in that those things which strike the senses outweigh things which, although they may be more important, do not strike it directly. Hence, contemplation usually ceases with seeing, so much so that little or no attention is paid to things invisible..."

Accordingly, direct access to heeded information in short-term memory via verbal report procedures, and indirect access to cognitive processes may well provide access to those 'important, yet invisible things'. The instruction to talk or think aloud, a skill thought to be part of every individual's repertoire, has demonstrated that previously perceived difficulties in verbalization techniques can be eliminated (see Ericsson & Simon, 1993). In the context of the formal models of thought initially proposed by Newell, Shaw, and Simon, (1958; see also Newell & Simon, 1972), verbal reports are now generally recognized as a major source and indicator of cognitive processing (Anderson, 1987).

In addition to performance measures, verbal report procedures were employed in Experiment 2 using an adaptation of the most representative and discriminating tasks to emerge from Experiment 1. Measures of anticipation and situational probabilities were adapted to incorporate both free and cued recall conditions to further elucidate the content of thoughts in short-term memory and processes underlying skilled performance. Given the complexity of the task, and that recall-type tasks are more predictive of anticipatory skill in adult soccer players (Williams & Davids, 1995), as opposed to young children (cf. Experiment 1), the adapted task was implemented using adult soccer players, allowing a preliminary insight to be gained into more developed cognitive processes underlying skilled performance. Given that no previous research has examined the use of verbal reports in a representative soccer task, or has integrated this approach with the task manipulations employed across all domains, the research findings from Experiment 2 make a novel contribution toward understanding the processes underlying skilled performance in soccer.

Experiment 2 adopted the information processing framework for giving verbal reports delineated by Ericsson and Simon (1980; 1993) and introduced in Chapter 3. This experiment was partly exploratory to determine the nature of perceptual-cognitive strategies employed by adult soccer players. The aim was to examine whether the processes previously proposed in analogous domains (see Charness et al., 2001; de Groot, 1978; Newell & Simon, 1972, Shannon, 1950) could be extrapolated to the dynamic context of soccer. The task of 'reading the game' in soccer was hypothesized to be much less search oriented than chess, and far more oriented toward perceptual-recognition processes. The data suggested that elite players were superior at encoding familiar patterns of play in short-term memory and could utilize these pointers (i.e., retrieval cues) to aid recognition of task-relevant information from long-term memory in both free and cued recall conditions. Anticipation was based mainly on perceptual-recognition based processing, whereas the identification of all key players and option prioritization was more representative of a combination of recognition and search-based processing. Specifically, the verbal report data revealed that superior representative task performance was biased towards the use of recognition-based processing.

While search-based processing was evident in the form of subsequent predictions and concomitant evaluations suggesting greater width of search than sub-elite counterparts, the lack of planning behavior indicated that, unlike chess, search was restricted to a depth of only one step in advance of the current action. Moreover, the degree to which elite participants' evaluations showed a positive propensity indicated that search was primarily used as a confirmatory process for recognized options, and only used for discovery purposes when a clear alternative was not perceived. In contrast, only a limited number of sub-elite participants utilized the perceptual-recognition strategy, and the majority of these players primarily relied upon search and discover tactics. This data is the first attempt to delineate the processes underlying expert performance in soccer using methods described by the second step of the expertise approach. Moreover, this data empirically support an adapted interpretation of skilled performance from that used in chess. Specifically, the balance in favor of perception and memory processes appear to be equally as, if not more important than search-oriented processes. However without the latter, effective monitoring and evaluation is unlikely to ensue (cf., Charness et al., 2001; de Groot, 1978; Ericsson & Delaney, 1999).

The findings of this study are also consistent with McPherson's (199a; 199b) interpretation of skilled performance in tennis using verbal protocols. Not only do elite players have greater and rapid access to more extensive problem representations, the skills with which they access this information appear more developed and reflective of experts in other sporting domains (for a review, see French & McPherson, 1999). The time constrained nature of sports performance in general may require rapid access to information stored in long-term memory, superior monitoring skills to detect changes in salient contextual information, and appropriate evaluation of that information to make on-line modifications to option prioritization. These strategies are likely to be much more productive than solely searching numerous consecutive moves in advance of the current action. Moreover, such a strategy may be redundant given the highly dynamic context of sport. If expertise were solely a product of planning and searching multiple steps ahead, and choosing an appropriate option based upon reviewed plans conjectured from the current situation, momentary advantages are likely to be lost, and strategy modification, and ultimately, adaptive expertise, would be problematic to achieve.

<u>The Expertise Approach – Step Three</u>

The general consensus is that a high degree of practice extending over a decade or so is required to attain expert levels of performance, and is necessary to acquire the knowledge and memory skills described above (Simon & Chase 1973; Ericsson et al., 1993; French & McPherson, 1999). However, data from

Experiment 1 suggested that a limited degree of specialized training and deliberate practice could promote the acquisition of perceptual-cognitive skills that typically reflect expert performance, even at nine years of age. To examine the issue of acquiring skilled levels of performance, the process of expertise acquisition was examined in Experiments 3, 4, and 5 using elite and sub-elite participants between 9 to 18 years of age. This examination constituted the third and final step of the expertise approach. Following the seminal work of Ericsson et al. (1993), a number of authors have examined the issue of acquiring expertise in sport (e.g., Hodges & Starkes, 1996; Starkes et al., 1996), and specifically soccer (Helsen, Starkes, & Hodges, 1998), using an adult population.

