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Running head: KNOWLEDGE STRUCTURE OF EXPERTS IN TEAM SPORT

Differences in Expert Knowledge Structure between Trainer and Players with Different Roles
in Team Sport

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1 ABSTRACT

2 The organization of the knowledge structure of the back/pivot relationship in handball was
3 examined in regards to the status of participant (player or trainer) and the position of players
4 (back or pivot). Seven expert trainers and 20 professional players performed a similarity
5 judgment task including 30 concepts within 4 main categories: defensive modalities, back's
6 game, pivot's game and information about defenders. The Pathfinder network scaling
7 technique was used to elicit knowledge structures. The data revealed that trainers organized
8 concepts in 3 main categories based on the fundamental principles of handball game. In
9 contrast, pivots and back players primarily organized their actions according to their own
10 position, and predominantly formed knowledge units related to specific game situations.
11 These units were more tactical and very operational. This difference could be related to the
12 specific roles of players in complex and demanding tasks, and dedicated to their efficiency.

13

14

15

16 *Keywords:* Back/pivot relationship, Expertise, Memory, Pathfinder, Similarity judgments,

17 Team Mental Model

1 Differences in Expert Knowledge Structure between Trainer and Players with Different Roles
2 in Team Sport

3 This study was designed to determine the cognitive factors associated with expertise in
4 team sport, and therefore specifically addressed the question of skilled athletes memory
5 (Gobet, 1998), as well as the organization of their knowledge. Team sport athletes usually
6 face dynamic and complex specific environments including high level of uncertainties and
7 temporal pressure. Their efficacy mainly depends on the semantic dimension of their
8 perceptive and decision-making skills that is, the knowledge acquired during their past
9 experiences (Garbarino, Esposito, & Billi, 2001; Williams, 2002). A period of 10 years is
10 commonly accepted as being necessary to achieve peak performance. Furthermore, the
11 deliberate and motivated practice must be oriented and exclusively focused (time and
12 experience) towards the improvement of the specific factors of the performance, strictly
13 connected with the desired final outcome (Ericsson, Krampe, & Tesch, 1993; Feltovich,
14 Prietula, & Ericsson, 2006). The specialization elicited by ongoing repetitions confers on
15 experts a very high level of skill specifically and selectively in the tasks of their field of
16 expertise (Ericsson et al., 1993; Ericsson & Lehmann, 1996). Obviously, the great amount of
17 practice time and a significant number of matches played at the highest level of competition
18 mainly contribute to improve the degree of expertise (Schulz, Musa, Stazewski, & Siegler,
19 1994). Expert athletes develop more extensively than novices their cognitive skills, including
20 (a) higher recall and recognition of game configuration, (b) more effective organization of
21 visual search patterns, (c) better use of advanced visual cues, and (d) greater anticipation of
22 future events (for review, see Starkes & Ericsson, 2003). There is now ample evidence that
23 such expert's cognitive superiority is based on refined and enhanced sport-specific knowledge
24 structures acquired through years of deliberate and purposeful practice (Ericsson &
25 Lehman, 1996).

1 An important number of theories have been developed to determine the organization
2 and retrieval of knowledge in memory. Early on, Anderson (1976) distinguished between
3 declarative knowledge, which is the factual information about a situation, and procedural
4 knowledge which refers to how performing, by associating a given action with a specific
5 context. Accordingly, all the conditions of the action are defined as a function of athletes'
6 specific goals in the related game situation. When acquiring a skill, knowledge is born in a
7 declarative form and is progressively integrated in a procedure to improve efficiency of the
8 skill (Anderson, 1982). Several sport studies provided evidence that the organization of
9 knowledge structures had a direct influence on both motor and decision-making skills (French
10 & Thomas, 1987), while others reported that motor skills developed knowledge structures
11 (French, Nevett, Spurgeon, Graham, Rink, & McPherson, 1996). Altogether, these data
12 suggest that the declarative knowledge contributes to the enhancement of motor skills, despite
13 the fact that the latter were built through action rather than through observation (Anderson,
14 1982; Williams & Davids, 1995).

15 Knowledge is organized on conceptual categories stored in long-term memory (LTM –
16 Charness, 1974; Chase & Simon, 1973; Egan & Swartz, 1979). In their theory of skilled
17 memory, Chase and Ericsson (1982), and Ericsson and Kintsch (1995) proposed that experts
18 organize their knowledge in hierarchical ways into LTM, and use retrieval structures to recall
19 information. These structures improve the speed of information retrieval and its efficiency by
20 a straight access to relevant features in LTM. From 1993 to 2008, McPherson and
21 collaborators investigated the content of knowledge structures according both to age and to
22 the level of expertise of athletes. They analyzed concepts' categories in tactical knowledge
23 structure, and developed a tool for coding these concepts using semi-directed interviews
24 during game situations. This tool allowed classifying concepts focusing on the contents of
25 units of information used by athletes to explain their actions. The data showed that tennis

1 experts used higher level concepts, with more connections between them, than novices
2 (McPherson, 1993, 1994, 1999, 2000; McPherson, & Thomas, 1989; McPherson & Kernodle,
3 2007). Their representations, conditions and actions concepts were more sophisticated (*i.e.*,
4 expressed in greater detailed level) for the selection and execution of the responses. In a
5 recent study, these authors further demonstrated that baseball experts used specific strategies
6 to encode and retrieve pertinent game events from LTM, and that training tactical skills
7 contributed to form effective knowledge structures mediating decisions (McPherson &
8 MacMahon, 2008).

9 Finally, experts have been consistently found to categorize knowledge in a different
10 way than novices. While novices used surfaces features (*i.e.*, superficial ones extracted from
11 the situation), experts rather referred to deep features to form their knowledge structures (Chi,
12 Feltovich & Glaser, 1981; Ericsson & Kintsch, 1995; Didierjean, Ferrari & Marmeche, 2004).
13 These deep features emanate from both rules and principles of game, and experts better
14 perform in complex tasks as they are less penalized by their variability (Haerem & Rau, 2007;
15 Rulence-Paques, Fruchart, Dru & Mullet, 2005). Likewise, Debanne (2003) revealed through
16 semi-directive interviews that international handball goalkeepers extracted the invariant
17 features of situations to create schematic and typical representations in their knowledge
18 structure. Garbarino et al. (2001) also demonstrated that professional soccer's based their
19 planning on strategic rules when temporal pressure was low, and that they referred to tactical
20 adaptations in other circumstances. Overall, these data provide evidence that experts
21 developed and used a specific knowledge structure, and that it might vary among sports. As
22 far as team sports are concerned, it would be interesting to investigate the way the different
23 teammates use different or shared knowledge to be efficient.

