Modes of Cognitive Control in Official Game Handball Coaching

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The purpose of this paper is to identify the dynamic adjustment of the cognitive control modes used by three professional head coaches during the defensive part of a handball match and, in particular, to highlight the contextual factors that have an effect on these modes. Two main aspects characterize cognitive control modes: the level of abstraction (symbolic/subsymbolic) and the origin (internal-anticipative/external-reactive) of the data used for control. Verbal communications between three coaches and their teams were recorded during 15 matches. The verbal meaningful units were encoded using a general cognitive method introduced by Amalberti and Hoc and coded using a predicate–argument format with MacSHAPA software. Analysis shows relationships between the mode of cognitive control used by coaches and the level of difficulty characterizing the situation. When the level of difficulty is low, coaches favor a reactive mode of control guided by external and subsymbolic data, whereas they favor a more abstract level of control and more internal data when facing a difficult situation. In the latter case, different coaching styles are in evidence.

Keywords: competitive context, team management, cooperative activity, decision making, coaching styles, naturalistic decision making

INTRODUCTION

First appearing as a genuine research topic at the end of the 1970s, the coaching process is composed of three components: training, competition, and organization (Abraham, Collins, & Martindale, 2006; Côté, Salmela, Trudel, Baria, & Russel, 1995). Studies analyzing in situ coaching practices have defined this process as being complex, dynamic, and context dependent (Cushion, Harvey, Muir, & Nelson, 2012; Jones, Armour, & Potrac, 2002; Lyle, 2002; Saury & Durand, 1998). Consequently, coaching expertise requires flexible adaptation to constraints (Jones & Wallace, 2006; Nash & Collins, 2006; Saury & Durand, 1998). Coaching activities are highly cognitive, and decision making has been identified as the core of coaches' expertise (Abraham et al., 2006; Lyle & Vergeer, 2013; Nash & Collins, 2006). Considering the time frame of a competitive session, several authors have emphasized the variations of the interactive decisions made by coaches during the competition phase according to the perceived characteristics of the situations (as either favorable or unfavorable, and the time of the game) and the characteristics of the players. These variations may concern player substitutions (Gilbert, Trudel, & Haughian, 1999), respect of the athletes' autonomy (d'Arrippe-Longueville, Saury, Fournier, & Durand, 2001), the hierarchical organization of the coach's tasks (Debanne & Fontayne, 2009), the interaction style (reflected in reactive or proactive profiles), and the instructional content of the coach's communication with the team (Mouchet, Harvey, & Light, 2013). These finding are reinforced by other studies, using systematic observation of coach behavior that showed the influence of the score on coaches' feedback (Calpe, Guzmán, & Grijalbo, 2013; Rodrigues & Pina, 1999) or on basketball coaches' time-outs (Gomez, Jimenez, Navarro, Lago-Penas, & Sampaio, 2011).

These different studies have focused primarily on behavioral changes. As suggested by Gilbert et al. (1999), we propose to provide an understanding of the thought processes underlying these behaviors. More precisely, we propose to investigate the micromanagement of coaching interventions in terms of cognitive control. *Cognitive control* refers to cognitive mechanisms

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that enable people to adjust to situational features and to flexibly adapt their behavior in the pursuit of an internal goal.

This paper focuses on coaching interventions with handball teams. It is known that providing verbal information to athletes is one way for coaches to be directly involved in the course of the competition (Calpe et al., 2013), and this is particularly true for an indoor team sport in which it is quite easy to communicate with players. Moreover, the game rules of handball allow coaches to make unlimited substitutions and request time-outs. Thus, handball assigns the coach a more significant role in a situation of competition than do other team sports, such as football or rugby. Hence, it provides a good opportunity to analyze the real-world decisions made by coaches in a competitive context.

Handball is an Olympic team sport in which seven players on each of two teams (six outfield players and one goalkeeper on each team) pass a ball to one another in order to throw it into the other team's goal area. The playing court is 40 m long and 20 m wide and consists of a playing area and two goal areas, which only the goalkeeper is allowed to enter. A standard match consists of two 30-min periods, and the team scoring the most goals wins. Substitutes may enter the court repeatedly and at any time. Like other team sports (e.g., soccer or basketball), team handball is an invasion game, but it is also a collision contact sport, like ice hockey, where contact is a necessary and integral part of play (Silva, 1983). Indeed, the game rules allow the use of bent arms to make body contact with an opponent and to control and follow the opponent in this way, and the use of a player's torso to block the opponent in a struggle for positions.

In this type of game, the defensive players' main objective is to stop the offensive players from reaching the goal. Debanne and Fontayne (2009) carried out a case study with a two-time world champion handball coach, using a video-cuing recall-stimulated interview (Lyle, 2003). They showed that coaches control the defensive players' involvement through verbal communication, provide technical information in order to improve player performance, and manage the team structure. The team structure is managed (a) at the team level by organizing defensive players in different systems in order to attempt to push their opponents away from the scoring area and to place as many of their own players between the ball and the goal or (b) at the player level by modifying the players' positions on the court.

The purpose of the present study is to analyze such interactions with players in terms of cognitive control modes and to highlight the contextual factors that influence these modes. The study focuses on the verbal communications of three handball coaches with their teams, which were recorded during the defensive part of 15 handball matches.

Modes of Cognitive Control

Cognitive control is a construct from contemporary cognitive neuroscience that refers to processes that allow information processing and behavior to vary adaptively from moment to moment, depending on current goals, rather than to remain rigid and inflexible. Research conducted in cognitive neuroscience has identified two control modes (Braver, 2012). Braver (2012) explains that the proactive control mode can be conceptualized as a form of early selection, in which goal-relevant information is actively maintained in a sustained manner, prior to the occurrence of cognitively demanding events, in order to optimally bias attention, perception, and action systems in a goal-driven manner. In contrast, in the reactive control mode, attention is recruited as a late correction mechanism that is mobilized only as needed in a just-in-time manner, such as after a high-interference event is detected. Thus, proactive control relies on anticipating and preventing interference before it occurs, whereas reactive control relies on detecting and resolving interference after its onset.