Contrary to original findings these authors suggested that deliberate 'team' practice was more predictive of expert sport performance than individual practice. Moreover, the skilled athletes tended to enjoy engaging in deliberate practice, whereas, original proposals had suggested that activities of this kind would not be inherently enjoyable. Despite the evidence in favor of attained expertise being a function of the amount of deliberate practice in which one engages, and the relatively early start and specialization of many elite athletes, Cote and colleagues (2001; Cote & Hay, 2002) suggested that deliberate play (i.e., rule-governed playful activities engaged in for fun) would be fundamental to the development of initial cognitive and movement skills and would allow the construction of preliminary representations that are required for expert performance to ensue. Moreover, Cote noted that elite athletes often specialized later than expected (e.g., 13 to 16/17 years of age). These authors therefore hypothesized that the development of expertise prior to specialization would be characterized by deliberate play whereas in later adolescence, post specialization, structured adult-type deliberate practice would be more beneficial.

In addition, a number of methodological issues needed to be addressed to determine the reliability and validity of the data typically recorded through retrospective questionnaires. For instance, Deakin and Cobley (2002) suggested that what athletes report doing may not reflect what they actually do and so when one asks an athlete to retrospect over numerous years the guarantee of gaining reliable data is considerably diminished. Moreover, an individual's ability to sustain engagement, and their respective commitment and motivation toward a domain has been only minimally addressed (see Scanlan et al., 1993a). These issues were examined in Chapter 4.

The data from the analysis of the third step of the expertise approach indicated that, consistent with previous research, deliberate 'team' practice was most reflective of elite level performance. However, the novel quasi-longitudinal design employed in these experiments extended previous findings and demonstrated that team practice, particularly in the most recent year of participation, was the main and often sole discriminating variable in all elite players from nine years of age onwards. Moreover, this variable was capable of predicting group membership for 85.3 to 94.9% of the participants. While all players engaged in more technical skills practice, the only variable to differentiate between skill groups in a typical practice session was the time spent in tactical and decision making activities. These findings, and the absence of any growth-related maturation differences, provided significant support for the superior anticipation and situational probabilities skills revealed in Experiment 1, and use of perceptual-recognition processes to sub-serve such skills identified in Experiment

2, being acquired through the process of deliberate practice. Cote and colleagues' (2001) assumption that younger elite players would engage in greater amounts of deliberate play was not supported. Moreover, no evidence was found for acquired levels of skill being a product of greater sporting diversity or later specialization. In addition, elite players were found to be more competent, dedicated, and perceived that they invested more time and effort in soccer than sub-elite counterparts. Ratings of enjoyment were also greater for elite players supporting the work of Starkes and colleagues (1996), however, where younger players gained greater enjoyment form the process of playing soccer, elite players' enjoyment was dictated more by the outcome of the activity. The quasi-longitudinal design used in this study allowed the data from each group to be cross-validated with the retrospective reports from older age groups. This approach provided an alternative method of providing reliability and suggested that retrospective techniques were reliable, at least for the last five years.

The research findings suggest that combined with the necessary motivation and the appropriate motivational climate, engaging in deliberate team practice from an early age, of the type described in Chapter 4, may provide a suitable vehicle for attaining expert levels of performance. This viewpoint is consistent with previous sport interpretations of the deliberate practice theory (e.g., Starkes et al., 1996; Helsen, Starkes, & Hodges, 1998). However, the present research extends these findings by clearly delineating the process of acquisition for each year of elite level performance between 9 and 18 years of age. Moreover, the current research indicates that not only are elite adult players differentiated on team practice in soccer, but, players as young as nine years old can also be discriminated on time spent in deliberate team practice.

In summary, the integrated approach adopted by this research has allowed representative tasks to be designed, mediating processes to be identified, and the process of acquisition to be delineated in soccer. The data from the multiple experiments in this thesis suggest that perceptual-cognitive expertise in soccer, specifically with respect to 'reading the game', may best be described in anticipation and situational probability terms. In addition, the mechanisms sub-serving successful performance appear to be a product of primarily perceptual-recognition processes and the use of confirmatory immediate forward search which is restricted in depth to only one step in advance of the current action. Acquisition of these mechanisms occurs from as early as nine years of age, primarily through engagement in deliberate team practice. The greater amount of time elite players spent in technical skills and particularly, tactical and strategic decision making activities is likely to influence the acquisition of such domain-specific perceptual-cognitive skills. Moreover, elite individuals appear to be more dedicated and perceive themselves to be more competent than sub-elite players which is likely to result in greater commitment and consequently, greater amounts of deliberate practice, thereby facilitating performance in a monotonic fashion.

Implications and Applications for Future Research

Training perceptual and cognitive skills.

One of the major implications of this thesis for future research concerns whether specialized perceptual-skills training can circumvent the need for countless hours of deliberate practice. The data from the younger elite participants in this thesis suggest that the limited amount of deliberate practice in which they have invested results in superior performance on representative tasks examining perceptual-cognitive skill. Although previous guidelines have indicated that players may benefit from perceptual training by around 12 years of age (see Williams & Grant, 1999), the results of Experiment one, in particular, suggest that there may be a plausible argument for reducing this age recommendation. McPherson and Thomas (1989) have demonstrated that 8-10 year old tennis players' decision-making skills could be improved following specific instruction. However, more recent research evidence suggests that children may not develop task-specific perceptual or cognitive skills before they have demonstrated proficiency of related technical skills (see French & McPherson, 1999). Moreover, the content of practice sessions is likely to both regulate motor skill development and produce different knowledge representations and memory skills that affect how players 'read the game'. The primary goal of instruction at an early age should therefore, be to focus upon developing key technical skills. When a sufficient level of mastery has been attained and the rules of the game understood, players are more likely to benefit from implementing perceptual and cognitive skills training programs that are consistent with the technical strategies employed in practice. This approach, coupled with the appropriate motivational climate, is likely to produce a conducive environment for developing successful game reading skills.

