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Mapping two new points on the tennis expertise continuum: Tactical skills of adult advanced beginners and entry-level professionals during competition

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Abstract

Research examining problem representations of individuals during task performance is advancing our understanding of information processing and expertise in a variety of sports. However, few studies using similar methodology have been conducted on individuals of various competitive standards in one domain in similar contexts. This study examined problem representations of adult advanced beginners and entry-level professionals accessed during singles tennis competition ($n = 12$). These groups were selected to represent players with performance skills that were different from those studied previously (i.e. adult beginners and varsity players). Immediate recall and planning interviews were conducted between points during singles tennis competition. Players competed within their respective expertise groups. Verbal reports were transcribed verbatim and concepts were scored according to a model of protocol structure. Several multivariate analyses of variance were conducted on rank scores for measures of concept content and structure using the *L*-statistic. Entry-level professionals exhibited more advanced problem representations than advanced beginners regardless of interview type. These findings together with those of previous research suggest adaptations in long-term memory profiles with increases in performance skills. For example, beginners lacked action plan and current event profiles because they generated goals and reiterated game events during both interviews. Advanced beginners, who had better performance skills than beginners, exhibited rudimentary action plan profiles and deficient current event profiles because they generated and monitored several detailed actions related to the current context during recall interviews and generated only a few goals during planning interviews. In contrast, varsity players and professionals processed tactical information in the current context and beyond denoting the existence of both action plan and current event profiles. Varsity players, with inferior performance skills than professionals, exhibited fewer and less associated tactical concepts than professionals during both interviews.

Keywords: *Information processing, knowledge base, verbal reports, cognitive strategies*

Introduction

Research on expertise in sport and cognitive science has been an active area of inquiry for more than three decades. Yet, we know very little about the type of information and processes individuals utilize over the course of competition. To overcome this limitation, some sport scientists interested in the nature of expertise are using verbal report analyses to examine individuals' thought processes during competition.

Verbal report analyses during problem solving or task performance in a variety of domains have provided evidence that: (a) higher-order processing and/or performance is due to the properties of individuals' domain-specific knowledge bases rather than their general cognitive strategies; (b) differences in expertise do not emerge when tasks are not domain-specific; (c) the properties of individuals' knowledge bases develop differently due to function and specialization in the domain; and (d) experts try to build highly evolved cognitive structures and remain in the cognitive/associative stage to achieve improved performance (see Ericsson, 1996, 2003a, 2003b).

Verbal reports during problem solving or task performance have revealed that activation of critical input and concepts from long-term memory forms an initial representation of the problem. Problem representations guide the interpretation of input and retrieval of relevant information accessed via working

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memory as solutions are generated or task performance progresses (see Chi, 1997; Ericsson & Simon, 1993; McPherson, 1993). Ericsson and Simon (1993) noted that verbal reports collected immediately after a performance were useful for capturing problem representations when individuals performed tasks that required motor executions. Thus, in sports, verbal reports collected during competition reveal information and processes (i.e. problem representations) players utilize to mediate performance (see French & McPherson, 2004; McPherson, 1993, 1994).

Although those interested in sport acquisition/expertise have suggested that verbal reports might be useful in understanding the nature of expert performance, especially in high strategy sports, the number of researchers using verbal report methodology to examine properties of sport performers' problem representations during simulated (e.g. Abernethy, Neal, & Koning, 1994; Ward, Williams, & Ericsson, 2003) or actual competition (e.g. Nevett & French, 1997) is limited (see Ericsson, 2003b; French & McPherson, 2004). An exception was a series of studies that used observational instruments and verbal report methodology to examine problem representations of high- and low-skilled male youth and female adults during simulated and actual tennis competition (McPherson, 1999a, 1999b, 2000; McPherson & Thomas, 1989). In these studies, performance skills (decision making and motor skill execution) were assessed by observational analyses of players' performances via videotape, whereas problem representations were assessed by verbal report analyses of players' utterances via audiotape.

Verbal report analyses consisted of scoring each player's transcript according to a model of protocol structure for tennis. According to this model, concepts (or units of information) are differentiated into five major categories: *goal concepts* (e.g. ''I need to win this point''), *condition concepts* (e.g. ''she likes to go wide on her serves''), *action concepts* (e.g. ''hit my lob to her backhand with topspin deep''), *regulatory concepts* (e.g. ''I missed that last volley''), and *do concepts* (''I will bend my knees''). Within each major category, subconcept categories are formed. For example, a condition subconcept category termed an *opponent's prior shot* would include utterances such as ''she hit her backhand out''. Measures of concept content and structure (see Methods section) are used to examine expertise differences in problem representations.

Two types of interviews were developed to examine players' thought processes (via verbal report analyses) between points during tennis competition. An immediate recall interview examined problem representations about a prior point, whereas a planning interview examined problem representations about an upcoming point. Thus far, only varsity and beginner players (McPherson, 1999a, 2000) have been exposed to both. The immediate recall interview between points during competition (McPherson, 1999a) indicated beginners processed minimal pertinent tennis information. Their weak problem representations consisted of goals related to their executions, failed actions (regulatory concepts) or reactions to game events. In contrast, varsity players accessed conditions about the current environmental context (e.g. player positions, ball location) together with past events such as conditions concerning their behaviours and opponents' behaviours (e.g. strengths, tendencies, prior shot). At times, they generated conditions about shot and position tactics. They also monitored success of their actions (and some decisions) and developed solutions in response to such events. The planning interview (McPherson, 2000) between points during competition indicated beginners generated few plans that contained goals or poor interpretations of conditions about current and past events. In contrast, varsity players planned actions based on tactical diagnoses of pertinent past events and anticipated context-specific conditions such as an opponent's positions and shot selections. Their plans also included solutions to enhance their actions (do concepts) and contained task-specific goals.

From this research and related studies, McPherson (see French & McPherson, 2004; McPherson & Kernodle, 2003; Tenenbaum, 2003) proposed that sport experts' superior decision skills during singles competition are due to two adaptations to long-term memory termed current event and action plan profiles. *Action plan profiles* are rule-governed prototypes used to match certain current conditions with appropriate visual and/or motor actions. This profile contains specialized strategies for monitoring current conditions such as player positions and ball placement, player formations, or coordination patterns of opponents to make accurate response selections. Other strategies include monitoring the success of their own actions or attaching verbal labels or cues to their own movement parameters to enhance motor execution. These profiles may reflect current skills, styles, and/or preferences of play (e.g. in tennis, a player with a strong serve and volley skills may prefer this style of play). Typically, motor skill drills promote action plan profiles since these drills are designed to build decision skills based on information in the current game context (e.g. in tennis, volleys are selected and directed to certain court areas depending on player positions and ball location, not opponent tendencies).

Current event profiles are structures used to keep relevant information active with potential past, current, and possible future events. These profiles

are tactical scripts that guide the continuous building and modifying of pertinent concepts to monitor during the competitive event. This profile is built from past competition or previous experiences prior to the immediate competition and from specialized monitoring, encoding, and retrieval processes used to collect information as competition progresses. For example during tennis competition experts are predicted to utilize a condition profile about his or her opponent. This profile would include tactical information and specialized strategies regarding how to analyse opponents in general that could be modified to build information about this particular opponent's shot tendencies, weaknesses or play preferences, to plan or analyse their own shot selections and tactics as competition progresses.