In the framework of cognitive system engineering, Hollnagel (1993) also identified several modes of cognitive control, from the most reactive (determined by the occurrence of external data and characterized by a short time process) to the most proactive (relying on the process of internal data and characterized by a longer time). Hoc and Amalberti (2007) defined this concept slightly differently. They defined cognitive control as

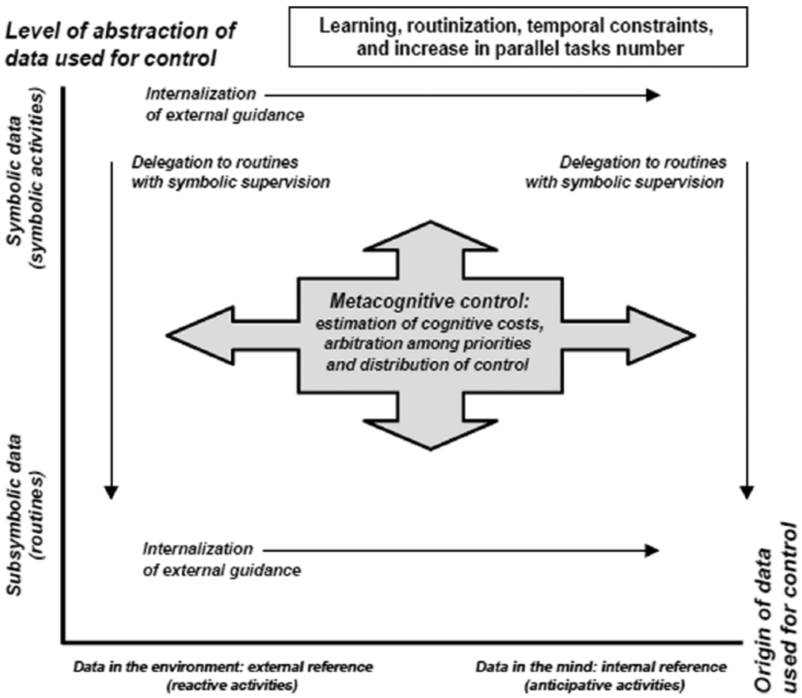

Figure 1. Modes of cognitive control. From "Cognitive Control Dynamics for Reaching a Satisfying Performance in Complex Dynamic Situations," by J.-M. Hoc and R. Amalberti, 2007, *Journal of Cognitive Engineering and Decision Making, 1*, p. 43. Copyright 2007 by Sage. Reprinted with permission.

> the authority that makes it possible to bring into play, in the correct order and with the appropriate intensity, the cognitive representations and operations required for adaptation, according to external and internal requirements. It includes direct control and supervisory control from one control level to another. (pp. 28–29)

The specific feature of Hoc and Amalberti's (2007) approach is that they have classified several cognitive control modes according to two dimensions. In accordance with Hollnagel (1993), they considered the origin of the data used for control (internal vs. external data) in relation to anticipative versus reactive processes on the one hand and the level of abstraction of the data required for control (symbolic vs. subsymbolic) on the other hand. Crossing the two dimensions generated four control modes among which cognitive control is distributed (see Figure 1). The symbolic control of external data refers to the interpretation of external data, such as concepts or signs, whereas the symbolic control of internal data refers to the processing of internal representations. Subsymbolic control can rely on internal data (e.g., the internal coordination of actions), whereas the subsymbolic control of external data is guided by affordances, that is, by the perceived and actual properties of the thing, primarily those fundamental properties that determine just how the thing could possibly be used (Norman, 1988). Metacognitive control is implied in this distribution to ensure situation mastery.

Hoc and Amalberti (2007) explained that routinization enables experts to perform more and more activities without symbolic control. At the same time, the availability of internal representations enables the cognitive system to operate with fewer external data gathered from the environment. However, Hoc and Amalberti also pointed out that symbolic control could precede or replace subsymbolic or routine control when the experts face a difficult situation.

Insofar as the coaching activity requires flexible adaptations to changing situational characteristics, it seems worth determining how coaches control this activity. We propose to examine the mode of cognitive control used by handball coaches during their interaction with players and to identify their adjustments according to situation features and, more particularly, the level of difficulty. Interactions consist in verbal communications with players. The message content was analyzed in terms of both abstraction level (subsymbolic or symbolic) and the data used (internal or external).

On the basis of a review of coaching literature and of the theoretical background related to the concept of cognitive control, we posited the following hypothesis: When coaches face a difficult (unfavorable) situation, they will use a symbolic control mode and internal data more often than when they face a favorable situation.

METHOD

Participants

Gomez et al. (2011) noted that it is very difficult to approach coaches during the competition period. To carry out the present study, we contacted all French professional first- and second-division coaches ($N = 28$) by telephone, asking them to participate in the study and to wear a dictaphone belt and lapel microphone during games so that their comments could be recorded throughout the entire game. To protect confidentiality and anonymity, the coaches were informed that the time of data submission would be shifted from the time of collection by at least one sports season and that there would be no information identifying them. Despite these precautions, only three coaches—known personally by the first author—agreed to take part in this study. Thus, this paper focuses on the activity of three head coaches (C_H, C_L, and C_Z), observed during 15 matches of France's top male professional championship. C_H is 47 years old, has 12 years of experience as a professional coach, and has been selected 163 times for the French national team. He was observed during five matches. C_L is 38 years old, has 4 years of experience as a professional coach, and has been selected 23 times for the French national team. He was observed during four matches. C_Z is 50 years old and has 10 years of experience as a professional coach. He was observed during six matches.

