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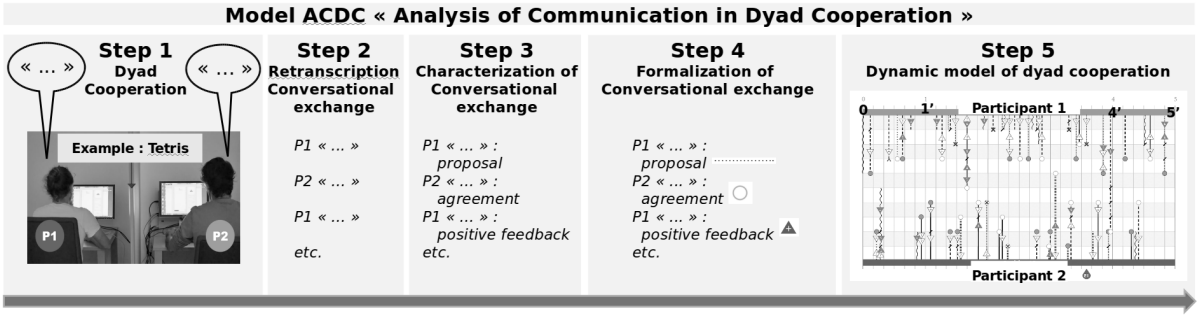

Abstract

This article has two objectives. First is the presentation of an updated model of conversation analysis designed and tested in a specific cooperation situation. Secondly, its validation by mixed methods combining a qualitative study based on user-centered methods and a quantitative analysis using interrater agreements. The first highlights the importance of adapting the model to the cooperation task by adding or merging typology categories. The second reveals guidelines for the use and reliability of the model based on rater skills. Interrater agreements show that an expert could use our model alone whereas novices should use pair rating for satisfactory results.

Highlights :

- Formalization of a new model for conversation analysis during a cooperation situation.
- The nature of conversational exchanges and their temporal dynamics are both represented.
- Conversational exchange typology is adapted and validated by mixed methods.
- Interrater agreements indicate good reliability of the model.
- An expert could use our model alone whereas novices should pair rate a conversation.

Key-words :

- Dyad cooperation, conversational exchanges, temporal dynamics, collaborative cognitics, mixed methods, knowledge eXchange

1. Introduction

Social cognition refers to how we perceive, process and interpret social information (Bertoux, 2016). The performance of a task (cognitive, motor, etc.) in a dyad situation can take place in a context of coordination, cooperation or collaboration (Belkadi et al., 2004) (Table 1). In the case of coordination, the goals are not necessarily the same for both people. Moreover, if there is a hierarchical relationship between them, the relationship of authority means that the tasks to be performed by each are often of a different nature (Gulati et al., 2012). Conversely, in the case of cooperation or collaboration, the goal is common. It is then the way of achieving this goal that will differentiate the two situations (Sébastien, 2001; Gulati et al., 2012; Henri and Lundgren-Cayrol, 1997). In a collaboration task, the responsibility is individual and we speak of associative interdependence. In a cooperation task, each person performs a part of the overall task. In this case, there is a strong interdependence between the two people and the success of the task is the responsibility of the group dynamics. Thus, contributions are meaningful only if understood and complemented by the work of others. The effectiveness of a collaboration or cooperation task depends on the quality of verbal communication between people (Clark, 1996; Meier et al., 2007): request for advice, proposal, suggestion, consensus, strategy development, order, etc. (Clark, 1996; Meier et al., 2007).

	Common goal	Interdependant responsabilities
Coordination	Not necessarily	No
Collaboration	Yes	"No" rather than "Yes"
Cooperation	Yes	Yes

Table 1 : Comparison of the 3 types of dyad situations : coordination, collaboration and cooperation.

In the present work, we focus on dyad cooperation situations. Even if the cooperation situation is based on a clear division of labor and thus on collective interdependence, the group dynamics that are created can lead to the emergence of social roles, such as leadership, followership or others (Demary, 2018, Dinh et al., 2014; Uhl-Bien et al., 2014; Oc and Bashshur, 2013; Tee et al., 2013). Thus, when two individuals perform a common cognitive task with a performance objective, they are led to implement one (or more) interaction strategies. Several authors have proposed semantic characterizations of these communications (Clark and Brennan, 1991; Meier et al., 2007). For example, Meier et al. (2007) proposed characterizing communications between two people based on 5 aspects: communication, informational process, coordination, interpersonal relations, and motivation. This classification is interesting, but limited: 1) it does not allow specifying the nature of the exchanges nor the roles of each person, 2) it does not consider the temporal dynamics of the exchanges. To analyze the data of an oral exchange, it is necessary to identify the parameters that must be observed during the interaction. They must also be transcribed and formalized into non-audio data that can be more easily processed and compared. To do this, data must be classified and characterized.
The case studied here is that of a cooperation dyad playing the same game of Tetris with complementary roles. The communicative interactions between the individuals were observed as short and repeated throughout the common task. The projective model of informational dialogue presented by Vernant (1992) is not suitable here since the modeling would have to be done for each exchange independently.