Both profiles are predicted to allow elite players easy access to and retrieval of important information via extensive pattern mechanisms (action plan profile) or situation prototypes (current event profile) to make decisions during competition and to compensate or make adjustments during time-constrained moments. Also, long-term working memory mechanisms (see Ericsson & Delaney, 1999; Ericsson & Kintsch, 1995) are predicted to develop with expertise to allow easy access to and retrieval of pertinent information associated with both profiles. Furthermore, current event and action plan profiles and long-term working memory mechanisms specific to these constructs are predicted to differ according to sport domain and player experiences (e.g. position, practice experiences) (e.g. McPherson & Kernodle, 2003).

Thus, the previously reviewed findings examining varsity and beginner players' problem representations accessed during competition indicated adaptations to long-tern memory for varsity players. That is, varsity players used both action plan and current event profiles during competition. For example, varsity players planned tactical shots based on the current context together with opponent's tendencies, their prior shot, and so on. In contrast, beginners lacked action plan and current event profiles as they processed and planned few pertinent concepts related to tennis competition. However, our understanding of the development of these memory profiles is limited. As a result, we examined competitive standards other than those previously studied. Advanced beginners and entry-level professionals were exposed to an immediate recall interview and planning interview between points during singles tennis competition within their respective groups. Based on previous research in this area (McPherson, 1999a, 2000; Nielsen & McPherson, 2001), both groups were expected to be highly goal oriented during both interviews; however, professionals were predicted to access more tactical reasoning and solutions in response to such goals than advanced beginners. Professionals were predicted to consistently access elaborate and tactical action plan and current event profiles to make decisions during competition, whereas advanced beginners were predicted to access rudimentary action plan profiles to make decisions during competition. Also, both groups were predicted to monitor the success of their motor skills similarly, yet professionals were predicted to access more sport-specific strategies for enhancing such skills than advanced beginners (e.g. modify their motor executions, apply different shot tactics, adjust profiles about player characteristics). Advanced beginners were also predicted to exhibit rudimentary current event profiles. For example, we predicted they would develop deficient profiles about their own or opponent's behaviours or shot tactics. In contrast, professionals were predicted to access highly tactical current event profiles. For example, they were predicted to access and update a variety of scripts regarding game tactics and condition profiles regarding their own and opponents' behaviours as competition progressed.

Also, both groups were predicted to process more information during the immediate recall than planning interview. For example, we speculated advanced beginners with deficient current event profiles would find it easier to recall or reiterate what happened during a previous point rather than plan or predict future actions or events for an upcoming point. Professionals were predicted to exhibit tactical problem representations regardless of type of interview. However, during the immediate recall interview we speculated they would reason about their previous decisions or actions, success of their actions, and update the accuracy of their current event profiles when recalling previous shots or decisions and use this information to plan an upcoming point. Consequently, their plans regarding an upcoming point would result in more solutions or application of tactics.

In addition, we were interested in determining whether the properties of these players' problem representation accessed during competition corroborate recent theory regarding the development of current event and action plan profiles with expertise. Previous research examining performance skills of these expertise groups in which verbal reports were collected (adult beginners and varsity players: McPherson, 1999a; adult advanced beginners and professionals: McPherson & Kernodle, 2003) indicated decision and motor skills increased as competitive standard increased. As such, we were interested in examining the development of players' problem representations among these expertise groups.

Methods

Participants

The participants were male adult entry-level professional ($n = 6$; mean age = 27.3 years) and advanced beginner ($n = 6$; mean age = 22.6 years) tennis players. All participants read and signed the Informed Consent for Human Participants in accordance with the university's regulations. Professionals were defined as *near elite* players who had held national rankings and had US Tennis Association (USTA) National Tennis Rating Program (NTRP) ratings of 5.5 – 6.5 at the time of data collection. In addition, the professionals were former university players who currently played an average of five professional tennis events (tennis tournaments offering prize money) each year. One professional was formerly a member of his country's Davis Cup team, while the others were winners of at least nine tennis tournaments each (within the last 10 years). Advanced beginners were defined as players with no tournament experience and who had NTRP ratings of 2.5 – 3.5. Demographic results indicated professionals had been playing tennis considerably longer (mean = 17.3 years, $s = 4.9$) than advanced beginners (mean = 5.3 years, $s = 2.7$). Furthermore, professionals practised and played tennis more often (mean = 4.1 times per week, $s = 1.0$) than advanced beginners (mean = 1.3 times per week, $s = 1.5$). All NTRP ratings ranging from 1.0 (the lowest) to 7.0 (the highest) [http://www.usta.com/usaleague/ntrp.html (accessed 23 August 2005)] were confirmed by USTA NTRP verifiers.

Also, performance skills for these and other (McPherson, 1999a) expertise groups are presented. The following performance skills are reported as mean percentages and standard deviations (in parentheses) for beginners, advanced beginners, varsity players, and professionals, respectively: tactical serve decisions [19.3% (18.0), 64.7% (21.5), 78.2% (11.0), and 96.5% (8.6)]; forceful serve executions [1.2% (2.9), 28.2% (10.0), 48.5% (27.5), and 70.3% (18.0)]; tactical shot decisions [36.6% (20.8), 65.0% (22.0), 72.7% (9.7), 95.2% (5.5)]; and forceful shot executions [6.5% (8.1), 42.0% (29.4), 45.7% (10.9), 64.5% (8.3)]. Percentages for each category were based on the highest category divided by the number of opportunities to respond.

Interview procedures

Video and audio recording was conducted on the same court for all participants; players competed within their respective groups. Before filming, the participants were familiarized with the videotape procedures and informed that they were going to play two modified sets. They were instructed that each modified set would consist of the best three of five games. All participants followed regulation play; they were instructed to play as if they were competing in a sanctioned tournament. Participants went through their traditional match warm-up until each agreed they were ready. Interviews were conducted between points during each game of the second modified set. Previous research indicated that these participants' performance behaviours were not affected by interviews (cf. Nielsen & McPherson, 2001). The recall interviews (''What were you thinking about while playing that point?'') and planning interviews (''What are you thinking about now?'') were administered between points. The recall interviews occurred immediately after the completion of each point; the planning interviews occurred directly after the recall interview and immediately before playing the next point. Interview questions were typed on one sheet of paper and attached to a clipboard. Clipboards were placed on the ground, off court, directly behind the serve hash mark near the baseline fence. Cassette recorders, assigned to each player, were also placed in these designated areas. Players were instructed to go directly to their tape recorder following each point and respond as accurately as possible to the questions about their thoughts during competition; and that there was no time constraint. Interview order was consistent throughout competition. Participants operated recorders manually; no mechanical or participant errors occurred during recording.

Coding verbal responses

An individual without any knowledge of this experiment transcribed each player's utterances verbatim. Another individual with tennis experience and without knowledge of this experiment listened to the utterances to ensure transcriptions were accurate. A total of 16 between-point verbal reports for each interview were coded for each participant. These were obtained by randomly selecting four points from the first three games followed by one random drawing of a point from each game until 16 between-point verbal reports were obtained. Concepts were separated according to the determined unit of information generated by each participant. Pauses longer than 2 s or ends of sentences were designated as one phrase; phrases could contain one to several concepts. Each player's utterances were classified according to five *major concept categories*: (a) *goal concepts* reflect the means by which the game is won, or purpose of an action selected, or an objective referring to the game's goal structure (''get first serve in''); (b) *condition concepts* specify a circumstance or

when or under what circumstances to apply the action or patterns of action to achieve the goal (''his lobs have not been too accurate''); (c) *action concepts* specify an action selected or patterns of actions which may produce goal-related changes in the context of a sport situation (''serve it wide to his forehand''); (d) *regulatory concepts* specify whether or not an action was carried out (''I kept it real low at his feet''); and (e) *do concepts* specify how to perform an action (''got to bend my knees''). Additional statements (e.g. emotional utterances) were coded yet not reported since they were not the focus of this study.