24

TEAM KNOWLEDGE

1 According to Salas, Dickinson, Converse, and Tannenbaum (1992), team's
2 characteristics include the dynamic, interdependent, and adaptive interaction between
3 members with different and specific roles, as well as a common and valued performance
4 outcome. In cognitive and complex motor tasks, achieving peak performance depends on the
5 capacity of team members to work together effectively. Team performance is supposedly
6 influenced by the knowledge that the team possesses (Cooke, Stout, & Salas, 1997; Stout,
7 Cannon-Bowers, & Salas, 1996) in which Cooke, Salas, Cannon-Bowers, and Stout (2000)
8 distinguish *team mental model*. This model refers to the collective task- and team-relevant
9 knowledge that team members bring to a situation. It provides a collective knowledge base for
10 teammates to preempt the actions and needs of the others in order to facilitate and improve
11 their interacting tasks and coordination (Entin & Serfaty, 1999). A part of this knowledge is
12 common within a team (*i.e.*, homogeneous among team members), while another part
13 includes complementary role-specific knowledge that is distributed among teammates (*i.e.*,
14 heterogeneous). The degree of heterogeneous or homogeneous knowledge overlap may
15 depend on the degree to which team members interact, and its effectiveness in the task. It may
16 also depend on the nature of knowledge evolved from formal training and experience. Hence,
17 sharing the declarative knowledge may improve performance, while sharing the procedural
18 one is detrimental (Banks & Millward, 2007; Stout, & al., 1996). Analyzing the part of
19 knowledge heterogeneity on the team is crucial to understand the distributional requirements
20 of the knowledge base associated with effective team performance. As far as we know, there
21 are no experimental studies in the literature addressing this question in sport activities.
22 Especially in team sport, the goals assigned to teammates need specific skills and abilities to
23 perform in the distinct subtasks of complex and dynamic game situations.

24

THE PRESENT STUDY

1 This study investigated the characterization of knowledge distribution among team
2 players and trainers in regards to the back/pivot relationship in handball, frequently
3 encountered during international competitive events (41 per match and team, for 63 ball
4 possessions on average). The main objective of this relationship is to create a situation of
5 advantage, or to shoot while physical and temporal constraints are very important in a limited
6 space with strong density of attackers and defenders (Costantini, 1997). The back and pivot
7 interaction is the most complex one in the game because the distance between the pivot and
8 his defender is small, and because actions or feints are quickly renewed. Moreover, in these
9 attack situations, the players can permanently initiate new goals and actions using their own
10 repertoire of available strategies included in a collective one. As shown by Entin and Serfaty
11 (1999), decisions makers operating as a team use a richer repertoire than does a single
12 decision maker. Indeed, decision-making and actions are organized on enhanced, organized,
13 and stabilized knowledge structure. This includes a common code to read the game (that is,
14 cues allowing a same understanding of a given situation) and/or on schemas supposed to be
15 mastered by players. In our study, we compared their organization according to the specific
16 roles assigned to the back, the pivot, and the trainer. While very few studies focused on
17 trainers' knowledge, Côté, Young, North and Duffy (2007) highlighted the various roles that
18 coaches may assume, and pointed out that their knowledge is not only specific but also
19 context-dependent and highly related to the typical problem encountered by players in
20 competition. Indeed, trainers' missions are: (1) managing the permanent balance of power
21 between attack and defence, (2) analyzing collective tactics and systems of opponents, (3)
22 elaborating relevant strategic solutions with regards to strengths or weaknesses of the
23 opponent, and (4) managing the inter-position relations and bring tactical answers in the game
24 while considering the variety of own players' profiles. In addition, Leas and Chi (1993)
25 showed that swimming coaches used principles to diagnose stroke techniques of their

1 swimmers, and therefore organized their knowledge structure on deep features. For example
2 biomechanical principles referred to categories like “body position” or “armstroke”: “the arm
3 should be under the body and not outside the hips”. Handball player tasks make them
4 adapting immediately and individually to game situations in various tactic contexts. They
5 have to recognize characteristics from the opposite team and opponent, in order to associate
6 this information taken in the environment with the relevant actions in a similar context. This
7 very specific approach of their position impacts how they focus their attention on skills,
8 according to their own morphological characteristics and preferences in the game. Moreover,
9 their tasks are mainly connected to the action by repeating varied opposition situations, and
10 they perform position specific decision-making and tactical analyses. Finally, other tasks
11 make them communicating and collaborating with their close partner to coordinate their
12 responses.

13 The specificity of the trainers’ or players’ tasks entails a specialization which could
14 model distinct knowledge structures, as previously suggested by Ripoll (1987). Indeed, the
15 author showed that the specialization of volleyball roles – that is, trainer, passer or attacker –
16 affected visual search strategies (nature, order, time and duration of visual fixations) and
17 modalities of decision-making. Therefore, due to the specificity of tasks assigned to trainer
18 and players (back or pivot), we formulated two main hypotheses: (1) a small part of
19 knowledge structure related to the back/pivot relationship should be similar, and (2) the
20 organization of the knowledge structure (links between concepts and groups of concepts)
21 should be different. Specifically, we postulated that trainers may analyze back/pivot
22 relationship based on more general and strategic knowledge, related to the collective balance
23 of power with these concepts occupying more central places in their structure. By contrast,
24 players might use more specific and operational knowledge concerning individual actions
25 directly related to their position.

METHODS

Participants

Twenty seven male subjects participated voluntarily in this experiment and signed informed consent. All were very high level professionals competing in the French National League of handball. They were assigned into three groups according to their role in the team (Table 1): trainers ($n=7$), back players ($n=13$) and players occupying the position of pivot ($n=7$). Players who played more than one role during their career were excluded from the study. All participants were recruited according to the 10 years of deliberate and motivated practice rule, and were considered experts (Ericsson & Lehman, 1996).

[Insert Table 1 here]

Procedure

We characterized the participants' knowledge structures from a similarity judgment task. Thirty concepts concerning knowledge about back/pivot relationship were selected (Table 2) within 5 categories: defensive modalities (5 concepts), backs' game (7 concepts), pivots' game (12 concepts), the consideration of defender's behavior by the attacker (5 concepts), and the specific relation between back and pivot (1 concept).

Similarity Judgment Task. The concepts' selection procedure followed 3 consecutive steps. First, the reviewing of 492 articles from the federal journal "Approches du Handball" permitted to retain 744 instructions related to the back/pivot relationship. Then, an external committee consisting of 6 expert trainers (M age = 43.2 years, SD = 4.26) and 6 professional players (M age = 25.5 years, SD = 3.08) was composed. Trainers intervened at the national or international level (M = 8.16 years, SD = 6.31), and had a national/international player's carrier (M = 11.17 years, SD = 3.31) beforehand. Players competed at the elite or international level (M = 6.33 years, SD = 3.20). This committee validated and classified the 744 instructions in a first knowledge structure, according to the

1 position of player – that is, back, pivot, opponent or attacker – and their precision. Then, in
2 order to represent the characteristics of knowledge used by experts, 30 discriminating
3 concepts of this structure were selected for the task, and the experiment duration was less than
4 1 hr 15 min. Practically, the 435 possible pairs of concepts were presented, and the experts
5 have to estimate the degree of similarity using a 7-point Lickert scale (1 corresponding to less
6 similar and 7 to more similar). The order of the 435 pairs was randomized for each
7 participant, and the position of the 2 concepts in a pair was counterbalanced across every half
8 groups.