Each team was ranked differently. Throughout the entire study, C_H's team was in last place, with no hope of leaving the relegation zone (i.e., the bottom group of teams that are in danger of being eliminated from the championship). C_H's team was composed of young players with a low level of autonomy and ability to manage problems on their own. C_Z's team was ranked number one throughout the study and dominated the championship. C_L's team was ranked 8th out of 14 at the beginning of the study. Over the course of the study, however, with many top players injured, his team lost all of its matches and fell to 12th place, risking finishing in the relegation zone.

Data Collection

Verbal data collection related to the coaches' activity. The kinds of data collected were (a) the main situational features (main events of each match), (b) the coaches' verbal communication with the defensive players, and (c) the video-cued recall interviews. Each coach and each match were video-recorded from the first to the final whistle of the game. The matches were downloaded from the website www.dartfish.tv. In order to film the coach, the camera was located transversally to the handball court on the side opposite the scoring table, as shown in Figure 2. Verbal communication between the coach and the players was collected using a digital voice recorder connected to a microphone. Video-cued recall interviews with the coach were conducted during the week following the match, using the video recording of the match and stimulated-recall interview techniques (Lyle, 2003). Two screens were shown during each interview: One showed the coach's activity, and the other, the match. The coach watched both his own and his players' actions. The audiotapes from the matches and interviews were transcribed. We removed (a) all communication between the coach and all other participants in the game (i.e., his assistant, referees, medical staff, and officials, namely, the scorekeeper, timekeeper, and delegate) except for his own players, (b) criticisms or praise, and (c) truisms (i.e., comments made by the coach stating the obvious), as recommended by Hastié (1999).

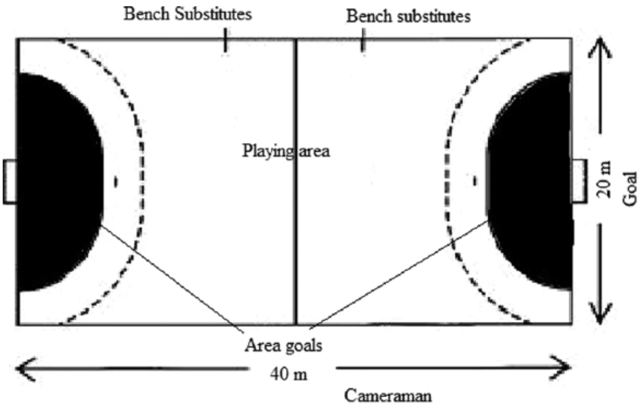

Figure 2. Team handball court and position of cameraman.

Measurement of game difficulty. In order to assess the level of difficulty of the situation, perceived by the coach as being favorable, balanced, or unfavorable, we recorded (a) the match outcome (lost [unfavorable], won [favorable], and draw [balanced]) and (b) the difference in the score between the two teams during the game (unfavorable for the team, favorable, or balanced). The score difference between the two teams was calculated during four game periods (the first and second parts of the first and second halftimes). The score difference was recorded at each ball possession, and an average was calculated for each of the four periods. The score difference is considered to be unfavorable when $\Delta_{\text{Score}} < -2$, balanced when $-2 \leq \Delta_{\text{Score}} \leq 2$, and favorable when $\Delta_{\text{Score}} > 2$. Table 1 indicates this information.

Data Analysis

Selecting units of analysis. Before dividing the corpus into elementary units, we defined the unit of analysis. Meaningful themes were chosen as the unit for analysis rather than linguistic units, such as words or sentences. Thus, a meaningful unit is considered as a "segment of text that is comprehensible by itself and contains one idea, episode, or piece of information" (Tesch, 1990, p. 116).

From this definition, we chose one of the 15 matches at random and, separately, divided the associated corpus into meaningful units. The first author divided the match transcript into 114 meaningful units, and the second, into 116 meaningful units. Both coders shared 108 meaningful units, indicating satisfactory intercoder agreement (93.1%). Special attention was paid to the part of the corpus that was not divided similarly by the coders. The ensuing discussion systematically resulted in consensus on interpretation. Then, the entire corpus was divided into meaningful units ($n = 1{,}664$).

All data (situational features, coach communication, and video-cued recall data) were synchronized. The verbal meaningful units were encoded using a general cognitive method introduced by Amalberti and Hoc (1998), which consists in inferring elementary cognitive activities from overt behavior, the context, a general cognitive architecture, and knowledge of the application domain. These units were coded using a predicate–arguments format with MacSHAPA software. MacSHAPA is a software tool built to help human factors investigators carry out protocol analyses. It allows them to develop sophisticated coding schemes—relying on a predicate–argument format— and to use statistical routines to analyze the data once they have been fully encoded (Sanderson et al., 1994). In logic, a predicate expresses a relation between different entities called arguments. Sanderson et al. (1994) provided several examples of such a relation. For instance, the fact that an operator (named Bill) plans to raise the heat is coded as follows in predicate–argument format: "PLAN (Bill, raise the heat)," where *PLAN* is the predicate and *Bill* and *raise the heat* are two arguments. Statistical

TABLE 1: Breakdown of Difficulty Situation Level and Match Outcome According to Game Periods and Coach-Team System

Game Characteristics		Difficulty Situation Level					
		Score Difference Between the Two Teams			Match Outcome		
Coach-Team System	Game Period	Balanced ($-2 \leq \Delta_{Score} \leq 2$)	Unfavorable ($\Delta_{Score} < -2$)	Favorable ($\Delta_{Score} > 2$)	Draw	Lost	Won
C_H	First or second halftime	7	13	0	0	4	1
	Break period	1	4	0			
C_L	First or second halftime	8	8	0	0	4	0
	Break period	3	1	0			
C_Z	First or second halftime	6	2	16	0	0	6
	Break period	2	0	4			
Total	First or second halftime	21	23	16	0	8	7
	Break period	6	5	4			

analysis may concern either the predicates or the arguments. They may be simple frequency measurements of key events (frequency of the predicate *PLAN*, for example) but also transition analysis or analysis of cycles between them.