Our objective is to represent the entire dialogue and all the exchanges that make it up on the same graphical representation in order to account for the dynamics of the exchanges and their fluctuations. Since we want to identify the elements of the dialogue to characterize the dynamics of the exchanges, we are interested in the nature of these exchanges. Does the individual address the other person? Is he or she asking the other person to do something? Does he talk to himself? In the situation we are studying, individuals must make decisions quickly and perform actions to complete the cognitive task and comply with the instructions given to achieve the best possible score. We therefore rely on the collection of the exchanges expressed and the observation of the resulting decision making. It is a performative language, linked to an action, as defined by Austin (1975).

Giving or accepting instructions is an illocutionary act that has an immediate effect on the game (Searle, 1972; 1990). These instructions form the core of our model. Additionally, we add elements that characterize the interaction between individuals in terms of valency and intention, based on Bales' categories (1950; 1972): the scope of the interactions (affective versus work-oriented), the value (positive versus negative), and the nature (intervention centered on oneself, on others, or on another intervention). This typology is interesting because it makes it possible to characterize the nature of exchanges according to their temporal dynamics.

Discourse analysis have been mainly qualitative or quantitative methods. But another alternative would be using mixed-methods and combining qualitative and quantitative approaches for data collection and analysis (Creamer, 2016). For example, it is now a common procedure to use statistical analysis on qualitative data to ensure the validity and reliability of discourse coding (Spooren, 2010). Sometimes, using qualitative and quantitative data in concert at the inference level is also the only way to draw conclusions (Campbell, 2010).

So we choose to use a mixed-methods approach to complete the objective of this work : 1- to formalize a model for the analysis of conversational exchanges within a dyad cooperation situation and 2- to consider the temporal dimension and propose a relevant, graphical representation of these exchanges.

2. Description of the design process

2.1 - Description of the cooperation task

There are many cooperation tasks already studied in dyad situations, including cooperative Tetris games (Mast and de Vries, 2016; Noah et al., 2015). This game is a playful, intuitive task with simple rules and it is easy to distribute the possible actions on the game pieces between the two people in an equitable way in terms of cognitive load (Noah et al., 2015). For example, participant 1 can move the pieces on the horizontal axis (i.e. from right to left) and lower them and participant 2 can rotate counterclockwise or clockwise. The success of this task, i.e. to build lines as quickly as possible, requires a very strong cooperation between the two participants. As illustrated in Fig. 1, the participants are placed side by side without seeing each other to force cooperation through verbal communication. They each have a screen in front of them that allows them to see the game and the actions performed.

Fig. 1 : Illustration of the experimental set-up: Two participants separated by a screen playing the same game of Tetris.

The experimental protocol takes place in two stages: 1) Participants play Tetris alone for 10 minutes to habituate to the controls; 2) they are then assembled in dyads and play cooperatively for 10

minutes. They are instructed to achieve the best possible score and are encouraged to communicate verbally as much as they wish, but they cannot see each other. In this situation, we record the conversational exchanges between the participants. This allows us to collect a corpus of data on which we develop and formalize our model for Analyzing Communication in Dyad Cooperation, called the ACDC model.

2.2 - Design process of the ACDC model

Formalizing the analysis model took place in several steps as illustrated in Fig. 2

- Step 1: Development of the model based on the literature;
- Step 2: Validation of the categories used and their wording using a focus group and a card sorting session;
- Step 3: Experimentation phase, dyads are formed and carry out the task of cooperative Tetris. The conversations are recorded and constitute our corpus of data;
- Step 4: Application of the ACDC analysis model to the data;
- Step 5: Calculate interrater agreements between judges and juries to evaluate the ease of use of the analysis model and its reliability;
- Step 6: Final formalization of the model and its best practices guide.