9 *Protocol and Instructions.* Before the beginning of the experiment, the complete set
10 of concepts was presented to the participants who could express their possible lack of
11 understanding. They were clearly informed that (1) the task was not any kind of evaluation
12 them; (2) there was no good or bad answer; and (3) the order of the concepts in the pair must
13 not be considered. Participants were instructed to make their ratings as quickly as possible
14 (approximately 5 seconds by pair) by using the full range of the scale. On average,
15 participants took about 1 hr to complete the task.

16 **Data Processing with Pathfinder**

17 The Pathfinder scaling algorithm was used to generate each participant's knowledge
18 structure based on paired comparison judgments (Schvaneveldt, 1990; Schvaneveldt, Durso &
19 Dearholt, 1989). Stout et al. (1996) argued that methods to characterize knowledge structures
20 such as Pathfinder can be used as a representation of an individual's mental model. The
21 ratings of each participant were placed in a 30×30 symmetrical proximity matrix where all
22 entries, other than the diagonal, represented the similarity judgment value for a pair of
23 concept. The Pathfinder scaling algorithm transforms a proximity matrix into a network in
24 which each concept is represented by a node in the network and relationships between
25 concepts by links. Each link has a weight, which is a positive real number computed with the

1 proximity matrix that reflects the strength of the relationship between the nodes. At first, the
2 Pathfinder algorithm generates a complete network in which each node is connected to each
3 other by a link. Then, a link remains in the network only if there is a minimum-length path
4 between two concepts. A path is an alternating sequence of nodes and links, and its length is a
5 function of the weights associated with the links in the path. Thus, this principle of Pathfinder
6 algorithm produces a network with shortest length paths. The selection of links uses two
7 parameters: q and r . The q -parameter is an integer value between 2 and $n-1$, where n is the
8 number of nodes. The Minkowski r -metric parameter is a real number between 1 and infinity,
9 and defines the metric used for computing the distance of paths. Both parameters decrease the
10 number of links in the network as their values increase. In the present study, the networks
11 with the minimum number of links was obtained with $q = 29$ ($n-1$) and $r = \text{infinity}$. Individual
12 and average networks were respectively generated for each participant (27) and each
13 experimental group (3).

14 **Dependent Variables**

15 Two quantitative dependent variables were measured: (1) the number of common links
16 between group average networks, and (2) the similarity measure, that is, the ratio between the
17 number of links shared by two networks and the total number of links. It measures the
18 correspondence of two networks (two identical networks would have a similarity of 1, while 2
19 networks without any common link would have a similarity of 0). In addition, three nodes
20 occupying a central place within the network were identified: higher degree, central, and
21 median nodes (Dayton, Durso, & Shepard, 1990). The higher degree node has the larger
22 number of direct links with the other concepts. This node facilitates the direct associations
23 within the knowledge structure that can place it in the center of a group of nodes or in the
24 intersection of axes. The two other nodes are concepts which possess the smallest maximal
25 distance with all other concepts. To identify these two nodes, a 30 X 30 matrix was elaborated

1 in each group: it contained the minimum number of links separating each pair of concepts.
2 The median node possesses the smallest average distance inside every column of the matrix.
3 So, in the structure of knowledge, it is the concept which is most easily connected to all the
4 others. Finally, the central node was determined by computing the biggest distance in every
5 column of the matrix, and by selecting the column which presents the smallest maximal
6 distance (the minimax). Thus, the central node is the concept which will be most easily
7 connected to the most remote concept.

8 **RESULTS**

9 **Similarities between Networks of Trainer, Back and Pivot.**

10 The 3 average networks shared 7 common links (concepts 1 and 2): (1) Back shooter –
11 Danger of back shoot and balance of power with goal keeper; (2) Taking into account
12 defender's timing by the attacker – Taking into account defender's moving by the attacker;
13 (3) Passer's quality of the back – Will of the back to maintain continuity of the game; (4) Low
14 aligned defence – Cutting the relations of defence; (5) Taking into account defender's
15 orientation by the attacker – Taking into account defender's placement by the attacker; (6) To
16 give advantage to a teammate by spreading out – To give advantage by liberating a space; (7)
17 Sliding game of the pivot – Breaking free game of the pivot. In addition, these 3 average
18 networks shared common main nodes. Trainers and pivots had the same central node "To give
19 advantage to back's outflanking", while pivots and backs used "Breaking free game of the
20 pivot" and "Taking into account defender's moving by the attacker" either as a higher degree
21 or a median node. These 7 common links and 3 common main nodes composed the
22 homogeneous part of the team mental model used by trainers, backs and pivots. Beyond this
23 part of common knowledge, coaches, backs and pivots also yielded different ways of
24 organizing concepts.

1 **Differences and Similarities in the Concepts' Organization between Trainer, Back and** 2 **Pivot.**

3 The similarity measures were very weak: $M = .165$, $SD = .047$ (backs vs. pivots), $M =$
4 $.153$, $SD = .048$ (trainers vs. backs) or $M = .151$, $SD = .033$ (trainers vs. pivots). These values
5 were not significantly different (one factor analysis of variance, $F(2, 228) = 2.099$, $MSE =$
6 $.004$, $p = .125$). Results showed that the 30 concepts are differently organized in the 3
7 networks, as confirmed by their following qualitative analysis. According to both the role and
8 the position of the player, knowledge structure got organized by categories, sub-network or by
9 coupling these two modalities.

10 Trainers organized concepts in 3 categories related to the position of the players and
11 fundamental game principles (Figure 1). These categories referred to those proposed initially
12 by the expert committee: the pivot's game, the back's game and the taking into account of the
13 defender's behavior by the attacker. In the pivot's game category, 11 out of 12 concepts
14 characterizing the pivot's actions were interconnected, whereas no other concept connected
15 between them. Pivot's actions were also organized according to the defensive context (stage
16 and height of the defence), which revealed a strategic organization related to handball game
17 principles (Costantini, 1997). For example, in the "Low aligned defence", pivot can execute
18 three adapted skills: to cut the defence ("Cut DEF"), to fix a defender ("Advantage Fix") or to
19 gain a position ("PVT gain Po"). The second category grouped 7 actions of back's game,
20 which were organized on a deep feature. It connected the "shooter" or "passer" role of the
21 back to his "outflanking" role. This promotes the possibility of the back to select 3
22 hierarchical goals: to shoot, to outflank, or to pass – which is a fundamental principle labeled
23 "triple threat" (Costantini, 1997). The third category concerned the behavior of the defender,
24 and grouped all concepts about "Taking into account of the defender's behavior by the
25 attacker". The particularity of this subgroup leads in its key concepts. It connected the

1 "Timing of the defender" with the "shooter" back's role. In another way, the "Defender
2 Placement" and "Defender Timing" concepts suggested that the back's player had to modulate
3 his game according to these information. This third category was also linked to the pivot's
4 game, and thereby to the defensive contexts.