Categorizing units of analysis. In this study, the predicates were sorted into several classes according to the coding scheme defined by Hoc (2001) in order to analyze cooperative activities. Hoc distinguished the following categories:

1. Cooperative activities at action level, which involve creating, detecting, anticipating, and resolving interference locally. Interference creation can be positive when it involves mutual control or cross-checking. In this case, one agent can inform another of their disagreement or give advice. At this level, available time is short, and the data used are mainly external.
2. Cooperative activities at planning level, which involve explicitly generating and maintaining a common frame of reference (COFOR) as a common representation of the situation. The situation includes the environment, currently referred to as situation awareness (SA), defined as "the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future" (Endsley, 1995, p. 36.); it also involves the agents' activities. Therefore COFOR also includes common goals, common plans, and function allocation. This planning level facilitates the action-level activity. Cooperative activities, at this level, are carried out quite a long time before action, and they mainly concern internal data.
3. Cooperative activities at the meta-cooperation level, which include high-level knowledge that is useful to other levels, such as mental models of the other agents and of oneself, and facilitate the planning-level activities.

The predicate CR-ITF represents the creation of interference, whereas the predicate PLA represents different planning activities concerning (a) the action plan (PLA-ACT-PLAN), (b) the allocation of functions between players (PLAN-REPFCT), and (c) the elaboration of shared situation awareness (PLA-ENV) (see Table 2). Each predicate has several arguments: the transmitter (in this case, it is always the coach), the receiver (one particular player or the whole team), and the object of the cooperative activity.

According to Debanne and Fontayne (2009), the creation of interference (CR-ITF) and action plan (PLA-ACT-PLAN) may concern (a) the players' involvement, (b) the team's structure,

TABLE 2: Extracts of Verbal Protocols

Predicate	Main Argument	Examples
CR-ITF (creation of an interference with a player's behavior [action level])	Structure	Don't remain flattened! Get out on the players!
	Involvement	Run! Come back!
	Technique	If you go back, you must fall with him.
PLA-ACT-PLAN (plan maintenance or elaboration [planning level])	Structure	Change defense system, align, 0-6.
	Involvement	The first halftime, you forget it. Now you must impose yourself, physically, with your team.
	Technique	Don't hesitate to pull his arms.
PLA-ENV (maintenance or elaboration of a shared situation awareness [planning level])	Information	He does not score as many goals as you think.
	Comprehension	Actually, we are in trouble only on Morgan's duels. Everything else is OK.
	Anticipation	Careful, they will play "Szeged" (name of combination).
PLA-ACT-REPFCT (maintenance or setting of role allocation [planning level])		Cedric, you will change with Morgan.
META (activities of meta-cooperation eliciting the different structures of knowledge used by the operators [general knowledge, task-related knowledge, knowledge about partners, etc.])		None
OTHER		

and (c) technique. In accordance with Endsley's (1995) model, we considered that the elaboration of a shared SA, defined as "the degree to which team members possess the same situation awareness on shared situation awareness requirements" (Endsley & Jones, 2001, p. 48), may involve giving (a) information, (b) elements of comprehension, and (c) elements of anticipation. SA may concern either the opposing team or one's own team.

Four independent variables were considered. Two of them make it possible to characterize the game period (first or second halftime vs. break period) and the coach-team system (C_H vs. C_L vs. C_Z). Two of them characterize the situation's level of difficulty (unfavorable vs. balanced vs. favorable) as mentioned earlier.

The meaningful unit (composed of a predicate and an argument) constituted the dependent variable. Meaningful units were distributed between the two dimensions of cognitive control mentioned earlier (subsymbolic-symbolic; external-internal) as follows:

1. Predicates make it possible to locate them on the external-internal dimension. The cooperative activities carried out at the action level (CR-ITF) are considered to be driven by external data and to indicate a reactive mode of control. The cooperative activities carried out at a planning level (PLA-ACT-PLAN, PLA-ENV, PLA-REPFCT) are considered to be driven by internal data and to indicate an anticipative mode of control.
2. Arguments make it possible to locate meaningful units on the subsymbolic-symbolic dimension. Considering that it is difficult to know which argument is more subsymbolic or more symbolic than another, we questioned coaches on this point

TABLE 3: Breakdown of Dependent Variables Among the Two Dimensions of Cognitive Control

Subsymbolic-Symbolic Dimension	External-Internal Dimension	
	External Data (Reactive)	Internal Data (Proactive)
Subsymbolic	$\text{CR-ITF}_{\text{Involvement}}$	$\text{PLA-ACT-PLAN}_{\text{Involvement}}$
Symbolic	$\text{CR-ITF}_{\text{Structure}}$	$\text{PLA-ACT-PLAN}_{\text{Structure}}$
	$\text{CR-ITF}_{\text{Technique}}$	$\text{PLA-ACT-PLAN}_{\text{Technique}}$
		$\text{PLA-ENV}_{\text{Identification}}$
		$\text{PLA-ENV}_{\text{Comprehension}}$
		$\text{PLA-ENV}_{\text{Anticipation}}$

during the video-cued recall interviews and then classified the arguments based on their explanations. Table 3 shows this categorization.

Statistical Analysis

Reliability of the classification scheme. To test the reliability of the coding scheme, 50 meaningful units were selected randomly and classified by both authors, who are experienced in qualitative methods of research. Special attention was paid to those that were not assigned to the same categories by the coders, and the discussion that ensued systematically resulted in consensus on the interpretation. Then, on the basis of this analysis grid, the two coders classified all the units. The overall Kappa revealed a satisfying rate of agreement between the two coders ($k = .71$; $z = 25.94$, $p < .001$). All of the conditional coefficients were also high and significant.

Significant relationships between factors. Chi-square tests were used to identify any significant link between factors considered two by two. Moreover, multiple correspondence analysis (MCA) was performed to detect patterns of contributory factors associated with predicates and arguments. MCA is a geometric data analysis technique that is the counterpart of principal component analysis (PCA) for categorical data. It is used to detect underlying structures in a data set by representing data as points in low-dimensional Euclidean spaces (Burt, 1950).