In addition to the findings from this thesis, empirical work in soccer goal keeping (Franks & Harvey, 1997; Williams & Burwitz, 1993) and other sporting domains suggests that specific perceptual training is a useful aid to the learning process and performance improvements can transfer to the field (e.g., Williams, Ward, & Chapman, in press; Williams, Ward, Knowles, & Smeeton, in press). However, Ericsson and Chase (1982) and Ericsson and Harris (1990) both demonstrated that while memory performance can be improved to superior or even exceptional levels in around 50 hours of training, performance in these trained individuals was primarily mediated by superficial characteristics, as opposed to, for instance, the deeper relations that chess experts perceive in order to select the next best move. The question then arises whether such training creates superficially skilled individuals that are only capable of mimicking near routine-expertise as opposed to the observed adaptability demonstrated by a wide range of experts in a host of performance domains (cf. Hatano & Inagaki, 1986). Examination of participants' thoughts during representative task performance via the collection of verbal reports on a regular basis, over a period of extended deliberate team practice and perceptual skill training in soccer, may provide the means to examining such questions. When contrasted to shorter training programs that may create only superficial memory skills and knowledge structures, such longitudinal work is likely to provide much insight into the dynamic nature of an individual's understanding, the development of mediating mechanisms and processes, and also, the depth of an individual's learning and development. Furthermore, this approach would allow the correspondence between the dynamic evolution of participants' retrieval structures and the amount and type of deliberate practice and perceptual skill training in which participants engage to be examined.

Transfer of perceptual and cognitive skills.

A central tenet of much of the expertise research to date has been that the highly specialized skills acquired by individuals for use in their domain of expertise are often of little use when one moves in to an alternative domain. Put simply, expertise is typically considered domain-specific. However, there is increasing evidence that related knowledge, skills, or abstractions of these entities can be transferred successfully to novel problem scenarios or when one moves in to a domain that is structured similarly (see Gentner, 1983; Gick & Holyoak, 1987; Reeves & Weisberg, 1994). Moreover, recent evidence from the sporting literature suggests that players may benefit from sporting diversity and specializing in their domain of expertise much later than one would typically expect to attain expert levels of performance. The suggestion is that sports players are able to transfer both general and specific skills acquired in other sports, games, or physical activities to their specialist domain (see Cote et al., 2001). Whilst support for the notion of sporting diversity or later specialization was not found in this thesis, which is likely to be a consequence of cultural differences between the samples used (see Chapter 4), recent research by Smeeton, Ward, and Williams (2002) suggests that those individuals who have gained experience in one sport may transfer perceptual and cognitive skills to domains or tasks that are structurally similar. Moreover, elite players can often adapt existing strategies for use even in dissimilar sports. The results of this thesis suggest that practice in a related domain, however, needs to be of a deliberate nature for any benefit to be gained in the specialist field. The implications are far reaching and intimate that individuals who have attained a high level of performance in a related domain may well be able to transfer, not only physical or motor skills, but also may be able to benefit from using analogical thinking as a tool for transferring knowledge to domains which are, or can be, structured perceptually or cognitively similarly. The use of the expertise approach to contrast and compare individuals' transfer across related performance domains, as employed in Smeeton et al. (2002), offers many advantages for unraveling the true nature of expertise. Moreover, tools such as analogical mapping may promote the development of adaptive-, as opposed to routine-expertise (see Holyoak, 1991). The former is likely to be far more characteristic or expert behavior in performance domains, such as sport, dance, surgery, and music (see Allard & Starkes, 1991; Sloboda, 1991).

Talent identification and development.

Howe et al. (1998) suggested that whilst the full effect of an individual's talents may not emerge in the early years of participation, advance 'talent' indicators allow a trained individual to identify its presence before exceptional levels of performance are reached. As a result, these indicators provide a basis for predicting performance. Previous research has highlighted that talent in most performance domains is likely to be a combination of both innate or genetic factors and environmental considerations (e.g., Howe et al., 1998; Sternberg, 1996). In order to gain greater understanding of the notion of talent, particularly in sport, both perceptual-motor and perceptual cognitive performance factors should be examined and, accordingly, anthropometrical, physiological, psychological, and sociological aspects of performance need to be considered (see Williams & Reilly, 2000). Those authors that have adopted a multidisciplinary approach in soccer have demonstrated that psychological characteristics, like anticipation and ego orientation as well as physical characteristics, such as speed and agility, were most predictive of expertise (Reilly, Williams, Nevill, & Franks, 2000). Williams and Reilly (2000) suggested that where physical factors are likely to be more predictive of skill level in soccer at an earlier age, psychological characteristics are likely to predict expert performance as players mature into adulthood. Practice-related variables, however, have typically been omitted from such consideration.