5 [Insert Figure 1 here]

6 Pivots organized concepts into 2 sub-networks, according to the height of defence, that
7 is, low or high (Figure 2). In each sub-network, concepts belonging to the 4 categories were
8 mixed: defensive modalities, pivot's game, back's game and the taking into account of the
9 defender's behavior by the attacker. In the first sub-network related to low defences, two
10 pivot's actions efficient in this defensive context showed a rich interconnection with other
11 concepts. For example, in a "Low aligned defence" context, pivots associated the action of
12 "Cutting the relations of defence" with two roles of the back player: "Shooter or Passer", or
13 "Shooter" when he represented a "Danger to the shoot". In the second sub-network related to
14 high defences, the 8 concepts of the pivot's game associated to the use of "space" or "depth"
15 were also interconnected with others concepts. In addition, pivots associated the concept "To
16 give advantage to the back's outflanking" with to 2 key concepts "Taking into account
17 defender's placement by the attacker" ("Defender Plact") and "Taking into account defender's
18 moving by the attacker" ("Defender Moving"), each opening to one sub-network.

19 [Insert Figure 2 here]

20 Back players organized concepts in 1 category as trainers, and 2 sub-networks as pivots,
21 in which concepts belonging to different categories were mixed (Figure 3). The category put
22 together 10 out of 12 concepts related to the pivot's game, without being associated with any
23 concepts from the other categories. This lack of connections might reveal a lack of knowledge
24 by players competing at this post, which may still be declarative. The rest of the network was
25 partitioned in 2 sub-networks according to back's choices in the game, that is, to shoot or to

1 pass. These 2 sub-networks passed both by the higher degree node "Taking into account the
2 defender's moving by the attacker" and the central node "Taking into account defender's
3 timing by the attacker". In each sub-network, back players formed more tactical and richer
4 interrelations between concepts related to their own game, defensive modalities and
5 defender's behaviors. For example, in the sub-network 1, back players connected 2 concepts
6 about their own game ("Back Outflanker/Passer" and "Passer's qualities of the back") with
7 both the concept "High aligned defence" and 2 concepts related to the defender's behavior:
8 "Taking into account defender's move by the attacker" and "Taking into account defender's
9 placement by the attacker". These interrelations reflected a more specific knowledge on their
10 own position – that is, more procedural and context-dependent – than that observed about the
11 pivot's game.

12 [Insert Figure 3 here]

13 **DISCUSSION**

14 The results of this study demonstrated the effects of specialization on the organization
15 of knowledge structure in handball. Specifically, data revealed that the knowledge structure of
16 trainers and players is quite different, though they share a small part in common. The main
17 findings further suggested that trainers tend to refer to strategic knowledge underpinning the
18 general principles of the game, whereas players prefer the operational and tactical knowledge
19 which is strongly associated with a specific role during the game.

20 **Common Knowledge Shared between Trainers and Players**

21 Although participants were subjected to the same 30 concepts for similarity judgments,
22 the networks of the 3 groups presented very weak similarities, hence revealing different
23 general organizations. The analysis regarding the main nodes used by the sample revealed 3
24 common concepts between the 3 networks. The trainers and pivots shared the same central
25 node, while looking at the networks of backs and pivots players pointed out 2 similar main

1 nodes out of 3. Overall, a total of 7 common links were found for the 3 networks. This limited
2 overlap could be considered as the part of the homogeneous knowledge within the “team
3 mental model” (Cooke et al., 2000). Stout and colleagues (1996) proposed that this
4 homogeneous knowledge is needed for effective coordination and shared expectations of
5 collective actions in the team. Other researchers empirically further supported the importance
6 of the homogeneous knowledge to team performance (*e.g.*, Mathieu, Heffner, Goodwin,
7 Salas, & Cannon-Bowers, 2000; Stout, Cannon-Bowers, Salas, & Milanovich, 1999). In a
8 flight-combat simulation task, Mathieu et al. (2000) showed that team mental model
9 sharedness related significantly to team performance. Stout et al. (1999) also reported that
10 teams engaging in high-quality planning had a greater homogeneous knowledge of the
11 informational requirements of each team member, and used more efficiently communication
12 strategies. The results of the present study rather suggest that when the same concepts
13 allowed the understanding of the situation, their organization was different according to the
14 specific roles of each teammate. Finally, what is shared in an expert team, according to the
15 specificity of the game outcomes, tend to be reduced to a part of common declarative
16 knowledge. As postulated by Banks and Millward (2007), the operational functions of
17 teammates tend to be specific in the roles, and heterogeneous in the team. Beside the few
18 pieces of common knowledge in trainers’ and players’ structures, the over part of their
19 structures were conversely organized on specific roles and task knowledge, composing the
20 heterogeneous part of team mental model.

21 **Specificity of Knowledge Structure related to the Specialization of Team Members**

22 Differences observed in the organization of knowledge structures according to roles
23 (trainer or player), or positions (back or pivot), confirmed our second hypothesis. All groups
24 categorized or partitioned concepts on deep structures, as expected for expert semantic
25 categorization. This organization followed functioning-rules related to the interaction between

1 players and the context, but trainers, backs and pivots combined the determinant cues in each
2 role-specific context (Rulence-Pâques et al., 2005). Trainers organized concepts in 3
3 categories related to the position of the players and fundamental handball game principles:
4 pivot's game, back's game and consideration of the defender's behavior by the attacker. This
5 organization is more strategic than tactical as the organization of actions is less context-
6 dependent (Gréhaigne, Godbout & Bouthier, 2001). Pivots partitioned concepts according to
7 the deep feature "height of defence". They simplified their complex tasks by acquiring
8 independent parcels of knowledge, *i.e.*, high or low. This result was consistent with those
9 reported by Lewandowski, Kalish, and Ngang (2002), who showed that fire experts
10 partitioned their knowledge according to the wind context to simplify complex tasks. In
11 addition, they showed that these partitions were selectively accessible from very specific key
12 concepts which serve as gating variable. These variables might thus be considered kind of
13 signals allowing to identify each category and to explain their interaction (Kivlighan, Markin,
14 Stahl & Salahuddin, 2007). In the pivots' network, these variables are "taking into account
15 defender's placement" and "taking into account defender's moving", known to influence high
16 or low defences (Costantini, 1997). Back players used deep features to organize pivots'
17 concepts in 1 category, and the concepts concerning their own game in 2 partitions depending
18 on their specific useful actions. Finally, the crucial difference between trainers', pivot's, and
19 back's knowledge structure was that players created, inside the partitions, numerous links
20 between specific defensive context, information on defenders, and actions of the player. Thus,
21 players analyzed each action as a specific game sequence resulting from a more tactical
22 practice orientated towards specific purposes (Feltovich et al., 2006; Gréhaigne et al., 2001).
23 This organization confirmed Bloom's conclusions that experts build cognitive elements of a
24 tactical nature that exceed the fundamental principles of the game (as cited in Baker, Horton,
25 Robertson, & Wall, 2003), and facilitate the execution of skillful performances (Muller &