RESULTS

We analyzed 1,664 units, coded in terms of predicate and argument. This section is organized to show two main interindividual effects, namely, coach-team system effects and level-of-difficulty effects. It also presents the differences observed at an intraindividual level, namely, the distribution of the predicates for C_H, since this coach obtained contrasting results: His team lost four matches and won one (see Table 1). Since the CR-ITF category is absent in the break period, the results of the predicate and argument analysis are presented separately for the two halftimes of matches and for the break period.

Effect of the Coach-Team System Variable on Predicate Breakdown During the Two Halftimes

Predicate–argument breakdown. The results concerning halftime periods are shown in Tables 4 and 5. Concerning the predicate breakdown (see Table 4), the analysis shows that two predicates are predominant: CR-ITF (coach interference with players' actions) and PLA-ACT-PLAN (plan maintenance or generation). Several links are significant; these are the links between the coach-team system and the following variables:

1. The predicate variable, $\chi^2(6, 1366) = 92.68$, $p = 0$. The predicate CR-ITF is overrepresented in C_Z's protocols and underrepresented in C_H's. The PLA-ACT-PLAN predicate is underrepresented in C_Z's. The PLA-ENV predicate appears overrepresented in C_L's protocols and underrepresented in C_H's. The PLA-REPFCT predicate is underrepresented in C_L's and C_Z's protocols and overrepresented in C_H's.
2. The CR-ITF variable, $\chi^2(4, 502) = 60.49$, $p = 0$. The structure argument is overrepresented in C_L's protocols and underrepresented in C_H's and even more so in C_Z's, whereas the opposite link can be observed for the involvement argument. The technique argument is also underrepresented in C_L's.

TABLE 4: Breakdown of Predicates (in Percentages) According to the Coach-Team System (Halftime Periods)

	Predicate			
Coach-Team System	CR-ITF	PLA-ACT-PLAN	PLA-ENV	PLA-REPFCT
C_H	10.8 (14.1)	15.8 (14.1)	4.3 (5.7)	6.7 (3.7)
C_L	10.2 (10.7)	11.3 (10.8)	5.6 (4.3)	1.5 (2.9)
C_Z	16.3 (12.7)	10.5 (12.7)	5.2 (5.1)	1.8 (3.4)
$\chi^2(6, 1366)$		92.68		
p		.0		

Note. Theoretical value in parentheses. CR-ITF = creation of an interference with a player's behaviour; PLA-ACT-PLAN = plan maintenance or elaboration; PLA-ENV = maintenance or elaboration of a shared situation awareness; PLA-REPFCT = maintenance or setting of role allocation.

TABLE 5: Breakdown of Arguments (for Each Predicate and in Percentages) According to the Coach-Team System (Halftime Periods)

	Predicate								
Coach-Team System	CR-ITF			PLA-ACT-PLAN			PLA-ENV		
	Involv.	Techn.	Structure	Involv.	Techn.	Structure	Inf.	Comp.	Antic.
C_H	14.5 (13.5)	7.1 (6.0)	8.0 (10.2)	14.7 (12.1)	10.8 (10.3)	13.7 (16.8)	21.0 (14.5)	4.0 (5.0)	4.5 (10.0)
C_L	7.8 (12.5)	3.0 (5.4)	16.5 (9.4)	9.3 (10.8)	7.6 (9.2)	18.1 (15.1)	12.0 (19.0)	6.0 (6.5)	20.0 (12.5)
C_Z	23.7 (19.9)	9.8 (8.6)	9.6 (14.5)	6.9 (8.0)	7.8 (6.7)	11.0 (11.0)	16.5 (16.0)	6.0 (5.5)	9.0 (11.0)
χ^2		(4, 502) = 60.49			(4, 408) = 10.62			(4, 200) = 26.64	
p		.0			.0031			.000024	

Note. Theoretical value in parentheses. CR-ITF = creation of an interference with a player's behavior; PLA-ACT-PLAN = plan maintenance or elaboration; PLA-ENV = maintenance or elaboration of a shared situation awareness; PLA-REPFCT = maintenance or setting of role allocation; Involv. = involvement argument; Techn. = technique argument; Structure = structure argument; Inf. = information argument; Comp. = comprehension argument; Antic. = anticipation argument.

3. The PLA-ACT-PLAN variable, $\chi^2(4, 408) = 10.62$, $p = .003$. The structure argument is overrepresented in C_L's protocols and underrepresented in C_H's; the involvement argument is greater than expected in C_H's protocols.
4. The PLA-ENV variable, $\chi^2(4, 200) = 26.64$, $p < .001$. C_H uses proportionally more information than his colleagues, whereas C_L uses more anticipation and less information.

MCA and coaching styles. An MCA was conducted in addition to the chi-square tests. This analysis was conducted with three main variables: the coach-team system, the main predicates (PLA-ACT-PLAN and CR-ITF), and their arguments (involvement, structure, and technique). The PLA-ENV predicate was not considered because it is not associated with the same arguments.