Identified concepts in each major category were also differentiated into *subconcept categories*; these categories emerged from these participants. Some possible subconcept categories for goals were: general about them (e.g. ''to get aggressive''); to get the ball in; to keep the ball in play; to execute the skill (general or specific shots); to keep the ball away from opponent (general about opponent, ''move him around''); to prevent opponent's aggressive shots (general about opponent, ''don't let him come in''); to make opponent make mistakes (''get an unforced error out of it''); specific goals about moving opponent (''force him to go backwards''); win attributes (''win this game''); to finish game; and to do the same thing or same plan. Subconcept categories for conditions were: their weakness, their strength, their prior (or future) shot, their position, their tendencies, opponent's weakness, opponent's strength, opponent's prior (or future) shot, opponent's position, opponent's tendencies, shot type (or tactic), service type, position type, and game status. Subconcepts for actions were: serve, return of serve, groundstroke, lob, approach shot, drop shot, passing shot, position move, and visual act. Subconcept categories for do and regulatory concepts were classified separately yet similar to action subconcept categories. Also, composition of goals and sophistication of conditions and actions were examined. Goals were classified according to three categories: goals about *skill and themselves* (''to get it over''); goals about *themselves and opponent* (''to keep him deep''); and goals about *win attributes* (''to win point''). Condition and action concepts were examined for details and classified as: inappropriate or weak; appropriate without any details; appropriate with one or more details; or appropriate with two or more details.

Concept structure was examined for connections and linkages. *Connections* were any words (e.g. if, then, to, so that) that connected any two concepts within a phrase. Words linking details within a concept were not considered a connection. *Linkages of concepts* were coded according to the number of concepts identified in a phrase.

Reliability of the coding system

The first author trained the second author on the coding instrument. Both coders were considered tennis experts in terms of teaching and coaching. Also, the second author was unfamiliar with this line of research or participant groupings at the time of verbal report training or coding. Both coders scored six randomly selected between-point interviews (recall and planning interviews) of professional and advanced beginner participants (three at each level). Also, both coders were blinded to group membership during all phases of the coding process. Inter-rater and intra-rater reliability were estimated by number of agreements/(number of agreements + disagreements) $\times 100 =$ percentage for all coded categories for each participant according to interview type. To determine intra-rater reliability, both coders scored the same participants 2 weeks later. Mean reliability estimates for inter-rater reliability were 0.95 for the recall interviews and 0.95 for the planning interviews. Mean reliability estimates for intra-rater reliability were 0.85 for the recall interviews and 0.89 for the planning interviews for one coder, and 0.98 for the recall interviews and 0.99 for the planning interviews for the other coder. One of these coders scored the remaining interviews. Both coders conducted one reliability check during this final coding session.

Design and analysis

Quantitative analysis of coded verbal reports was conducted to compare the concept content and structure of problem representations verbalized during the recall and planning interviews. Measures of content and structure were scored separately for each participant according to interview. Concept content was scored according to: total or sum of all concepts generated for each major concept category; variety or sum of all subconcept categories generated for conditions, actions, and goals; sophistication or sum of all concepts exhibiting one or more details for conditions and actions; and hierarchy or sum of all concepts generated in each category. Concept structure was scored according to total connections (sum of all connections) and total linkages (sum of all two or more concept linkages). The previously mentioned frequency scores for measures of content and structure were transformed to rank scores for all statistical analyses, since sample size was small and the data did not meet assumptions of normality. Separate 2 (level of expertise) $\times$ 2 (interview type) multiple analyses of variances (MANOVAs) with repeated measures on the last factor were conducted on rank scores using the *L*-statistic (see Thomas, Nelson, & Thomas, 1999) for measures of content

and structure. This non-parametric approach is based on the Puri and Sen (1985) L treated as a χ^2 approximation with the degrees of freedom = pq ($p = k - 1$ where k is the number of groups; q = number of dependent variables). The L-statistic for all MANOVAs = $[(N - 1)\ r^2]$, where r^2 = Pillai's trace. Univariate analyses of variances (ANOVAs) were conducted when appropriate using the L-statistic. The L-statistic for all *post-hoc* ANOVAS = $[(N - 1)\ r^2]$. Normality assumptions and multicollinearity issues (correlations < 0.85) were not a concern for rank scores on each of the previously mentioned measures for MANOVAs. Alpha was set at 0.05; Bonferroni adjustments were applied to *post-hoc* univariate tests.

Once the verbal reports were coded, both coders together conducted a closer inspection of the players' verbal reports to examine the properties of problem representations accessed according to expertise and interview. This procedure was undertaken to identify and/or infer the nature of collective units of information, larger memory constructs such as action plan and current event profiles, and sport specific (or specialized) strategies (see French & McPherson, 2004).

To examine changes in problem representations with increases in performance skills, verbal report data collected from the present study (adult advanced beginners and entry-level professionals) were compared with previously collected data (adult beginners and university varsity players; McPherson, 1999a, 2000). Median scores were used for descriptive comparisons since the verbal data were analysed using rank scores and non-parametric statistical tests.

Results

Table I displays mean and median rank scores for measures of concept content and structure for main effects and interactions. The MANOVA on rank scores for measures of *total conditions, actions, and goals* when tested as χ^2_3 was significant for expertise ($L\ [(N - 1)\ r^2] = (11)\quad 0.829 = 9.12,\quad P \leq 0.05$) and interview ($L\ [(N - 1)\ r^2] = (11)\ \ 0.834 = 9.17$, $P \leq 0.05$). The interaction was not significant. Univariate ANOVAs when tested as χ^2_1 indicated professionals generated more total conditions than advanced beginners ($L\ [(N - 1)\ r^2] = (11)\ \ 0.567 = 6.24$, $P \leq 0.02$); total goals and actions were not significant, although mean ranks were higher for professionals than advanced beginners. Univariate ANOVAs when tested as χ^2_1 indicated players generated more conditions during the recall than planning interviews and more goals during the planning than recall interviews ($L\ [(N - 1)\ r^2] = (11)\ \ 0.679 = 7.48,\ \ P \leq 0.01$; $L\ [(N - 1)\ r^2] = (11)\ \ 0.705 = 7.75,\quad P \leq 0.01$, respectively). Mean ranks indicated players generated more actions during the recall than planning interviews, yet this trend was not significant. The MANOVA on rank scores for *variety of conditions, actions, and goals* when tested as χ^2_3 was significant for expertise ($L\ [(N - 1)\ r^2] = (11)\quad 0.785 = 8.64,\quad P \leq 0.05$) and interview ($L\ [(N - 1)\ r^2] = (11)\ \ 0.802 = 8.82$, $P \leq 0.05$). The interaction was not significant. Univariate ANOVAs when tested as χ^2_1 indicated that professionals generated diverse conditions more often than advanced beginners ($L\ [(N - 1)\ r^2] = (11)\ \ 0.668 = 7.35$, $P \leq 0.01$). Variety of actions and goals were not significant, although higher mean ranks were noted for professionals than advanced beginners. Univariate ANOVAs when tested as χ^2_1 indicated more diverse conditions were generated during the recall interviews ($L\ [(N - 1)\ r^2] = (11)\ \ 0.672 = 7.39,\ \ P \leq 0.01$) and more diverse goals were generated during the planning interviews ($L\ [(N - 1)\ r^2] = (11)\ 0.53 = 5.88$, $P \leq 0.02$). Mean ranks for variety of actions were higher during the recall than planning interviews, but not significantly so.