1 Rabbitt, 1989). Hence, practice directed towards tasks with different specific purposes about
2 back/pivot relationship is likely to selectively influence the organization of the knowledge
3 structure. These effects of specialization are consistent with the main findings shown by
4 Bilalic, McLeod & Gobet (in press), where expert chess players better remembered and
5 solved problems arising from their area of opening specialization than problems outside their
6 specialization. These results were interpreted as a direct outcome of the more fine tuned
7 knowledge structures related to the area of specialization.

8 **Knowledge Heterogeneity of Team Mental Models and Performance of Expert Team**

9 As discussed, the 3 experts' networks yielded a lot of intergroup differences, despite
10 some similarities. It clearly shows that the part of the distribute knowledge is predominant in
11 the team mental model. This finding also supports that the necessary complementarities of
12 teammates impose to build the team mental model from interactions about coordinating
13 process with regards to each player roles and functions (Cooke, Gorman, Duran, & Taylor,
14 2007). Moreover the difference between players and trainers is in accordance with the
15 findings by Banks and Millward, (2007) showing that sharing declarative knowledge in a
16 team is convenient to improve team performance while sharing procedural knowledge is
17 prejudicial. In pivot and back players' network, the complex association between context and
18 actions (*i.e.*, the defensive context, the behavior of defender, the teammates' actions and the
19 specific actions related to their position) shed light on the important part of procedural
20 knowledge in the structure. Indeed, to face demanding and complex task, players with
21 specialized roles have to associate relevant skills with the cues of the situation. This part of
22 knowledge structure evolves differently because it is completely organized and dedicated to
23 the efficiency of their role.

24 **Perspectives**

1 The present results point out some distinctive perspectives which may contribute to
2 improve this research area. The first one lies in understanding and explaining the semantic
3 meaning of links between concepts, since it certainly guides the modalities of the structures'
4 organization. Indeed, the present data provided evidence that they were either organized in
5 categories and/or partitioned. The next step is to understand interrelations between concepts
6 in order to know whether they answer to particular rules (Rulence-Pâques et al., 2005). A
7 second perspective would consist in determining which knowledge is necessary to coordinate
8 members of a team, as well as the related level of expertise. These perspectives may have
9 direct implications in the field and might contribute to develop the relation between
10 teammates, their coordination, and their mutual expectations in the situation. Finally, future
11 research should explore in greater details the team situational model of the back/pivot
12 relationship, *ie.* the dynamic knowledge acquired and used by players during the situation and
13 the specific cues of the situation (Cooke et al., 2000). This promising line of research should
14 definitely contribute to a better understanding of experts' knowledge structure for the benefit
15 of training. One possible application of these future studies should be to generate a reference
16 structure concerning back/pivot relationship in handball, as initially suggested by
17 Schvaneveldt (1989; 1990). The creation of this reference structure would allow an important
18 educational economy and facilitate teaching and learning of the knowledge (McCall, Arnold,
19 & Sutton, 2005). It could also serve to evaluate players' acquisition of the knowledge required
20 to understand back/pivot situations and to make good decisions about possible courses of
21 action (Goldsmith, Johnson & Acton, 1991; Schvaneveldt, Tucker, Castillo & Bennett, 2001).
22

REFERENCES

- 1
- 2 Anderson, J. R. (1976). *Language, Memory, and Thought*. Hillsdale, NJ: Erlbaum.
- 3 Anderson, J. R. (1982). Acquisition of cognitive skill. *Psychological Review*, 89 (4), 369-406.
- 4 Baker, J., Horton, S., Robertson, W. J., & Wall, M. (2003). Nurturing sport expertise: Factors
5 influencing the development of elite athletes. *Journal of Sports Science and Medicine*,
6 2, 1-9.
- 7 Banks, A. P., & Millward, L. J. (2007). Differentiating knowledge in teams: The effect of
8 shared declarative and procedural knowledge on team performance. *Group Dynamics:
9 Theory, Research, and Practice*, 11 (2), 95-106.
- 10 Bilalić, M., McLeod, P., & Gobet, F. (in press). The importance of specialization: Memory
11 and problem solving in expert chess players. *Cognitive Science*.
- 12 Charness, N. (1974). Memory for chess positions: The effects of interference and input
13 modality. Unpublished Doctoral dissertation, Carnegie Mellon University, Pittsburgh.
- 14 Chase, W. G., & Ericsson, K. A. (1982). Skill and working memory. *The Psychology of
15 Learning and Motivation*, 16, 1-58.
- 16 Chase, W. G., & Simon, H.A. (1973). Perception in chess. *Cognitive Psychology*, 4, 55-81.
- 17 Chi, M., Feltovich, P., & Glaser, R. (1981). Categorization and representation of physics
18 problems by experts and novices. *Cognitive Science*, 5, 121-152.
- 19 Cooke, N. J., Stout, R. & Salas, E. (1997). Expanding the measurement of situation awareness
20 through cognitive engineering methods. *Proceedings of the Human Factors and
21 Ergonomics Society 41st Annual Meeting*, (pp215-219). Santa Monica, CA: Human
22 Factors and Ergonomic Society.
- 23 Cooke, N. J., Gorman, J. C., Duran, J. L., & Taylor, A. R. (2007). Team cognition in
24 experienced command and control teams. *Journal of Experimental Psychology*, 13 (3),
25 146-157.