The findings from this thesis suggest that psychological characteristics, such as anticipation and the use of situational probabilities are predictive of elite performance as early as early as nine years of age and that elite players of a similar age can be differentiated from their sub-elite counterparts on psychological constructs such as perceived competence, dedication, and perceived time and effort invested. Moreover, deliberate team practice in the most recent year of participation between 9 and 18 years of age accounts for a significant proportion of the variance and, clearly, is paramount in developing talented young athletes. The provision of a motivational climate which facilitates productive practice and meets the requirements of both task and ego oriented individuals is likely to foster increased intrinsic motivation and perceived competence and result in a sustained investment and ultimately, skill mastery and talent development. These findings have significant implications for identifying and developing expert performers across a host of domains. Where the tendency has been to concentrate mainly on physical characteristics in domains that possess a significant perceptual-motor component, a shift of emphasis toward attained perceptual and cognitive skill level, perceived competence, and particularly, the amount of time invested in deliberate team practice to date may provide an alternative and plausible basis for talent identification and performance prediction. Moreover, increasing the time spent in these activities is likely to further encourage talent development.

Theoretical application.

While qualitatively different types of expertise may be apparent in different skill domains, and the development of "different types of mechanisms acquired through different types of learning and adaptation processes" may add to a more complete definition of expertise than those restricted to a "specific type of acquisition through learning" (Ericsson & Smith, 1991, p.32), Ericsson and Kintsch (1995) have contended that the same type of memory mechanisms mediate performance in a range of domains. In fact, two different types of associations (as opposed to different mechanisms per se) within integrated memory structures were proposed to account for the majority of expertise effects across many domains and tasks. That is, the associations between retrieval cues and retrieval structures, and elaborative encodings that generate new structures with associative relations (see also Ericsson & Delaney, 1999). By examining the nature of LTWM across tasks and experts, the types of mechanisms originally proposed by Ericsson and Kintsch, (1995) can be empirically tested.

An integral aspect of skilled and expert performance is the ability to anticipate future retrieval demands and to maintain access to relevant information. According to Ericsson and Kintsch's (1995) long-term working memory (LTWM) theory, access to this information is maintained by developing encoding skills that allow skilled individuals to index information in such a way that it can be reliably retrieved when relevant to the task. Research in chess suggests that the encoding of a chess position in this manner into LTMW facilitates both early perceptual organization and is a necessary prerequisite for cognitive activities such as evaluation and planning in order to explore alternative move sequences (see Ericsson, Patel, & Kintsch, 2000; de Groot, 1965). However, the structure and nature of encodings of LTWM and the resultant cognitive processes are likely to differ depending upon the demands of the tasks in which experts engage. The skill-based theory of expert performance proposed by Ericsson and Kintsch (1995) indicates how differing tasks that impose differing working memory demands result in different LT-WM structures. Previous reviews have summarized the applicability of this theoretical viewpoint across several domains (see Ericsson & Kintsch, 1995; Ericsson & Delaney, 1999; Ericsson, Patel, & Kintsch, 2000). Future examination of expert performance in real-world tasks is likely to benefit from adopting the expertise approach used in this thesis. Not only will this approach facilitate the identification of representative tasks across a breadth of domains but the specific nature of acquired mechanisms and the process of acquisition can be fully examined.

Chapter 6

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Appendix

A1: Task Analysis

Overview of the task

The participant was requested to assume the role of a defender by viewing the 11 v 11 soccer test film from a defensive perspective. The participant's task was to 'read the game'. That is, to determine the potential options available to the opposing player in possession (PIP), and rank each highlighted options, in terms of the opponents next best move(s) (e.g., which options would put the defense under the most pressure, and consequently, should the participant be aware of to formulate an effective defense?). In addition, the participant's task was to determine what was going to happen next on occlusion of the test film (e.g., what the PIP was actually going to do with the ball, for instance, shoot, pass, retain possession/run) (for more detail see Chapter 3, methods section).

Player / Scenario Coding – Trial 16

On the last frame of action, each player on the pitch was arbitrarily coded using an alphanumeric. The offensive team (red) were coded from 'R1 to R11', and the defensive team (white) were coded from 'W1 to W11' (see Figure A.1). Areas of the pitch have been marked to denote the available areas of the pitch to which a pass could be made (Figure A.2). Play progressed toward the goal at the bottom of the picture. At the end of trial 16, R2 is in possession of the ball. He is running down the right wing (left side of the pitch from the participants perspective) and is about to 'do something' with the ball (see overview of the task).