A one-way MANOVA was conducted to examine expertise differences on rank scores for *total do and regulation concepts* generated during the recall interviews. Expertise was significant ($L\ [(N - 1)\ r^2] = (11)\ \ 0.65 = 7.12$, $P \leq 0.01$) when tested as χ^2_2. Univariate ANOVAs indicated advanced beginners (mean rank = 18.3, median rank = 19.3) generated more do concepts than professionals (mean rank = 9.2, median rank = 7.5) ($L\ [(N - 1)\ r^2] = (11)\quad 0.493 = 5.42$, $P \leq 0.02$) when tested as χ^2_1. Although mean ranks for regulatory concepts were higher for professionals (mean rank = 19.6, median rank = 19.5) than advanced beginners (mean rank = 16.4, median rank = 16.3), this finding was not significant. These measures for the planning interviews were not tested, since the players did not generate regulation concepts and advanced beginners exclusively generated do concepts (median = 1.0, range = 1.9).

The MANOVA on rank scores for *sophistication of conditions and actions* when tested as χ^2_2 was significant for expertise ($L\ [(N - 1)\ r^2] = (11)\ \ 0.710 = 7.81$, $P \leq 0.02$) but not significant for type of interview or the interaction. Univariate ANOVAs when tested as χ^2_1 indicated professionals generated more detailed conditions and actions than advanced beginners ($L\ [(N - 1)\ r^2] = (11)\ \ 0.676 = 7.44,\ P \leq 0.01$; $L\ [(N - 1)\ r^2] = (11)\ \ 0.568 = 6.25,\ P \leq 0.02$, respectively). The MANOVA on rank scores for *composition of goals* when tested as χ^2_3 was significant for interview ($L\ [(N - 1)\ r^2] = (11)\ \ 0.764 = 8.40$, $P \leq 0.05$) but not significant for expertise or the interaction. Univariate ANOVAs when tested as χ^2_1 indicated players generated more goals about *skill*

Table I. Mean and median rank scores on verbal report measures of content and structure for expertise, interviews, and interactions.

	Main effects				Interactions			
	Expertise level		Interview type					
Variables	AB	P	RI	PI	AB-RI	P-RI	AB-PI	P-PI
Total goals	10.6 (10.8)	14.4 (17.5)	7.7 (6.5)	17.3 (18.0)	7.0 (6.5)	8.3 (6.5)	14.2 (14.3)	20.5 (20.5)
Variety of goals	11.3 (10.5)	13.7 (16.0)	9.7 (5.8)	15.3 (14.5)	10.1 (9.0)	9.3 (4.0)	12.5 (12.5)	18.1 (18.8)
Goals about *skill and themselves*[a]	10.3 (11.0)	14.7 (17.5)	8.0 (5.5)	17.0 (5.4)	7.1 (4.4)	8.8 (6.7)	13.5 (5.2)	20.5 (2.8)
Goals about *themselves and opponent*[a]	11.0 (10.8)	14.0 (16.0)	10.9 (6.6)	14.1 (7.2)	10.8 (5.9)	10.9 (7.7)	11.3 (6.7)	17.0 (6.9)
Goals about *win attributes*[a]	12.6 (14.0)	12.4 (13.5)	7.5 (3.6)	17.5 (5.2)	6.8 (3.3)	18.4 (4.2)	8.2 (4.1)	16.6 (6.4)
Total conditions	8.4 (6.8)	16.6 (17.5)	16.0 (17.0)	9.0 (8.3)	12.5 (13.0)	19.5 (19.5)	4.3 (4.5)	13.7 (12.0)
Variety of conditions	8.1 (6.5)	16.9 (18.3)	16.0 (17.0)	9.0 (7.8)	11.3 (11.8)	20.6 (20.0)	4.8 (4.8)	13.3 (13.0)
Conditions with one or more details[b]	7.3 (4.0)	17.8 (18.3)	14.1 (15.8)	10.9 (10.5)	8.7 (6.3)	19.6 (20.0)	5.8 (4.0)	15.9 (15.0)
Total actions	9.5 (7.8)	15.5 (16.5)	14.7 (16.5)	10.3 (10.0)	11.3 (10.0)	18.0 (19.0)	7.7 (5.0)	13.0 (11.5)
Variety of actions	10.2 (10.5)	14.8 (15.5)	14.2 (15.5)	10.8 (10.5)	12.5 (12.5)	16.1 (18.5)	8.1 (5.8)	13.6 (12.5)
Actions with one or more details[c]	8.4 (5.8)	16.6 (16.5)	14.7 (16.5)	10.3 (10.0)	11.2 (10.0)	18.2 (18.0)	5.7 (3.5)	15.0 (14.3)
Total connections	9.5 (5.5)	15.5 (15.0)	14.0 (14.0)	11.0 (9.5)	13.3 (13.3)	14.7 (14.0)	5.6 (5.5)	16.4 (17.5)
Linkages[d] with two or more concepts	8.3 (5.8)	16.7 (16.5)	14.3 (15.5)	10.7 (10.3)	11.6 (11.3)	17.0 (18.3)	5.1 (4.5)	16.3 (15.5)

Note: Verbal reports were collected during singles tennis competition. Players competed within their respective expertise level. P = entry-level professionals ($n = 6$); AB = advanced beginners ($n = 6$); RI = immediate recall interviews; PI = planning interviews. Medians for rank scores are in parentheses.

[a]Composition of goals; [b]Sophistication of conditions; [c]Sophistication of actions; [d]Linkages were based on any combination of goal, condition, action, do and/or regulatory concepts within a phrase.

and themselves and *win attributes* during the planning than recall interviews ($L\ [(N-1)\ r^2] = (11)\ 1.936 = 21.30$, $P \leq .001$; $L\ [(N-1)\ r^2] = (11)\ 2.384 = 26.22$, $P \leq 0.001$, respectively). Mean ranks indicated the players followed this trend for goals about *themselves and opponent*, but this finding did not reach significance.

The MANOVA on rank scores of *total connections and total linkages* when tested as χ_2^2 was significant for expertise ($L\ [(N-1)\ r^2] = (11)\ \ 0.624 = 6.86$, $P \leq 0.05$). Type of interview and the interaction were not significant. Univariate ANOVAs when tested as χ_1^2 indicated professionals generated more concept linkages than advanced beginners ($L\ [(N-1)\ r^2] = (11)\ \ 0.611 = 6.72$, $P \leq 0.01$); professionals generated more connections than advanced beginners, but this finding did not reach significance.

In summary, expertise main effects indicated professionals generated a higher number of conditions, which were more varied and detailed than advanced beginners. Also, professionals exhibited more detailed actions and more concept linkages than advanced beginners. However, advanced beginners generated more do concepts than professionals during the recall interviews; only advanced beginners generated do concepts during the planning interviews. Interview main effects indicated the players generated a higher number of conditions, which were also more varied, as well as more regulatory concepts during the recall than planning interviews. Also, the players generated a higher number of goals that were more varied in nature as well as more goals concerning *skill and themselves* and *win attributes* during the planning than recall interviews. Interactions were not significant since expertise differences were consistent (parallel) across interviews.

Tables II and III present inferences about the nature of players' problem representations according to expertise for the recall and planning interviews, respectively. Sample verbal reports are also presented to support these inferences and are coded to illustrate concept content and structure and type of long-term memory profiles (i.e. action plan and/or current even profiles).