- 1 Cooke, N. J., Salas, E., Cannon-Bowers, J. A., & Stout, R. (2000). Measuring team
2 knowledge. *Human Factors*, 42, 151-173.
- 3 Costantini, D. (1997). *Handball*. Paris : Editions "Revue EPS".
- 4 Côté, J., Young, B., North, J. & Duffy, P. (2007). Towards a definition of excellence in sport
5 coaching. *International Journal of Coaching Science*, 1 (1), 3-17.
- 6 Dayton, T., Durso, F. T., & Shepard, J. D. (1990). A measure of knowledge reorganization
7 underlying insight. In R. Schvaneveldt (Ed.), *Pathfinder Associative Networks: Studies*
8 *in Knowledge Organization* (pp. 267-277). Norwood, NJ: Ablex.
- 9 Debanne, T. (2003). Activité perceptive et décisionnelle du gardien de but de handball lors de
10 la parade: Les savoirs d'expert. *STAPS*, 62, 43-58.
- 11 Didierjean, A., Ferrari, V., & Marmèche, E. (2004). L'expertise cognitive au jeu d'échecs:
12 Quoi de neuf depuis de Groot (1946)? *L'Année Psychologique*, 104, 771-793.
- 13 Egan, D. E., & Schwartz, E. J. (1979). Chunking in recall of symbolic drawings. *Memory &*
14 *Cognition*, 7, 149-158.
- 15 Entin, E.E., & Serfaty, D. (1999). Adaptive team coordination. *Human Factors: The Journal*
16 *of the Human Factors and Ergonomics Society* 41 (2), 312-325.
- 17 Ericsson, K. A., & Kintsch, W. (1995). Long-term working memory. *Psychological Review*,
18 102, 211-245.
- 19 Ericsson, K. A., & Lehmann, A. C. (1996). Expert and exceptional performance: Evidence of
20 maximal adaptation to task constraints. *Annual Review of Psychology*, 47, 273-305.
- 21 Ericsson, K. A., Krampe, R. T., & Tesch, R. M. C. (1993). The role of deliberate practice in
22 the acquisition of experts performance. *Psychological Review*, 100 (3), 363-406.
- 23 Feltovich, P. J., Prietula, M. J., & Ericsson, K. A. (2006). Studies of expertise from
24 psychological perspectives. In K. A. Ericsson, N. Charness, P. J. Feltovich, & R. R.

- 1 Hoffman (Eds.), *Cambridge Handbook of Expertise and Expert Performance* (pp. 41-
2 67.) New York: Cambridge University Press.
- 3 French, K. E., Nevett, M. E., Spurgeon, J. H., Graham, K. C., Rink, J. E., & McPherson, S. L.
4 (1996). Knowledge representation and problem solution in expert and novice youth
5 baseball players. *Research Quarterly for Exercise and Sport*, 67 (4), 386-395.
- 6 French, K. E., & Thomas, J. R. (1987). The relation of knowledge development to children's
7 basketball performance. *Journal of Sport Psychology*, 9, 15-32.
- 8 Garbarino, J. M., Esposito, M., & Billi, E. (2001). L'orientation de l'action chez les joueurs de
9 football experts: une approche par les verbalisations. *STAPS*, 55, 49-60.
- 10 Gobet, F. (1998). Expert memory: A comparison of four theories. *Cognition*, 66, 115-152.
- 11 Goldsmith, T. E., Johnson, P. J., & Acton, W. H. (1991). Assessing structural knowledge.
12 *Journal of Educational Psychology*, 83, 88-96.
- 13 Gréhaigne, J. F., Godbout, P., & Bouthier, D. (2001). The teaching and learning of decision
14 making in team sports. *Quest*, 53, 59-76.
- 15 Haerem, T., & Rau, D. (2007) The influence of degree of expertise and objective task
16 complexity on perceived task complexity and performance. *Journal of Applied*
17 *Psychology*, 92 (5), 1320-31.
- 18 Kivlighan, D. M., Markin, R. D., Stahl, J. V., & Salahuddin, N. M. (2007). Changes in the
19 ways that group trainees structure their knowledge of group members with training.
20 *Group Dynamics: Theory, Research, and Practice*, 11 (3), 176-186.
- 21 Leas, R. L., & Chi, M. T. H. (1993) Chapter 5 – Analysing diagnostic expertise of
22 competitive swimming coaches. In J. L. Starks & F. Allard (Eds.), *Cognitive Issues in*
23 *Motor Expertise* (pp. 159-188). Amsterdam: Elsevier Science Publishers.

- 1 Lewandowsky, S., Kalish, M., & Ngang, S. K. (2002). Simplified learning in complex
2 situations: Knowledge partitioning in function learning. *Journal of Experimental*
3 *Psychology: General*, 131 (2), 163-193.
- 4 Mathieu, J. E., Heffner, T. S., Goodwin, G. F., Salas, E., & Cannon-Bowers, J. A. (2000) The
5 influence of shared mental models on team process and performance. *Journal of*
6 *Applied Psychology*, 85 (2), 273-283.
- 7 McCall, H., Arnold, V., & Sutton, S. G. (2005). Use of knowledge management systems and
8 the impact on declarative knowledge acquisition. *Journal of Information Systems*, 22
9 (2), 77-101.
- 10 McPherson, S. L. (1993). Chapter 9 - Knowledge representation and decision making in sport.
11 In J. L. Starkes & F. Allard (Eds.), *Cognitive Issues in Motor Expertise* (pp. 159-188).
12 Amsterdam: Elsevier Science Publishers.
- 13 McPherson, S. L. (1994). The development of sport expertise: mapping the tactical domain.
14 *Quest*, 46, 223-240.
- 15 McPherson, S. L. (1999). Expert novice differences in performance skills and problem
16 representations of youth and adults during tennis competition. *Research Quarterly for*
17 *Exercise and Sport*, 70 (3), 233-251.
- 18 McPherson, S. L. (2000). Expert-novice differences in planning strategies during collegiate
19 singles tennis competition. *Journal of Sport and Exercise Psychology*, 22, 39-62.
- 20 McPherson, S. L., & Kernodle, M. (2007). Mapping two new points on the tennis expertise
21 continuum: Tactical skills of adult advanced beginners and entry-level professionals
22 during competition. *Journal of Sports Sciences*, 25 (8), 945-959.
- 23 McPherson, S. L., & MacMahon, C. (2008). How baseball players prepare to bat: tactical
24 knowledge as a mediator of expert performance in base ball. *Journal of Sport and*
25 *Exercise Psychology*, 30, 755-778.