Figure A.1. Coding system used in the task analysis to denote each player

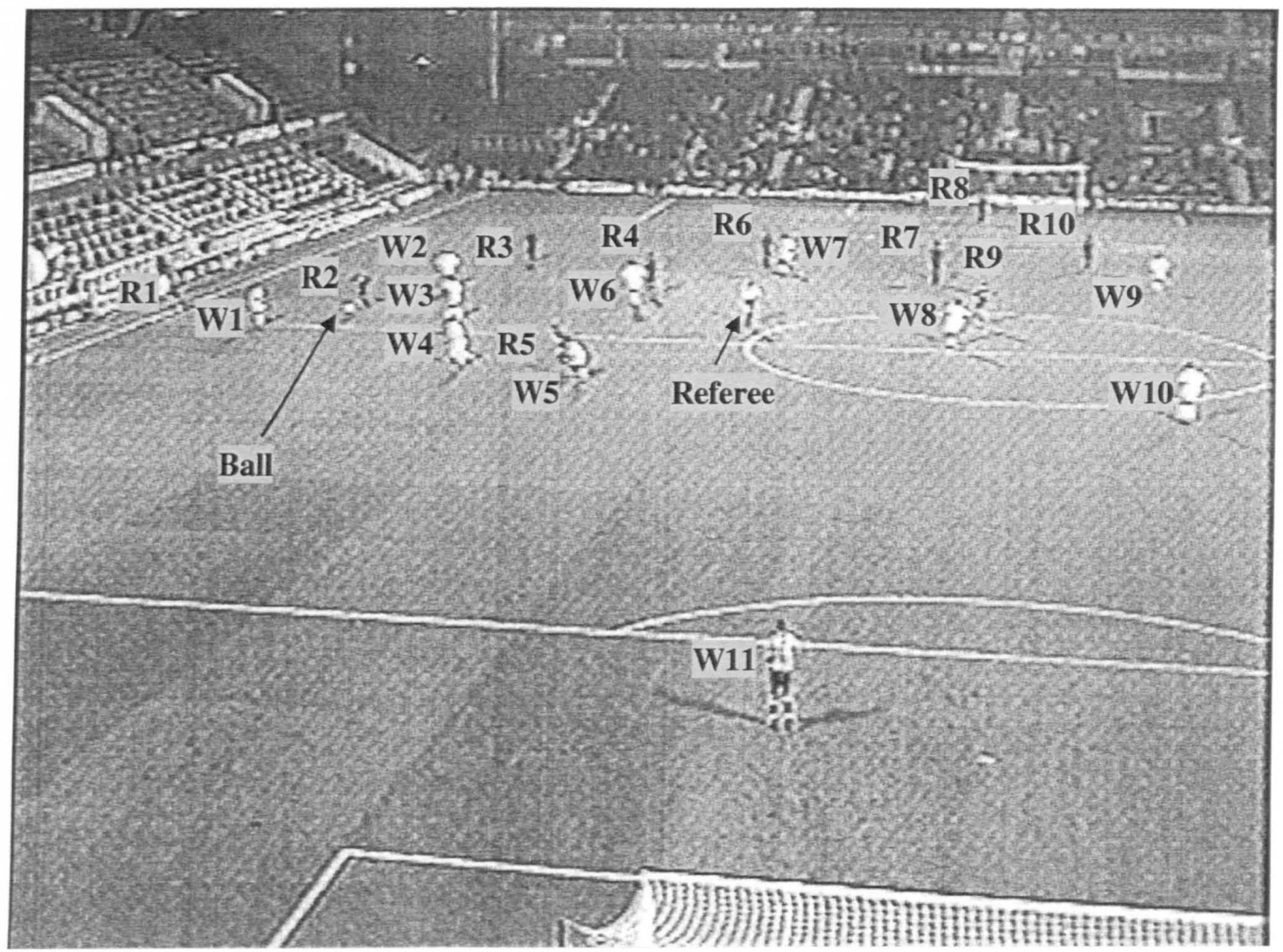
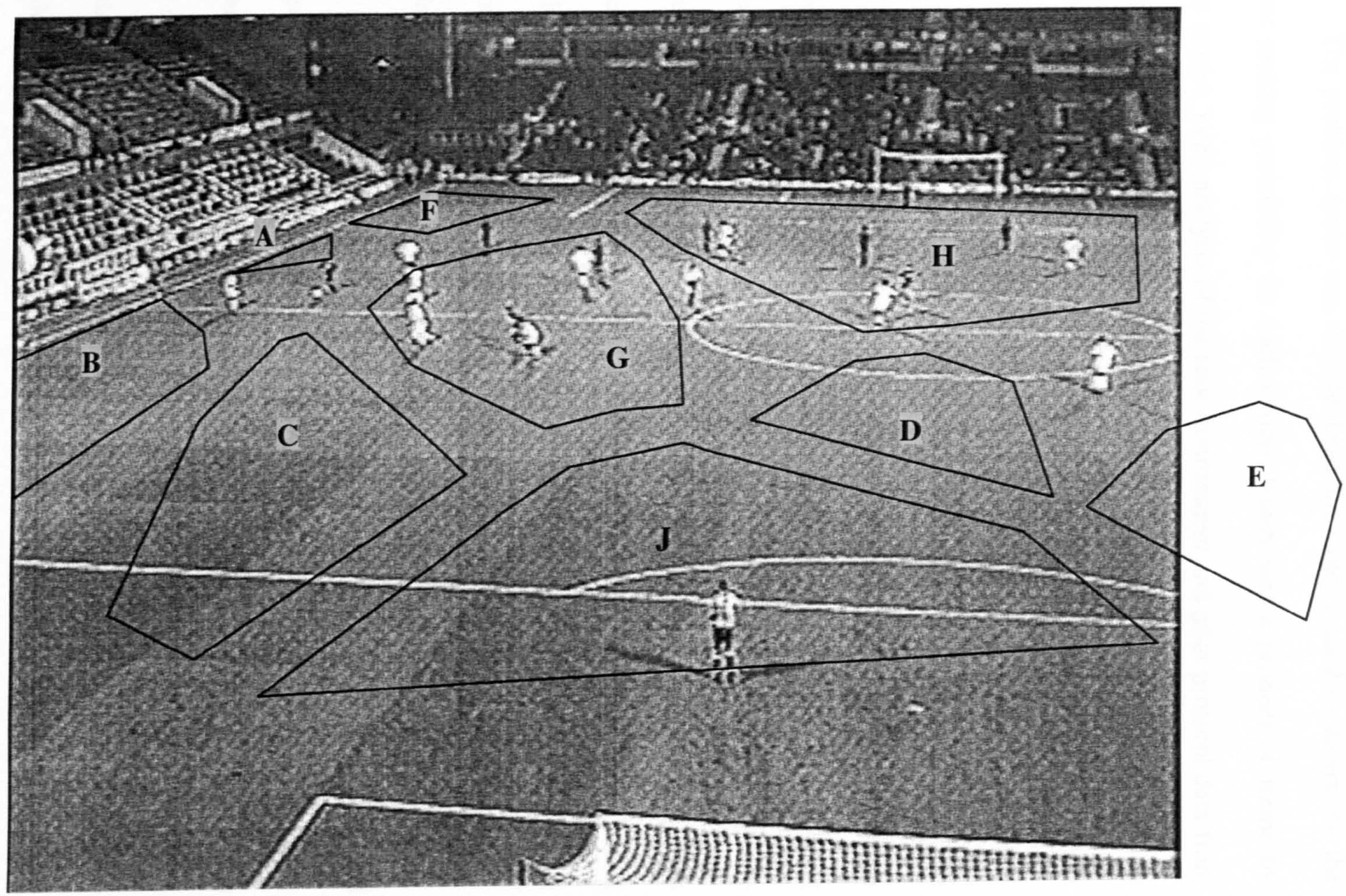