Three axes explain 69.5% of total inertia. (Inertia is a measure of the dispersion of the points in the full m-dimensional space.) Axis 1 (26.83% of inertia) opposes the coach-team system (C_L), predicate (PLA-ACT-PLAN), and argument (structure) modalities on the negative side to the coach-team system (C_Z) and argument (involvement) modalities on the positive side. Axis 2 (22.86% of inertia) opposes the coach-team system (C_H) and argument (technique) modalities on the negative side to the

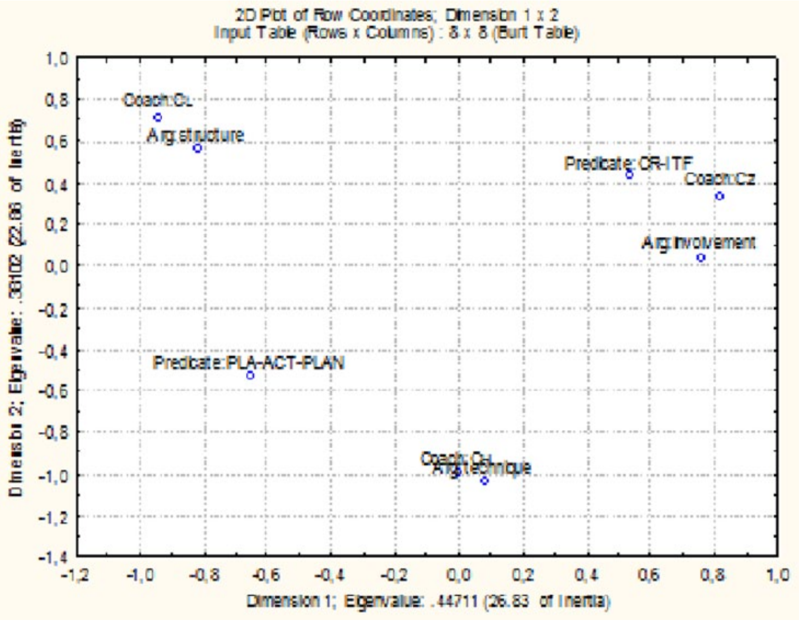

Figure 3. Multiple correspondence analysis on the main variables

coach-team system (C_L) modalities on the positive side. Axis 3 (19.79% of inertia) opposes the coach-team system (C_Z) and argument (technique) modalities on the negative side to the coach-team system (C_H) and argument (involvement) modalities on the positive side.

Crossing these axes shows several patterns of modalities. Crossing Axes 1 and 2 highlights the following patterns, shown in Figure 3: (a) predicate (CR-ITF)–coach-team system (C_Z)–argument (involvement), (b) coach-team system (C_L)–argument (structure), and (c) coach-team system (C_H)– argument (technique). Crossing Axes 1 and 3 highlights the following pattern: predicate (PLA-ACT-PLAN)–coach-team system (C_L)–argument (structure). Finally, crossing Axes 2 and 3 highlights the pattern predicate (CR-ITF)–coach-team system (C_L)–argument (structure).

Effect of the Coach-Team System Variable on Predicate Breakdown During Break Periods

Three predicates are represented during break periods: PLA-ACT-PLAN, PLA-ENV, and PLA-ACT-REPFCT. A relationship does exist between the predicate and the coach-team system variables, since C_H never mentions the environment (PLA-ENV). The relationship remains significant when we consider the other two predicates only (PLA-ACT-PLAN and PLA-ACT-REPFCT), $\chi^2(2, 208) = 6.06$, $p = .048$. Proportionally, we observed more PLA-ACT-REPFCT and fewer PLA-ACT-PLAN predicates in C_L's protocols than in the others. C_Z's protocols were characterized by the opposite pattern.

Effects of Level of Difficulty on Predicate Breakdown During the Two Halftimes

The results are shown in Tables 6 and 7. Several links are significant between the match outcome and the following elements:

1. The predicate variable, $\chi^2(3, 1366) = 23.20$, $p < .001$. The proportion of CR-ITF predicates in won matches is greater than the hypothesized proportions, whereas PLA-ACT-PLAN and PLA-REPFCT appear proportionally more often in lost matches.
2. The CR-ITF predicate, $\chi^2(2, 502) = 43.88$, $p = 0$. The structure argument is overrepresented when the team's score is unfavorable and underrepresented when it is favorable.

TABLE 6: Breakdown of Predicates (in Percentages) According to the Level of Difficulty (Halftime Periods)

	Predicate			
Difficulty Level	CR-ITF	PLA-ACT-PLAN	PLA-ENV	PLA-REPFCT
Δ_{Score}				
Balanced	15.6 (15.3)	15.7 (15.3)	6.4 (6.2)	3.1 (4.1)
Unfavorable	11.6 (13.7)	14.3 (13.7)	5.1 (5.5)	5.6 (3.6)
Favorable	10.2 (8.5)	7.6 (8.5)	3.6 (3.4)	1.2 (2.3)
$\chi^2(6, 1366)$	37.06			
p	.000002			
Match outcome				
Lost	19.5 (22.5)	24.5 (22.5)	9.2 (9.1)	6.9 (6.0)
Won	17.9 (14.9)	13.1 (15.0)	5.9 (6.0)	3.1 (4.0)
$\chi^2(3, 1366)$	23.20			
p	.000037			

Note. Theoretical value in parentheses; CR-ITF = creation of an interference with a player's behaviour; PLA-ACT-PLAN = plan maintenance or elaboration; PLA-ENV = maintenance or elaboration of a shared situation awareness; PLA-REPFCT = maintenance or setting of role allocation.

3. The PLA-ACT-PLAN predicate, $\chi^2(2, 408) = 12.17$, $p = .002$. The proportion of the structure argument is greater in lost matches than the hypothesized proportion and less in won matches.
4. The PLA-ENV predicate, $\chi^2(2, 200) = 12.13$, $p = .002$. The information argument is more often present in won matches than expected whereas anticipation is more often present in lost matches.

Moreover, several significant links appear between the score difference and the following elements:

1. The predicate variable, $\chi^2(6, 1366) = 37.06$, $p < .001$. The proportion of the CR-ITF predicate is less than hypothesized when the score difference is unfavorable and is greater when the score difference is favorable. Conversely, the proportion of PLA-REPFCT is overrepresented when the scores difference is unfavorable for the team and underrepresented when it is favorable or balanced. Last, the occurrence of PLA-ACT-PLAN is less than expected when the score difference is favorable to the team.
2. The CR-ITF predicate, $\chi^2(4, 502) = 10.33$, $p = .035$. Structure is overrepresented when the team's score is unfavorable and is underrepresented when it is favorable.