- 1 McPherson, S. L., & Thomas, J. R. (1989). Relation of knowledge and performance in boys'
2 tennis: Age and Expertise. *Journal of Experimental Child Psychology*, 48, 190-211.
- 3 Muller, H. J., & Rabbitt, P. M. (1989). Spatial cueing and the relation between the accuracy of
4 “where” and “what” decisions in visual search. *Quarterly Journal of Experimental*
5 *Psychology: Human Experimental Psychology*, 41 (4-A), 747-773.
- 6 Ripoll, H. (1987). Stratégies de prise d'informations visuelles dans des tâches de résolution de
7 problèmes tactiques en sport. In H. Ripoll and G. Azemar (Eds.), *Neurosciences du*
8 *Sport: Traitement des Informations, Prise de Décision et Réalisation de l'Action en*
9 *Sport* (pp. 329-353). Paris : Editions INSEP.
- 10 Rulence-Pâques, P., Fruchart, E., Dru, V., & Mullet, E. (2005). Cognitive algebra in sport
11 decision-making. *Theory and Decision*, 58, 387-406.
- 12 Salas, E., Dickinson, T. L., Converse, S. A. & Tanenbaum, S. I. (1992). Toward an
13 understanding of team performance and training. In R. W. Swezey & E. Salas (Eds.),
14 *Teams: Their training and performance* (pp. 3-29). Norwood, NJ: Ablex.
- 15 Schulz, R., Musa, D., Stazewski, J., & Siegler, R. S. (1994). The relationship between age and
16 major league baseball performance: Implications for development. *Psychology and*
17 *Aging*, 9, 274-286.
- 18 Schvaneveldt, R. W. (1990). *Pathfinder associative networks: Studies in knowledge*
19 *organization*. Norwood, NJ: Ablex.
- 20 Schvaneveldt, R. W., Durso, F. T. & Dearholdt, D. W. (1989). Network structures in
21 proximity data. *The Psychology of Learning and Motivation*, 34, 249-284.
- 22 Schvaneveldt, R. W., Tucker, R., Castillo, A., & Bennett, W., Jr. (2001, November).
23 Knowledge acquisition in distributed mission training. Paper presented at the 2001
24 Interservice/Industry Training, Simulation and Education Conference, Orlando.

- 1 Starkes, J. L. & Ericsson, K. A. (2003). *Expert performance in sports: Advances in research*
2 *on sport expertise*. Champaign, IL: Human Kinetics.
- 3 Stout, R., Cannon-Bowers, J. A., & Salas, E. (1996). The role of shared mental models in
4 developing team situation awareness: Implications for training. *Training Research*
5 *Journal*, 2, 85-116.
- 6 Stout, R., Cannon-Bowers, J. A., Salas, E. & Milanovich, D. M. (1999). Planning, shared
7 mental models, and coordinated performance: A empirical link is established. *Human*
8 *Factors*, 41 (1), 61-71.
- 9 Williams, A. M. (2002). Perceptual and cognitive expertise in sport. *The Psychologist*, 15,
10 416-417.
- 11 Williams, A. M., & Davids, K. (1995). Declarative knowledge in sport: A byproduct of
12 experience or characteristic of expertise? *Journal of Sport and Exercise Psychology*, 17,
13 259-275.

Table 1

Characteristics of the Three Groups of Participants.

Participants	N	Age (years)	Experience in the	Practice of handball
		<i>M (SD)</i>	post (years)	(years)
			<i>M (SD)</i>	<i>M (SD)</i>
Trainers	7	35.1 (7.43)	10.71 (5.17)	16.7 (5.22)
Backs	13	25.1 (3.88)	12.46 (4.88)	12.46 (4.88)
Pivots	7	23.3 (1.89)	9.71 (3.49)	9.71 (3.49)

Table 2

Concepts used in the Similarity Judgment Task and their Abbreviation in Networks.

CONCEPTS	ABBREVIATION
DEFENSIVE MODALITIES	
Low aligned defence	DEF L Al
High aligned defence	DEF H Al
Low staged defence with possibility of anticipation of the opposite defenders	DEF L St
High staged defence with possibility of anticipation of the opposite defenders	DEF H St
High staged defence with or without pressure on the holder of ball	DEF H St / phb
PIVOT'S GAME	
Breaking free game of the pivot	PVT B Free
Sliding game of the pivot	PVT sliding
Gain of position or space for the pivot	PVT gain Po
To give advantage to a team-mate by spreading out	Advantage Spread
To use depth toward a free space	Use Depth
To give advantage by liberating a space	Advantage L S
To give advantage to back's outflanking	Advantage Outflank
To give advantage by fixing defenders	Advantage Fix
To give advantage to a pass of the back	Advantage Pass
Cutting the relations of defence	Cut DEF
Morphology of the pivot	PVT Morpho
Motricity of the pivot: Capacity of catching and explosive aptitude	PVT Mot
BACK'S GAME	
Will of the back to maintain continuity of the game	Back Conti.G
Back Shooter	Back Shooter
Back Shooter / Outflanker	Back S/Out
Passer's qualities of the back	Back Q Pass
Back Shooter / Passer	Back S/P
Back Outflanker / Passer	Back Out/P
Danger of back shoot and balance of power with goal keeper	Back Dang Shoot
THE TAKING INTO ACCOUNT OF DEFENDER'S BEHAVIOR BY THE ATTACKER	
Taking into account defender's timing by the attacker	Defender Timing
Taking into account defender's orientation by the attacker	Defender Or
Taking into account defender's relation with his team-mates	Defender / Teammate
Taking into account defender's moving by the attacker	Defender Moving
Taking into account defender's placement by the attacker	Defender Plact
SPECIFIC BACK / PIVOT RELATION	
Specific relations between back and pivot: Knowing about teammates	Spe Rel/ teammates

Figure 1

Trainers: Pathfinder Network Representation of the Specific Back/Pivot Relationship Concepts Derived from the Average of Ratings.

There is a total of 33 links. The abbreviations used for the 30 concepts are described in Table 2. Central Node – Higher Degree Node – Median Node.