Figure A.2. Coding system used in the task analysis to referenced areas of the pitch



Problem Space – Trial 16: Plausible Options Available to the PIP

The problem space was derived from the criteria used to determine the correct ranking probability for each option, which was a product of frame by frame expert 'item' analysis of the task environment and pilot protocol data from expert judges. Inter observer reliability measures for the final criteria used to select each 'option' are presented in the results section. The WIN/TIE/LOSE metrics presented below are used only as a guide to reflect the expert criterion.

Ironically, in the following analysis, a WIN in favor of the opposing team [RED], resulting in an effective attack against the participant, is proposed as an 'ideal' solution that each participant should strive towards (e.g., via forward search, minimaxing, recognition process, etc.) allowing an appropriate probability value to be effectively assigned to each 'next' move. No assumption has been made about the degree or depth of search, or the underlying mechanisms which would promote such activity, other than to detail every possible alternative about potential future options foreseeable by expert judges, given the current scenario.

Option: Shoot at goal

R2 (PIP) is some 50-60 yards away from goal. His body shape does not suggest that he is about to shoot. The defensive goalkeeper, W11, is moving back towards his line to cover the goal. There is ample time for the W11 to intercept a shot at goal should R2 decide to take this option. It is very unlikely that this option would result in a goal and any future moves beyond those immediately available would be forfeited.

Option: Retain possession/run with the ball

W2 and W3 are approaching R2 at speed and narrowing the space between them and R2. If R2 decided to run with the ball, W3 is likely to close down the space within approximately 1 to 2 seconds and/or his run would be intercepted by W4 within a short space of time. If R2 decided to retain possession for the short amount of time available, R1, R5, R9 and R11 may be available as potential future passing options. However, the white team is holding a high defensive line (e.g., close to the centre line) and so R1, and R5 would have to withhold their run until R2 decided to release the ball. If they did not hold their run until the pass had been made, the play would likely be called off-side. If R2 retained possession and then passed to either R9 or R11, these players are likely to be too far away from R2 for any pass to be threatening to the defense or to make an effective attempt at goal without being tackled. If R2 retained possession he may lose any strategic advantage currently available, and is unlikely to gain any further advantage by pursuing his run. R2's previous movements indicate that he has noticed the locations of the three defenders, W2, W3, and W4, and is aware of the time pressure. At best, R2 would win a challenge from W3 or W4. However, R2 appears to be headed down field and his body shape suggests that he is about to pass. A number of 'plausible' scenarios can be derived from this description:

Retain

(a) Offside: R2 retains possession and runs forward, R1 and/or R5 begin to advance down the pitch beyond the defensive line, R2 passes the ball forward and referee calls off-side. (LOSE)

(b) Tackle: R2 retains possession and runs forward, R1 and R5 begin to advance down the pitch but stay on-side, W1 or W4 close down and tackle R2. R2 either (b-i) loses possession (LOSE), or (b-ii) wins possession and begins to build an attack again. (TIE)

<u>(c) Retain, Pass:</u> R2 retains possession and runs forward. R1 and R5 begin to advance down the pitch but stay on-side. W1 or W4 start to close down R2. R2 passes to R1 in area 'B' (see Figure A.2) but the pass is either (c-i) intercepted by W1 (LOSE), (c-ii) too-long and goes out of play, or allows time for W1 or W4 to close and tackle (LOSE-TIE), (c-iii) too short and is intercepted by a W1 (LOSE), or (c-iv) the pass is received by R1 successfully (WIN) (see Retain, Successful Pass – R1). Alternatively, R2 may pass to R5 in area 'C' and a similar scenario happens. The pass is either (c-v) intercepted by W4 or W5 (LOSE), (c-vi) too-long and allows time for W4 or W5 to close and tackle (LOSE-TIE), (c-vii) too short and is intercepted by W3 or W4 (LOSE), or (c-viii) the pass is received by R5 successfully (WIN) (see Retain, Successful Pass – R5-i). If R2 holds on to the ball, R5 can also change direction back inside and run toward the edge of area 'D/J'. A *lofted* pass/cross to area 'D/J' is either (c-ix) too short/low and is intercepted by W3, W4, or W5 (LOSE), (c-x) too long or wayward and allows time for W11, W10, or W9 to intercept/challenge (LOSE-TIE), or is successfully received in area 'D/J' (WIN) (see Retain, Successful Pass - R5-ii).