Effects of Level of Difficulty on Predicate Breakdown During Break Periods

The occurrence of the predicates also depends strongly on the match outcome, $\chi^2(4, 298) = 32.92$, $p = 0$. In lost matches, there is an overrepresentation of the PLA-REPFCT and an underrepresentation of the PLA-ACT-PLAN predicates. The opposite pattern characterized won matches. There is no significant relationship between the predicates used during the break period and the score difference.

Intraindividual Effects

As stated earlier, C_H is the only coach to obtain contrasting results. He lost four matches and won one. He indicated, during video-cued recall interviews, that he had the feeling he was in control of the situation throughout the match that was won, whereas this was not the case during the other matches.

At the intraindividual level of the C_H-team system, a significant relationship appears between match outcome and the occurrence of the arguments of the predicate PLA-ACT-PLAN, $\chi^2(2, 178) = 19.47$, $p < .001$. The involvement argument is the main argument used in the

TABLE 7: Breakdown of Arguments (for Each Predicate and in Percentages) According to the Level of Difficulty (Halftime Periods)

	Predicate								
	CR-ITF			PLA-ACT-PLAN			PLA-ENV		
Difficulty Level	Involv.	Techn.	Structure	Involv.	Techn.	Structure	Inf.	Comp.	Antic.
Δ_{Score}									
Balanced	20.7 (19.2)	7.2 (8.3)	13.9 (14.3)	11.8 (12.1)	11.5 (10.3)	15.9 (16.8)	23.5 (21.5)	4.0 (7.4)	16.0 (14.6)
Unfavorable	12.2 (14.5)	6.2 (6.3)	13.1 (10.7)	13.5 (12.6)	7.8 (10.7)	19.6 (17.5)	11.0 (10.9)	5.0 (3.7)	6.0 (7.7)
Favorable	13.1 (12.3)	6.6 (5.3)	7.0 (9.1)	5.6 (6.1)	6.9 (5.2)	7.3 (8.5)	15.0 (17.1)	8.0 (5.8)	11.5 (11.6)
χ^2		(4, 502) = 10.33			(4, 408) = 8.18			(4, 200) = 7.18	
p		.035			.08 (*ns*)			.13 (*ns*)	
Match outcome									
Lost	16.1 (21.9)	8.4 (9.5)	23.1 (16.2)	17.6 (19.3)	14.0 (16.4)	30.9 (26.8)	22.0 (27.7)	10.0 (9.5)	24.0 (18.7)
Won	29.9 (24.1)	11.6 (10.4)	11.0 (17.8)	13.2 (11.6)	12.3 (9.8)	12.0 (16.1)	27.5 (21.8)	7.0 (7.5)	9.5 (14.7)
χ^2		(2, 502) = 43.88		(2, 408) = 12.17			(2, 200) = 12.13		
p		.0		.0023			.0023		

Note. Theoretical value in parentheses; CR-ITF = creation of an interference with a player's behavior; PLA-ACT-PLAN = plan maintenance or elaboration; PLA-ENV = maintenance or elaboration of a shared situation awareness; PLA-REPFCT = maintenance or setting of role allocation; Involv. = involvement argument; Techn. = technique argument; Structure = structure argument; Inf. = information argument; Comp. = comprehension argument; Antic. = anticipation argument.

match that was won. Conversely, the structure argument is used mainly in the lost matches. The results also highlight a significant relationship between the match outcome and the occurrence of the arguments of the predicate CR-ITF, $\chi^2(2, 149) = 8.4$, $p = .015$. The involvement argument is overrepresented in the match that was won, whereas the structure argument is overrepresented in the lost matches.

DISCUSSION

The purpose of the present study was to identify the main cognitive control modes used by handball coaches during the defensive part of a handball match and particularly to highlight the contextual factors that had an effect on these modes. In the study, cognitive control is a theoretical framework that was used to understand the coaching process in a sports setting. Research dealing with cognitive processes in this domain is quite recent, and to our knowledge, these processes have never been studied in terms of cognitive control. This study used an original design to draw out aspects of the cognitive process that professional handball head coaches employed during matches when faced with various levels of difficulty in the games.

The results show that the cognitive control activity of a team handball coach consists mainly in (a) creating interference with a player's behavior and (b) maintaining or elaborating a plan.

Modes of Control and Level of Difficulty

As concerns the game phase, the results confirm the general hypothesis. When the team ranking is good (the coach-team system for C_Z and his team), when the game outcome is positive, and when the score difference is favorable for the team, the coach favors interference with his team's actions rather than other kinds of interactions, and interference concerns mainly players' involvement. He tends therefore to favor a reactive mode of cognitive control and the processing of subsymbolic data. Conversely, when the team ranking is mixed or poor, when the match outcome is negative, and the score difference is not favorable for the team, the coaches use an anticipative cognitive control mode more often, involving planning or replanning their actions or modifying role allocation among the team members. For coach C_L and for lost matches, replanning and interference often concern the team structure, indicating the processing of symbolic data. If interactions concerning the environment do not vary notably according to the level of difficulty, it must be noted that information about the environment is more often present in matches that were won than was expected, whereas anticipation is more often present in lost matches.

These results correspond to results of other studies using the systematic observation of coaches' behavior. Analyzing the influence of the score on coach feedback, Rodrigues and Pina (1999) showed that following a lost set, coaches gave more information on the opponent and tended to provide more tactical cues. However, when the situation is favorable, although coaches respect the players' autonomy (d'Arripe-Longueville et al., 2001), we show that they do not stop interacting with them. They continue interfering with the players' actions in order to obtain an optimal player involvement. The latter result seems to be original.