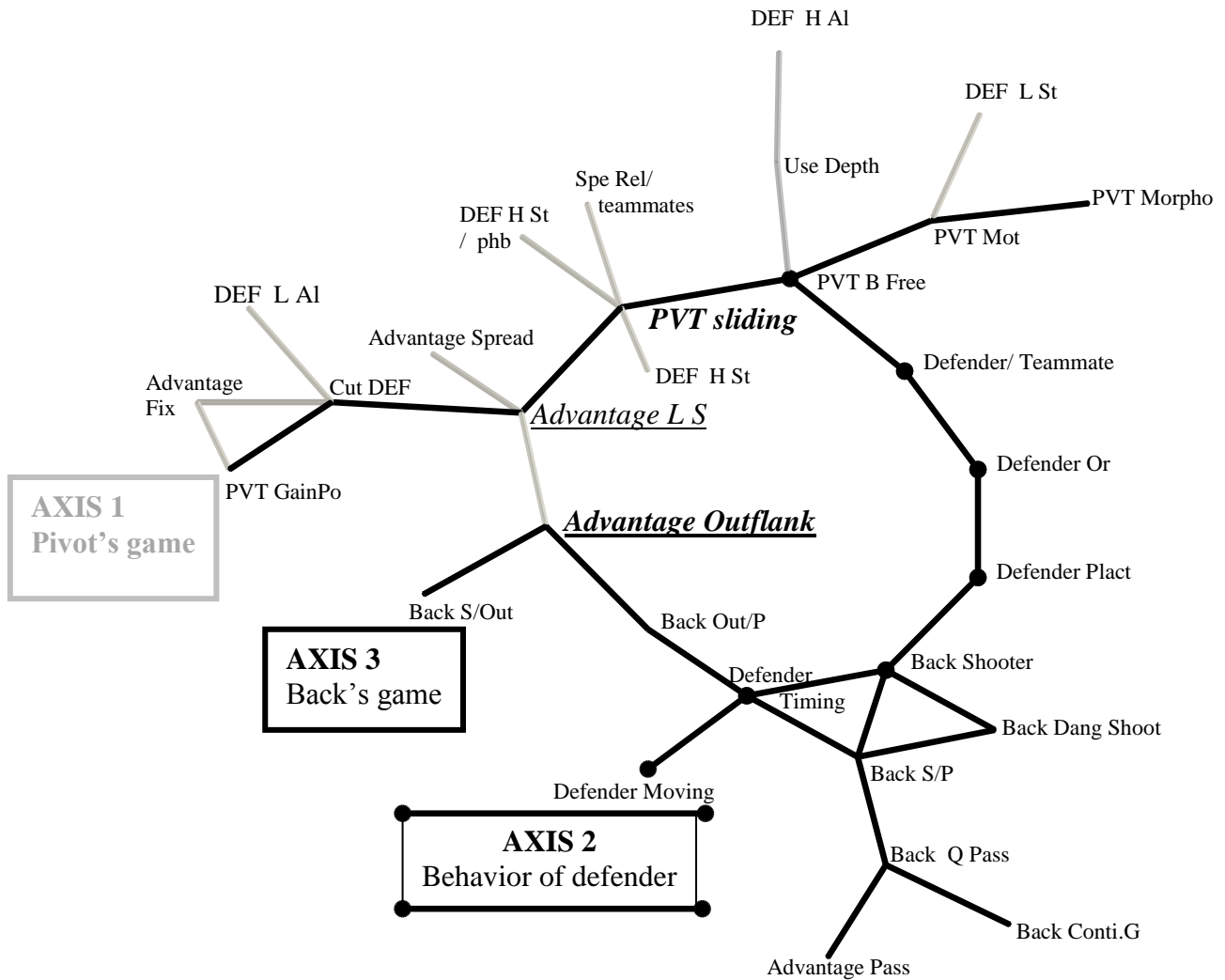


Figure 2

Pivots: Pathfinder Network Representation of the Specific Back/Pivot Relationship Concepts Derived from the Average of Ratings.

There is a total of 32 links. The abbreviations used for the 30 concepts are described in Table 2. **Central Node** – **Higher Degree Node** – **Median Node**.

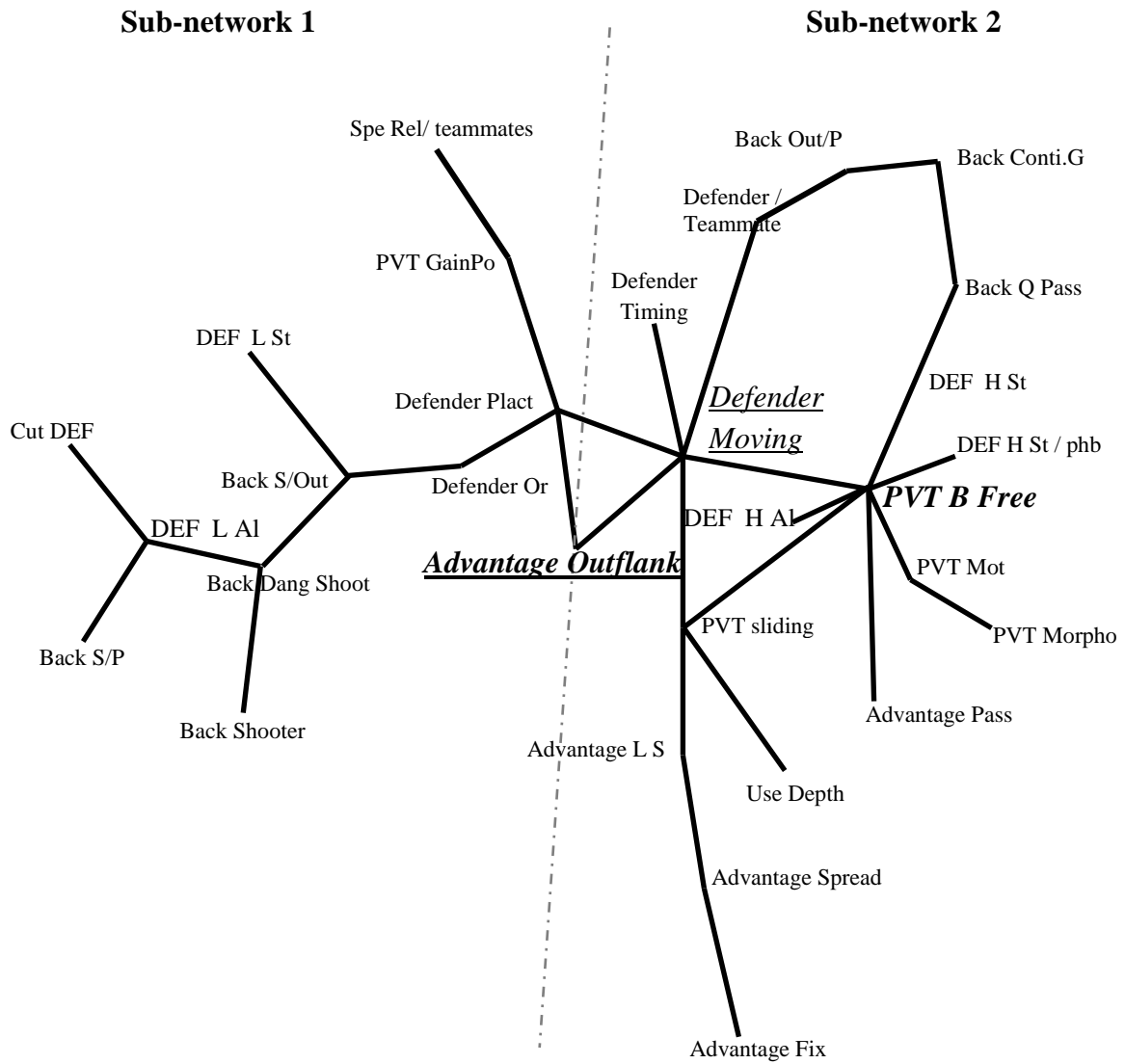


Figure 3

Backs: Pathfinder Network Representation of the Specific Back/Pivot Relationship Concepts Derived from the Average of Ratings.

There is a total of 39 links. The abbreviations used for the 30 concepts are described in Table 2. **Central Node** – **Higher Degree Node** – **Median Node**.