<u>Retain, Successful Pass – R1</u>

R2 retains the ball, and then passes to R1 in area B, successfully. R1 runs toward the corner flag/edge of the penalty box. (d) If players are running in toward area 'J' then a cross could be made into the penalty area (see Cross). If not, R1 could either (e) look for supporting players behind (e.g., R2, R5) (see Support), (f) hold the ball up until advancing or supporting players arrive and then cross or pass to a supporting player (see Hold), or (g) take the ball inside himself (see Dribble).

(d) Cross: If R1 attempts to cross the ball toward area 'J' (see Figure A.2) he may either (d-i) be tackled by W1 and lose possession (LOSE), (d-ii) or tackled by W1, but win the challenge and rebuild an attack (TIE), (d-iii) have his cross intercepted by W1, W4, or W5 (LOSE), or may cross the ball without tackle or interception. If the latter occurs, assuming R1 successfully crosses the ball into the area, advancing players (e.g., R2, R5, R9, R11) could (d-i) win the cross and have an attempt on goal (WIN), (d-ii) win the cross and be challenged by surrounding defenders (W3, W5, W8, W10) (TIE), or (d-iii) lose the cross to a surrounding defender (W3, W5, W8, W10) (LOSE).

(e) Support: If R1 decides not to cross (e.g., no advancing attackers), assuming there are supporting players approaching areas 'B/C' (see Figure A.1 & A.2), R1 could pass back to one of his team-mates (e.g., R2, R5, R3, R4). However, a pass back is likely to meet with a challenge from a defender (e.g., W1, W4, W5) (TIE). If the pass is successful, whilst having more attacking players further up the pitch, each would also have to contend with the increased proximity of defenders (TIE). If the pass met with a team-mate in space, they could potentially put in a good cross toward goal (WIN-TIE).

(f) Hold: If R1 held the ball to wait for supporting or advancing attackers, then W1 is likely to challenge R1 (TIE). If R1 beats the challenge from W1, he is likely to either pass to a supporting player (see Support), or cross the ball toward the penalty box / area 'J' (see Cross).

(g) Dribble: If the options to cross, or pass to a support player are poor R1 may decide to dribble the ball toward the penalty area. However, again, he is likely to meet a challenge from W1 (TIE). If R1 beats the challenge from W1, continuing his dribble would meet with subsequent challenges from either W3, W4, and/or W5 (TIE-LOSE). If R1 has the option to pass before being challenged, he could pass to a supporting player (see Support), or cross the ball toward the penalty box / area 'J' (see Cross).

Retain, Successful Pass – R5-i

R2 retains the ball and passes into area 'C', where R5 has made his initial run. The pass is completed successfully. R5 can either (h) continue the direction of his diagonal run toward the corner of the penalty box and pass to R1 on the wing, (i) drive straight forward down the pitch, or (j) turn inside toward goal.

(h) Pass to R1. If R5 passes out to the R1, the ball may be potentially intercepted by W4, W1 (LOSE). If the pass is successful, R1 could resume as detailed in section 'Retain, Successful Pass – R1'. However, unless R5 released the ball early to R1, R5's continued direction toward the corner of the penalty box would have given R1, one less attacking option to cross to, relying upon R2 to get across, and R4, R9, and R11 to move in toward area 'J' (TIE).

(i) Drive forward. If R5 drives straight forward, W5 and other defenders are likely to be close on his shoulder. Given the time R2 would have spent retaining the ball, R5 running with the ball, and in the ensuing defensive challenge (e.g., R5 v W5/W4) (TIE-LOSE), this attack is likely to be followed or even preceded by supporting defenders (e.g., W3, W6, W8) (LOSE). However, if the ball is released early, and R5 can beat the challenge presented by W5, and get into the left side of the penalty box, there is a potential option to cross the ball into area 'J' for attacking players to run on to (e.g., R9, R11, R2, R4) (TIE-WIN) (see also *Option: Pass to R5*).

(j) Turn toward goal.

Given the time difference between the current frame and the point at which R5 turned toward goal, the defensive cover is likely to be similar to (i) driving forward, if not greater (e.g., also W10) (TIE).

Retain, Successful Pass - R5-ii

R2 retains the ball and moves forward. R5 changes his current running direction and moves inside toward area 'D/J'. A pass is made to area D/J. The time it would take the ball to travel to this area would be sufficient for the defenders W5, W4, and W10 to move across, and W8 to drop back. Potentially the play could be switched out to R11 from here but the advantage would be no greater than current, and there would be enough time for the whole defense to move across.

Option: Pass to R1 direct

W1 is located between R2 (PIP) and R1 and so there is a high certainty that W1 would intercept a direct pass (e.g., shortest possible route between players) (LOSE). To make this pass a viable option R2 would have to draw W1 out of his current position. If space can be created by drawing W1 away from the line of the pass between R2 and R1, then there is a potential passing option available direct to R1 (TIE).

Option: Pass to R1-A

There is space to play a 'square' pass to area 'A', that is, perpendicular to, and toward, the side line. However, this pass would be behind R1, not in the direction that R1 is currently moving, against the current progression of play, and away from both the goal. In addition, R2 has just turned slightly away from R1 to face down field.

The angle that would be created by the line of this pass to area A, and W1's current position relative to R2, suggests that W1 could potentially intercept this pass (LOSE). If W1 did not intercept the ball successfully, he is still in a good position to challenge R1 upon receipt of the ball (TIE). A pass to R1-A, however, would provide few future alternatives other than to pass back to R3 in area 'F', who could then play a long ball down field (TIE), or spread the play back across the defense to the other side of the pitch. W7 and W9 are well positioned to counter such a defensive move (TIE). None of these options would build upon the current initiative and would worsen the current position.