During the recall interviews (see Table II), advanced beginners exhibited rudimentary action plan and current event profiles that were highly goal oriented. At times, goals were their only solutions. Their use of action plan profiles was noted in selections of actions and the nature of goals and conditions. That is, advanced beginners frequently generated a variety of actions (e.g. shot selections), general execution goals, and conditions about the current context about player positions and ball

Table II. Properties of advanced beginners' and professionals' problem representations and sample verbal reports generated during immediate recall interviews.

Properties of problem representation	Samples of between-point verbal reports "What were you thinking about while playing that point?"
Advanced beginners' PR contained: • Variety of goals that were more often general than specific and often the only solution • Several conditions that often lacked detail • Some conditions that were often reiterations about events in the current context such as player positions and ball locations • Some conditions that were often reiterations about past events such as player behaviours, game status, shot types • Several and varied actions that often lacked detail and rationales for such actions • Several regulatory concepts that were often reiterations of events that happened to them rather than interpretations of why such events occurred • Some actions that were based on rudimentary or isolated conditions about player positions and ball location • Some actions that were based on rudimentary interpretations of conditions about player behaviours, game status • Several regulation and do concepts that primarily described failed motor executions	• *Just get it over the net* (G) *and hitting it* (G). AB4 • *Double fault* (C), *I wasn't thinking of nothing actually* (C). AB5 [CEP] • *I was trying to make him move* (G). AB3 • *That was a good serve* (R). AB6 [APP] • *I knew he was not gonna make the two serves* (C). AB6 [CEP] • *He just hit a serve* (C) *and I didn't hit it* (R), *I didn't follow through* (D). AB4 [APP] • *I wasn't hitting mine that good* (R). *Tried to put a little slice on it* (A), *it went deep* (R). *I was just wanting to get the ball in* (G). AB2 [APP] • *He hit a short return to me* (C), *I was just thinking whether to hit a slice on it or a topspin backhand* (A), *couldn't make up my mind, got caught* (C) *and hit it straight down into the net* (R). AB2 [APP] • *That's what I wanted to do* (R). *I wanted to hit a short shot in the middle of the court* (A), *hit him halfway* (C) *and hit a forceful shot in the same position* (C), *make him hit it over the net* (G), *he made a mistake* (C). AB1 [APP] [CEP] • *I just have to keep the ball in play* (G) *and hit it deep instead of hitting it* short (C) *because he charges the net* (C). *Just need to hit lobs and hit them high* (C) *because he can't swing around them* (C). AB1* [CEP] • *Right now his first serve is not very accurate* (C) *so uh when I get up to return against him I am just hoping he won't get in his first serve* (C) *which means he will have to slow down his second* (C), *which will be a lot easier to get to* (C). AB2* [CEP]
Professionals' PR contained: • Goals that were more often specific than general and linked to solutions or tactical reasoning • Several detailed conditions that were about current or anticipated context such as player positions and ball location • Several detailed conditions that were about past, current, and anticipated events such as player behaviours, game status, shot types • Several varied and detailed actions that were linked to rationales for such actions • Several detailed actions that were based on predictions about player positions and ball location • Several detailed actions that were linked to a variety of detailed and pertinent conditions about past, current, and anticipated events such as player behaviours, game status, shot types • Several regulatory concepts that reflected monitoring of success of actions based on interpretations of past events (e.g. characteristics of opponent's behaviours) more often than reasons for failed motor executions	• *I was thinking about coming to the net* (C), *putting the pressure on* (G), *making him hit first volleys* (G), *making him pass me* (G). P11 [CEP] • *One of the best returns of the day* (R), *keeping it low* (C), *no free points for him* (G), *make him hit up* (G) P12 [APP] [CEP] • *I was thinking about trying to get the ball into his forehand* (A), *which I did* (R), *he tends to hit the ball flatter* (C). P10 [APP] [CEP] • *He just served the first point and I got it* (C), *he hit an unforced error* (C), *he's been serving and volleying a lot* (C) *so I'm just going to try and hit the returns low* (C), *try to attack when I can* (G). P8 [CEP] • *I got an easy first serve in* (R), *it helped me get the point* (C), *I gotta stick to the backhand* (C), *he's still chipping and charging* (C). P12 [APP] [CEP] • *Love 30* (C), *missed my first serve again* (C), *I still got to work on it* (G), *got to bend my knees* (D). P8 [APP] [CEP] • *Did exactly what I wanted to for serve* (C) *and I got a point* (G). P9 [CEP] • *I missed the first serve* (R) *so I needed to get the second serve in with a lot of spin* (A) *to keep him on his toes* (G). *I did that* (R) *and pushed him back a little bit* (C), *which I came in* (A) *and did a good volley* (R). P7 [APP]

Note: Verbal reports were collected during singles tennis competition. Players competed within their respective expertise level. PR = problem representations; P = entry-level professionals; AB = advanced beginners; G = goal concept; C = condition concept; A = action concept; R = regulatory concept; D = do concept; RS = reactive statement; APP = this sample verbal report denotes existence (not quality) of action plan profile; CEP = this sample verbal report denotes existence (not quality) of current event profile. *These sample verbal reports of AB1 and AB2 were not representative of all verbal reports generated by these players or other advanced beginners.

Table III. Properties of advanced beginners' and professionals' problem representations and sample verbal reports generated during planning interviews.

Properties of problem representation	Samples of between-point verbal reports "What are you thinking about now?"
Advanced beginners' PR contained: • Variety of goals that were more often general than specific and often the only plan • Several conditions that often lacked detail or tactical analysis • Some conditions about past or anticipated context such as player positions and ball location • Some conditions about past, current, or anticipated events such as player behaviours, current game status • Several actions that often lacked detail and rationale for such actions • Some actions that were based on rudimentary or isolated conditions about player positions and ball location • Some actions that were based on rudimentary interpretations of conditions about own and opponent's behaviours and game status • Several do concepts that described mechanical adjustments to their motor skills	• *I'm going to try to keep him moving side to side* (G). AB3 • *Let's see what I'm going to do, I'm going to play safe* (G) *and go for glory here* (RS), *so ah that's all I'm thinking about right now.* AB5 • *So right now let's see, his first serve was kind of slack* (C), *so I'm going to just concentrate on second serves* (C), *maybe hit a winner or two here* (G). AB5 [CEP] • *So just concentrate on that first serve* (G), *he might hit a winner* (C) *or something so be careful* (G). AB6 [CEP] • *For right now I would just like to win this game* (G), *so I'll be up 2 – 0 that will be a nice advantage* (C). AB4 [CEP] • *I'm going to make sure next time run as hard as I can to get up there* (A), *to return it* (G). AB2 [APP] • *I need to hold my racket face open* (D), *just try to hit harder* (A). AB4 [APP] • *I just need to score some points in this game* (G), *I got to swing up over the ball instead of just half way swinging through it* (D). AB1 [APP]
Professionals' PR contained: • Specific goals that were linked to solutions or tactical reasoning • Several detailed conditions that were about current or anticipated context such as player positions and ball location • Several detailed conditions that were about past, current, and anticipated events such as player behaviours; game status; and serve, shot, and position tactics • Several detailed actions that were based on predictions about player positions and ball location • Several detailed actions that were linked to a variety of detailed and pertinent conditions about past, current, and anticipated events such as player behaviours, game status, shot types	• *I want to try and keep the ball deeper* (C), *so that he doesn't come in* (G) *and I know he attacks and loves to play at the net* (C), *so I'm going to try and keep him behind the baseline* (G). P9 [CEP] • *I want to get my first serves in* (G) *because he's going to attack my second serves* (C), *that's all I want to do, get my first serves in, even if I've got a little less pace* (C). P9 [CEP] • *Think I need to do the same on this point* (G), *try to either, try to look for that short ball* (A), *come in right behind it* (A). P10 [APP] [CEP] • *He's still going to keep coming in* (C), *I gotta play him deeper* (G), *or he's just gonna crush me* (C). P12 [CEP] • *Let's see if we can move this ball now; see if we can't change up* (C), *hit a serve wide* (A). P12 [APP] [CEP] • *I'm up 40-love* (C) *again, put more pressure on him* (G) *and try to get that first serve in* (G), *if not I'm going to put a little extra on the second serve* (A). P7 [APP] [CEP] • *And right now I'm up on him* (C), *so I'm going to try and play a little more aggressively* (C), *same game plan, keep the returns low* (C), *try to move him around* (G) P8 [CEP] • *Um' its deuce* (C), *I need to chip* (A) *and charge* (A). P11 [APP] [CEP] • *Right now I need to think about working his backhand (A), waiting for my short approach to come in* (C), *that's where I'm going to beat him* (G). P11 [CEP]