Concerning the break phases, the results show that in lost matches, the coaches' interactions with their teams deal more often with the allocation of functions, whereas they focus more frequently on planning or replanning in matches that were won. When the team ranking is good (the coach-team system for C_Z and his team), the coach has confidence in the composition of his team and knows which particular adjustments can be made. As a result, he can focus on the COFOR. Conversely, when the team ranking is mixed or poor, the coaches (C_H and, even more so, C_L) will take advantage of the break period to modify the function allocation between the team members. Therefore, they try to answer the following questions: Which players should play? Which positions should they play? Will they have enough resources to solve the problems?

Modes of Control and Coaching Styles

The results show an obvious difference between the modes of cognitive control used by C_Z (more often reactive and subsymbolic) and by his two colleagues (more often anticipative and symbolic). Furthermore, they highlight a difference in coaching style between C_H and

C_L concerning the cooperative activity between the coach and his players. During games, the former, more often than the latter, attempted to modify the allocation of roles among team members. His plans related more often to the involvement of the team members. Conversely, he was less concerned with shared SA, and it must be emphasized that he provided no information on the environment during the break period. In contrast, C_L tried to maintain shared SA in his team. His interactions with his team concerned primarily the team's structure and seldom involved the technical aspects of the game. These differences between the cognitive control modes used by these two coaches can be explained when we consider team characteristics. C_H's team was composed of young players with low autonomy and ability to manage problems on their own. This is probably why C_H did not try to improve their SA during the break phase. The frequent use of role allocation by C_H may also be explained by the players' youth. As stated during C_H's video-cued recall interviews, this coach turned to substitution players as a sanction for poor performance, especially after an inadequate action.

Coaching styles are usually analyzed in terms of leadership styles (e.g., Chelladurai, 1990, for review; Kent & Chelladurai, 2001). This study provides an original point of view on this topic. It reveals the existence of two main coaching styles depending on the difficulty of the situation: reactive-subsymbolic on the one hand and anticipative-symbolic on the other. The study results thus complement the work of Mouchet et al. (2013), conducted with rugby coaches and identifying reactive or proactive profiles. Mouchet et al. explained these styles using personal characteristics, past experiences, objectives for the team, expectations for the game, and characteristics of the players. Within the anticipative-symbolic style, the present study shows that when the level of difficulty of the situation is high, the coach's cooperative activity may involve either modifying role allocation or planning or replanning his team's activity. When modifying role allocations, a coach may choose to substitute one or more players and/or to reposition first-team players (e.g., between the back and wing player). When planning or replanning his team's activity, he may change the team structure by adjusting a player's position on the court (laterally or in depth) or change the team organization (i.e., select a new defense system). These two coaching styles, however, are not exclusive; rather, they represent two extremes on a continuum.

Implications for Coach Training

From a practical point of view, these findings are expected to influence coach training and, more generally, the training of supervisors in dynamic and competitive situations. According to these study findings, we suggest that a coach carries out the following actions:

1. Increase the players' physical and mental involvement and guide the players' actions when assessing team performance as sufficient or when the coach thinks that the team is able to manage the situation on its own. In such cases, the coach can use the break period to assure COFOR maintenance.
2. Act on role allocation and/or action planning when the coach thinks team performance is insufficient or that the team is unable to manage the situation on its own. In such cases, action planning may involve (a) adjustments of players' positioning on the court in depth (in order to be not too far from, or too close to, the target) and laterally (team density), (b) choosing the most relevant team organization (i.e., defense system) considering the opponents' characteristics, and (c) choosing the best-suited players for this team organization as mentioned by the two-time world champion handball coach in Debanne and Fontayne's (2009) study.

Theoretical Implications

The coaching activity in a sports setting lends itself to the analysis of cognitive control because it is carried out in a very dynamic and changing environment, driving frequent variations of the cognitive control mode that can be revealed by the coaches' verbal communications. From a theoretical point of view, this study validates Hoc and Amalberti's (2007) model since it shows that coaches may use a reactive or an anticipative mode of control as well as symbolic or subsymbolic data in both modes. It shows, nevertheless, that it may be difficult to operationalize the notion of symbolic versus subsymbolic data. The study findings confirm the fact that symbolic control can precede or replace subsymbolic or routine control when the expert faces a difficult situation, as shown by Hoc and Amalberti. They also show that a reactive mode of control is sufficient when there are no particular difficulties. On the contrary, coaches have been shown to modify their plans when the situation shows these to be ineffective and therefore adopt a more anticipative mode of control. This finding complements those of Hoc and Amalberti. However, it contradicts Braver's (2012) findings showing that a proactive pattern was observed in a low-load condition whereas the pattern was more reactive in a high-load condition. However, it must be emphasized that our study was conducted with experts observed in naturalistic settings, and it is known that experts are flexible. In other words, they are able to adapt to ambiguous, changing, and complex environments because they can call upon a wide range of strategies to respond to the characteristics of a situation and, in particular, to manage uncertainty. They know how and when to use a strategy and when to change strategies.

Limitations and Future Research

The main limitation of this study is related to the fact that we were unable to untangle whether the differences seen in communication and cognitive mode were driven by the team performance or whether the team performance, as a result of coach intervention, was driven by the cognitive mode. Moreover, only one coach experienced victories and losses. Therefore, except for the one coach, we were unable to conduct an intraindividual analysis of the cognitive control adjustments according to the situation features. Hence, it would be worth conducting similar studies in more varied contexts.

Another limitation concerns the coaches' profiles. All of them are experts, and one is a super-expert. (The notion of super-expert refers to the top experts in a particular field; Raufaste, 2001). As it is well known that expertise influences coaches' decision-making abilities (Debanne, Angel, & Fontayne, 2014), it would be worth studying the ability of less experienced coaches to adjust their mode of cognitive control. For this topic, it would also be necessary to conduct further studies.

Last, it must be emphasized that this study relies on the interaction between coaches and players only during the defensive parts of 15 handball matches. It would be worth reproducing it in other sports settings and, particularly, in other court sports, such as basketball or volleyball, where the process speed is higher and where we could hypothesize a more anticipative mode of cognitive control than what has been observed in handball.

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