Option: Pass to R1-B

The pass could be played into the channel, that is, diagonally down the field, towards the side line and into space (area B). R1 and W1 are moving at relatively the same speed down the pitch. R1 is running down the line, whereas W1 is running on a slight diagonal line inside, away from the side line, and away from R1. The gap between R1 and W1, created by W1's movement, is increasing (gap is currently 4-5 yards). R1's continued run down the line whilst W1 moves slightly inside has created an advantage in favor of R1 receiving the ball if the pass is made into space (area 'B', see Figure A.2). However, W1's body shape and diagonal run suggests that he may have anticipated a potential pass to R1 into area B (TIE). If a good pass is made to R1 and is successful, then R5, R9, and R11 provide potential future passing options for R1, and goal scoring opportunities for the team. This scenario is similarly addressed in the 'Retain, Successful Pass – R1' section. However, the current option would take advantage of R1's movement, would not pose any off-side threat, would put each of the defenders much further up-field and away from goal than in the 'retain and pass' option, creating a weaker defense and stronger attacking position. The future options available after this pass to R1 are the similar to those in '*Retain Possession*: Retain, Successful Pass – R1', presented previously. The difference is that there is likely to be less spatio-temporal pressure by choosing this option both for R1 and the options that follow, rather than R2 first retaining possession.

(*Note.* 'Pass to R1-B' was ranked as the second best option by the expert judges)

Option: Pass to R5-C

R5 has just made a diagonal run infield toward W5, losing his original marker, W4. W5 turned toward the centre circle, away from the side line, to cover this diagonal run. R5's immediate change in direction back out toward the side-line/down the pitch puts him 'ball-side' of W5, that is, R5 is located between W5 and the ball. W5 is slightly further down the field than R5. However, R5 is moving quicker than W5 who has just had to turn to face the same way as R5 before he could increase his pace. W4 has his back to R5 and cannot see, and therefore, anticipate R5's intended run. There is a high likelihood that the ball will be passed into space (area C) in front of R5 and W5 (WIN). R5 would have an excellent to good chance of successfully receiving a pass into this location depending upon the quality of the pass. In addition, given the proximity to the goal, a pass into area C would place a greater immediate threat upon the defense than a pass to R1 in area 'B'. As mentioned in the previous section, the R5 and the ensuing options would be under far less spatio-temporal pressure if this option were taken without R2 first retaining possession. If the pass is made, and made well, R5 would be in a one versus one situation with the goalkeeper (WIN). In addition, R5 could cross the ball to area 'J' directly to provide an immediate threat on goal and goal scoring opportunities for the team (TIE-WIN).Alternatively, R5 has the option to pass out to R1 in area 'B', who could in turn cross it toward area 'J' for an attempt at goal by oncoming attackers R5, R9 and R11 (and potentially R4) (TIE-WIN).

(*Note.* Pass to R5 was ranked as the best option by the expert judges)

Option: Pass to R5-G/R4-G

A direct pass between R2 and R5 or immediately beyond (e.g., area 'G', see Figure A.2), or a direct pass to R4 are not viable options. They are likely to be intercepted by one of the three defenders W2, W3, and W4 located between R2, R5, and R4 (LOSE). Each option is against the run of play and is potentially in an alternative, if not opposite, direction to the run being made by R5.

Option: Pass to R9-D

R9 has made a sharp diagonal run behind W8. His body shape suggests he is about to make a run into area 'D'. However, W10 is in a defensive covering position. In the time it would take to pass the ball across the field both W8 and W10 would be in a position to provide immediate defensive cover to R9 (TIE-LOSE). Moreover, there would be time for the whole defensive line to restructure and move across the pitch to provide extra cover. There is no foreseeable advantage to be gleaned from making this pass and the immediate potential goal scoring opportunities are relatively low. There is also a high risk of losing possession (depending upon the quality of the pass).

Option: Pass to R11

R11 has made a diagonal run from the centre circle to a position off the right of the screen. His position with respect to being 'on-side' is unknown. R11 has no supporting players and W10 is providing defensive cover. As in the previous scenario, in the time it would take to pass the ball across the field there would be time for the whole defensive line to restructure and move across the pitch to provide extra cover. Similarly, there would be no additional advantage made from this pass, only an increased risk of losing possession (TIE-LOSE).

Option: Pass back to R3-F

A direct pass to R3 would be intercepted by W2. The only viable passing option backwards is to area F. However, as stated in section 'Pass to R1-A', the only available option after passing back to R3, would either be to play a long ball down field (TIE), or spread the play back across the defense to the other side of the pitch. W7 and W9 are well positioned to counter such a defensive move (TIE). This option does not take advantage of the current initiative and is against the current movement of attacking team mates, and the player in possession.

Option: Pass to R6, R7, R8, or R10, area H.

An attempted pass to any of these players is likely to be intercepted by an opposing player, W2 or W3 (LOSE). If not intercepted, 4 defending players (W6, W7, W8, W9) are in a good position to get to the ball first (TIE). A pass to one of these players would be against the current progression of play (e.g., R2's current direction), and would require R2 to turn before passing allowing time for the defense to adjust. In addition, this line of attack does not match, or would not increase the current advantage to the PIP and there is a highly likelihood of loosing possession.