Note: Verbal reports were collected during singles tennis competition. Players competed within their respective expertise level. PR = problem representations; P = entry-level professionals; AB = advanced beginners; G = goal concept; C = condition concept; A = action concept; R = regulatory concept; D = do concept; RS = reactive statement; APP = this sample verbal report denotes existence (not quality) of action plan profile; CEP = this sample verbal report denotes existence (not quality) of current event profile.

location. However, these conditions and actions often lacked detail and consisted of reiterations rather than diagnoses of game events. Also, such reiterations often contained other aspects of action plan profiles such as monitoring their motor skills (regulatory concepts) and why such motor skills failed (do concepts). Overall, advanced beginners accessed weak current event profiles since most of their condition concepts reflected reiterations or poor diagnoses of game events rather than developing pertinent situation or condition profiles. For example, only two players on one occasion generated some type of shot tactic based on pertinent information about their opponent's behaviour. Finally, they generated few associated concepts due to their limited profiles.

In contrast, professionals during recall interviews (see Table II) exhibited tactical current event profiles and action plan profiles as indicated by their reasoning of pertinent game events and ways to accomplish specific goals. Professionals frequently selected detailed actions based on tactical analyses of current context (i.e. conditions about player positions) and success of their actions (regulatory concepts). They often modified their condition profiles regarding their shot selections or predictions about opponent's behaviours rather than their techniques (do concepts). Also, their conditions indicated they accessed and developed current event profiles as information about pertinent game events (e.g. conditions about opponent's weaknesses) was updated as competition progressed. Thus, professionals utilized action plan profiles in conjunction with current event profiles to select and enhance actions and/or develop tactics. Similarly, their concepts were highly associated.

During planning interviews (see Table III), advanced beginners accessed rudimentary action plan and current event profiles and primarily planned general goals. For example, their plans contained few detailed actions, weak corrections of technique (do concepts), and few condition–action linkages indicative of weak action plan profiles. Also, advanced beginners rarely developed plans based on pertinent conditions about player behaviours or game events. This finding was indicative of their deficient current event profiles. As a result, advanced beginners generated few associated concepts in their plans. In contrast, professionals developed plans based on tactical action plan and current event profiles that were linked to a variety of specific goals. Their plans often contained detailed actions or patterns of actions. Also, professionals frequently based actions or goals on pertinent and detailed condition profiles about: anticipated player positions and ball locations; abstract serve, shot or position tactics; their own and opponent's behaviours; and game status. Furthermore, their plans lacked adjustments in techniques noted by lack of do concepts. Also, they noted how well their plans were working and modified them accordingly. Thus, their tactical solutions contained associated concepts.

Median scores for measures concept content and structure from this (adult advanced beginners and entry-level professionals) and previous studies (adult beginners and university varsity players; McPherson, 1999a, 2000) are presented in Figure 1 for the recall interviews and Figure 2 for the planning interviews to examine changes in problem representations with increases in performance skills. Median scores during recall interviews (Figure 1) indicated professionals and advanced beginners mediated their performances via goals more often than beginners and varsity players. Advanced beginners utilized more diverse goals than the other groups. Composition of goals indicated: beginners exclusively generated goals about skill and themselves; only professionals and advanced beginners generated goals about their opponent; and no group utilized goals about win attributes. Among groups, utilization of condition, action, and regulation concepts increased with expertise. Exceptions were: higher levels of detailed conditions for varsity players than professionals; similar variety of actions for advanced beginners and varsity players; and similar detailed actions for varsity players and professionals. Also, advanced beginners and varsity players exclusively utilized do concepts. Among groups, associations among concepts increased with expertise. Although advanced beginners exhibited some exceptions during recall interviews, their concept content was less tactical than that of varsity players and professionals.

Median scores during planning interviews (Figure 2) indicated professionals planned more and varied goals than the other groups, and advanced beginners planned more goals than varsity players. Composition of goals indicted: professionals planned more goals about skill and themselves and about themselves and opponent than other groups; advanced beginners planned more goals about themselves and their opponent than varsity players; beginners planned goals only about skill and themselves; and all groups (except beginners) planned some goals about win attributes. Professionals planned more conditions than varsity players; both groups were similar for variety and detail of conditions. Beginners and advanced beginners planned few conditions and actions with minimal variety or detail. Varsity players planned more, varied, and detailed actions than professionals. Varsity players planned more do concepts than advanced beginners; do concepts were not planned by beginners and professionals. Also, associations among concepts increased as expertise increased.

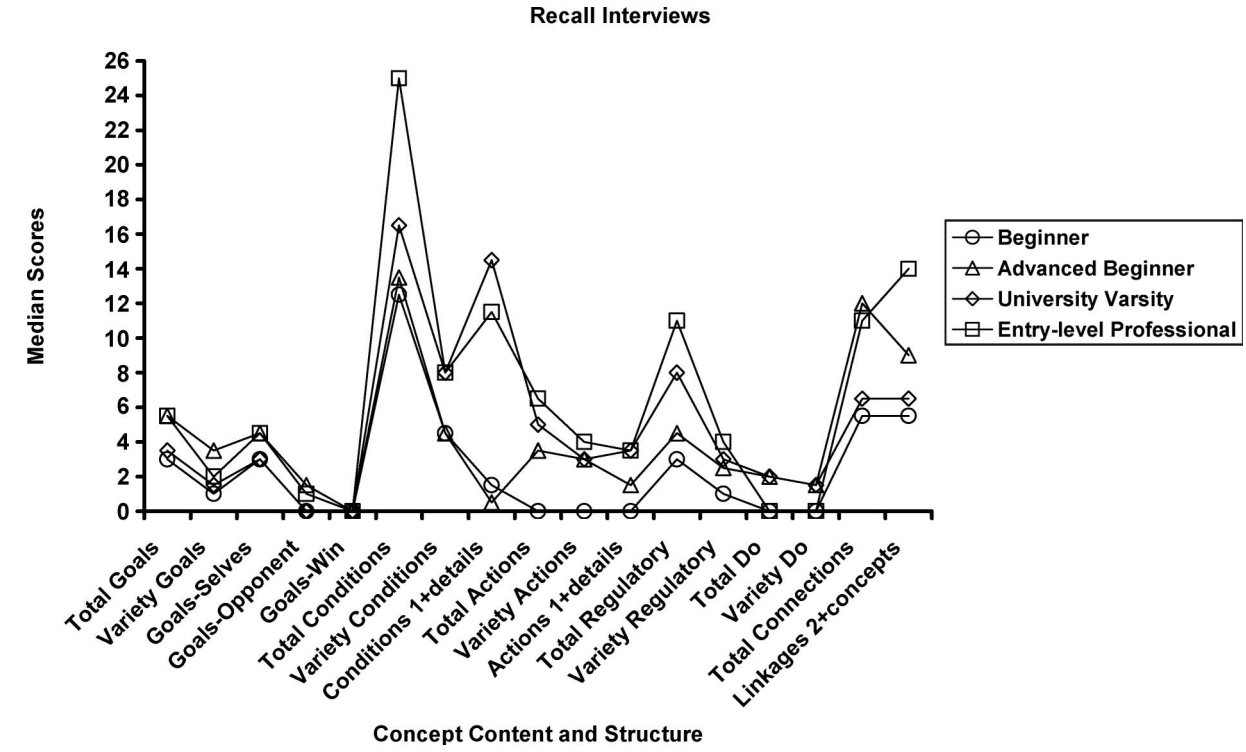

Figure 1. Median scores for verbal report measures of concept content and structure for recall interviews according to expertise groups. Verbal reports were collected during singles tennis competition. Players competed within their respective expertise level.

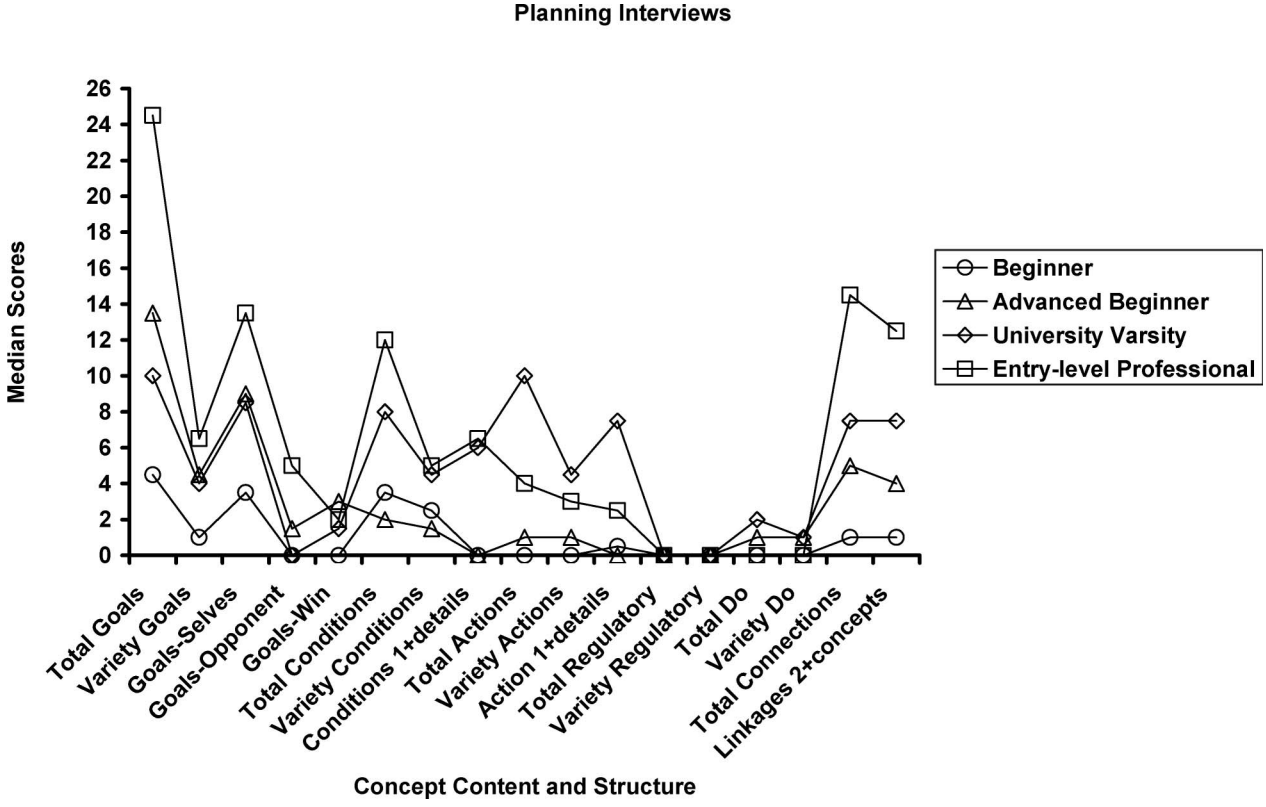

Figure 2. Median scores for verbal report measures of concept content and structure for planning interviews according to expertise groups. Verbal reports were collected during singles tennis competition. Players competed within their respective expertise level.

Discussion

As predicted, professionals exhibited more advanced problem representations than advanced beginners. For example, both groups were highly goal oriented during competition, albeit professionals generated more specific goals, whereas advanced beginners exhibited more global or general goals. As expected, professionals generated more tactics and solutions in response to their goals than advanced beginners, who primarily utilized rudimentary action plan profiles to select shots and monitor their actions. This was evident as some advanced beginners monitored player positions and ball location to make decisions about shot or serve selections. In contrast, professionals consistently utilized both tactical action plan and current event profiles to process information and make decisions as competition progressed. As predicted, the two groups monitored the success of their serve or shot executions (regulatory concepts) similarly. However, in response to this monitoring, advanced beginners modified their techniques to enhance motor execution problems (do concepts) while professionals modified tactics about conditions related to serve or shot selections or other events. Thus, professionals monitored actions to develop tactics while advanced beginners monitored actions to correct failed serves or shots. This finding indicates advanced beginners primarily accessed action plan profiles while professionals accessed both action plan and current event profiles.

However, two advanced beginners on one occasion accessed rudimentary current event profiles. That is, they developed shot tactics based on previous events concerning their opponents' behaviours. This suggests advanced beginners may have been capable of processing more pertinent information during tennis competition, but lacked sufficiently developed current event profiles to do so. Consistent with predictions, professionals utilized tactical current event and action plan profiles during competition. Professionals indicated they accessed and updated a variety of scripts regarding game tactics, condition profiles about their own and opponents' behaviours, status of game, and so on to achieve specific goals or to select actions. Both profiles were used to update tactics or select actions. As predicted, the type of interview influenced the nature of the problem representations accessed by players. That is, players, irrespective of expertise, processed more information during the recall than planning interviews. Also, advanced beginners with deficient current event profiles had more difficulty planning or predicting future actions or events than reiteration of what happened during a prior point. In contrast, professionals exhibited more elaborate problem solving during the recall than planning interviews due to their long-term memory constructs. Why? During the recall interviews, professionals consistently reasoned about (a) their bases of decisions or shot selections, (b) the success of their actions and ways to enhance such actions, and (c) updated profiles about their own and their opponent's behaviours, shot tactics, and used such information to generate their plans (i.e. planning interview). During the planning interviews, professionals applied specific tactics or solutions, which resulted in less reasoning. For example, professionals rarely updated condition profiles in their plans. Finally, all players generated more goals about skill and themselves and win attributes during the planning than recall interviews. Yet, advanced beginners utilized goals as their only solution or poor reasoning based on rudimentary action plan and current event profiles. Professionals, in contrast, utilized specific goals as part of their tactical solutions derived from tactical reasoning (tactical action plan and current event profiles).

Also as predicted, improved performance skills were accompanied by increases in tactical problem representations when verbal report data collected from the present study (adult advanced beginners and entry-level professionals) were compared with previously collected data (adult beginners and university varsity players; McPherson, 1999a, 2000). That is, the recall and planning interviews indicated beginners, with the lowest performance skills among groups, lacked action plan and current event profiles. This was evident in their reiterations of game events and general goals. Advanced beginners, with higher performance skills than beginners, accessed rudimentary action plan profiles during the recall interviews. For example, they generated several general yet diverse goals, some pertinent conditions about current context, and several detailed actions that were monitored and analysed when unsuccessful. Yet, they lacked current event profiles since they rarely generated thoughts beyond the current game events. Their access to weak long-term memory profiles was most evident during planning interviews, as their plans were few and limited to goals. As performance skills increased, problem representations showed improvements.

Varsity players and professionals processed tactical information in the current context and beyond as evidenced by both action plan and current event profiles. During both interviews, varsity players, with lower performance skills than professionals, exhibited fewer and less associated concepts (especially concerning conditions) than professionals. For example, during the recall interviews professionals utilized pertinent condition, action, and regulatory concepts more often than varsity players. Also, only varsity players modified their techniques during both

interviews. During planning interviews, varsity players planned specific shots (actions) and techniques (do concepts) whereas professionals planned shot types (conditions). Also, professionals included more condition profiles (e.g. predictions about an opponent's behaviours) and specific goals in their plans than varsity players. This was evident as varsity players planned more actions, fewer conditions, and fewer goals than professionals. These findings suggest that, during planning, varsity players utilized action plan profiles more often than current event profiles than professionals. Thus, as predicted, professionals exhibited the most sophisticated action plan and current event profiles among groups during both interviews. Also, techniques were modified with more discretion as performance skills increased (McPherson, 2000), yet this trend may vary according to sport, experimental context, and so on (McPherson & Vickers, 2004).

These findings regarding improvements in players' problem representations and performance skills with increasing expertise also support the role of deliberate practice and acquisition of expert performance (Ericsson, Krampe, & Tesch-Romer, 1993). The number of years of reported experience among these expertise groups followed a similar pattern. Specifically, professionals had more mean years of experience than varsity players (19.3 and 10.8 years, respectively) and advanced beginners had more mean years of experience than beginners (5.3 and 2.2 years, respectively). While years of experience should not be equated with skill, several sport expertise studies have noted that level of skill exhibited a positive linear relationship with amount of accumulated practice (see Starkes, Deakin, Allard, Hodges, & Hayes, 1996). However, we suggest these trends have more to do with the standard of competitive play and performance skills as these participants were sampled across levels of expertise. Thus, we caution that variables such as tactical knowledge and years of experience (or accumulated practice) may not always develop in a slow linear trend. That is, a player's tactical knowledge may be influenced more by what is practised or may be accompanied by acquisition of a specific motor skill (e.g. ability to execute an approach shot successfully) rather than the amount or years of practice. However, research examining these and other variables is limited.

Overall, the current findings provide new information about the development of action plan and current event profiles with increases in performance skills during tennis competition. As previously noted, performance behaviours during competition increased for beginners, advanced beginners, varsity players, and professionals. Similarly, problem representations of these same groups during competition showed the same pattern of improvement in terms of increases in sophistication of current event and action plan profiles accessed during competition. This finding is consistent with Ericsson's (2003a, 2003b) prediction that experts will continue to remain in the cognitive associate stage (i.e. develop more elaborate and extensive current event and action plan profiles) to achieve better performances and supports recent predictions about the stages of development of tactical knowledge with sport expertise (Starkes, Cullen, & MacMahon, 2004). Thus, as decision skills and motor skills increase, adaptations in long-term memory also increase. Based on the current findings, memory constructs emerge from smaller units of information and

Table IV. Examples illustrating how long-term memory constructs and specialized strategies develop with increasing expertise.

Level	Conditions about opponent	Specialized strategies
1	Conditions about opponent not in problem representation; utterances do not contain this concept	No need to monitor opponent; thus no general or specialized strategies
2	Conditions about opponent reflect general or weak analyses; utterances at times contain weak concepts about opponent	Monitor opponent occasionally reiterate events; thus general working memory strategy
3	Conditions about opponent regard his or her position on court and/or prior shot; utterances are in the moment and thus reflect evidence of rudimentary action plan profile	Monitor player positions and shots; concepts about opponent linked to shot selection or reiteration of events
4	Conditions about opponent's position and shot tendencies are updated on a regular basis; conditions about opponent emerge from action plan and current event profiles; these profiles become more tactical and associated and are linked to other profiles (e.g. about their own behaviours)	Analyses opponent's position and shot tendencies to update profile and develop tactics and shot selections; strategies are highly specialized and may be linked to other specialized strategies in other profiles
5	Condition profile about opponent is highly tactical and based on prior knowledge of other opponents' style of play and preferences; action plan and current event profiles become more tactical and associated and are linked to other profiles (e.g. about their style of play and preferences)	Same as #4: opponent profile is used to anticipate opponent's tactics

Note: Levels represent advancing levels of expertise (1 = lowest level; 5 = highest level).

domain-related strategies (see French & McPherson, 1999, 2004; McPherson & Kernodle, 2003) and undergo development first in action plan profiles, followed by current event profiles, and continues to develop via refinement and association within and between both profiles.

Table IV provides an example to illustrate how adaptations in action plan and current event profiles develop with tennis expertise. Among experts, problem representations of professionals and varsity players exhibited several condition profiles and specialized strategies like those presented at level 4. Yet, professionals exhibited more extensive and varied profiles than varsity players. Among novices, advanced beginners at times exhibited condition profiles and specialized strategies like those presented at levels 2–3, whereas beginners exhibited problem representations at levels 1–2. Yet, our knowledge of how these players acquired such memory structures is limited. For example, the experiences of these players and their impact on decision skills and tactical knowledge were not documented in this study. In the future, researchers should not only examine how players utilize tactical knowledge but how they acquire it as well. So far, this type of research has been conducted in domains other than sport such as chess (Ericsson *et al.*, 1993). Furthermore, in line with Ericsson's (2003a) expert performance approach, we suggest the next phase of this line of research should include controlled experiments using representative tasks *that simulate the type of processing players encounter during actual tennis competition* to test postulates in tennis (McPherson, 1999) concerning long-term memory profiles and long-term working memory mechanisms (e.g. Ericsson & Delaney, 1999). Importantly, laboratory simulations examining players' decision skills such as shot selections must contain enough contextual information over long enough periods of time to adequately examine players' use of current event profiles during problem solving and reasoning tasks. So far, most laboratory simulations (that involve decision tasks, motor tasks, or both) limit such processing and test the nature of players' action plan profiles (e.g. test differences in players' shot decisions based on current conditions in the context) more often than current event profiles or interplay of both.

Another approach is to begin to examine possible interactions among players in terms of the performance skills they have available, performance skills their opponents have available, and how this influences the nature of their problem representations accessed during competition. For example, if a tennis player has not acquired an adequate level of "serve and volley" performance skills during singles tennis competition yet his or her regular tennis opponents have, how does this influence performances (via observational analysis) and tactics (via verbal report analysis) of this player during singles tennis competition? The instruments utilized in the current study would be useful in examining these issues.

According to Ericsson (2003a, 2003b), these players may remain at their current level (arrested development) unless they seek experiences to achieve improved performance. We suggest players at any competitive level may benefit from direct instruction designed to build tactical knowledge (French & McPherson, 1999, 2004; McPherson & Kernodle, 2003). Although McPherson and Kernodle offered instructional interventions for improving players' tactics, research in tennis is limited in the area of knowledge base training, unlike perceptual skill training (Williams, Ward, Knowles, & Smeeton, 2002), and is limited to adult beginners (McPherson & French, 1991; McPherson, 1994). Thus, research in this area is warranted.

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