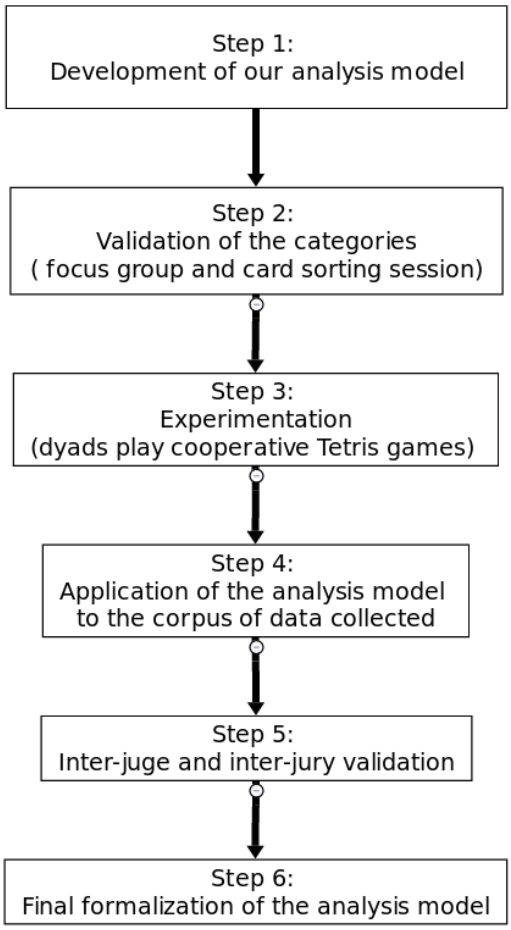

Fig. 2: The stages of the design process.

2.3 - Mixed-method approach

A mixed approach is developed to design and validate the analysis model.

The development of this methodology is motivated by the observation that there is no satisfactory methodology dedicated to the modelling of conversational activity. Existing methods are not easily usable and their handling is complex. We present here a process for designing and validating a new analysis model adapted to our particular situation and accessible to non-expert experimenters.

The design process starts with the development of a model, first validated using user-centred qualitative methods. Then the model is validated by an experiment where qualitative data is collected, analyzed and interpreted.
The transformation of the data is initially done through qualitative transcription, characterization and formalization of the conversations. This application of the ACDC model to a qualitative database is conducted by several judges and results in integrated qualitative and quantified data, more detailed below. Finally, this data transformation allows us to compare different points of view through inter-judge measurements and to quantitatively validate the reliability of our analysis model.

The integrated qualitative and quantified data are also used at the inference level, in order to allow a more solid understanding of the results of the experiment and to identify possible improvements to our analysis model.

The final formalization of our analysis model integrates the qualitative and quantified data into a single visual plan. This formalization is linked to a mixed methods' technique called "joint display", as suggested by Guetterman et al (2015). In our study, we use this joint display to capture and understand the dissonances and congruences between the formulations of the dyads and judges, and to suggest improvements to our ACDC model.

3 - Description of the analysis model

The objective of the model is to specify the nature of conversational exchanges in dyad cooperation situations and to propose a relevant graphical representation which considers temporal dynamics. Thus, our analysis model is based on two complementary phases:

- Determine the typology (nature and duration) of the exchanges between the two participants;
- Formulate a relevant graphical representation of these exchanges and their temporal dynamics

3.1 - Determination of a typology for conversational exchanges

A conversation refers to the totality of dialogue between two participants during the experience. In this case, we model a conversation of 10-minutes. Conversations are composed of several exchanges, themselves made up of one or more successive speeches. Each time one of the two participants speaks, he or she makes a speech. ***Speaking*** is the smallest unit in our model. We consider an ***exchange*** to be all the successive speeches of the two participants that follow the same action statement. As soon as one of the participants starts talking about another action or another subject, a new exchange has begun.

Thus, when transcribing the recordings according to the ACDC model, the entire verbal interaction is broken down into exchanges. For each defined exchange, several characteristics are specified:

1. The temporality: start and end time to the nearest second
2. The initiator of the exchange (Participant 1 or Participant 2)
3. The initiator of the action (Participant 1 or Participant 2)
4. The length of the exchange (discrete timing)
5. The presence of speech cuts (yes or no)
6. The type of exchange: directive actions (orders, instructions, proposals) or non-directive actions (comments, soliloquies, non-verbal actions)
7. The type of final decision made: assent or dissent
8. The qualifiers of the interaction: task-related interactions (information communication, questioning, negative game-oriented remark, positive game-oriented remark, control) and socio-emotional interactions (positive feedbacks to the partner, negative feedbacks to the partner)

Initiator of the exchange and initiator of the action

The initiator of the exchange is distinguished from the initiator of the action. It may happen that one participant elicits the participation of the other but does not state an action taken or to be taken. To initiate an action, a direction must be verbalized, a non-verbal action must be taken, or a comment or soliloquy must be made. Being proactive and engaging the other person is relevant. Therefore, to avoid any loss of information, the initiator of the exchange will also be considered and symbolized in the modeling. Thus, the initiator of the exchange and the initiator of the action are often the same person, but this is not systematic. For example, if an exchange starts with an invitation to give a directive: the participant giving the directive is the initiator of the action, but the other one is the initiator of the exchange.

Length of exchanges and speech cuts

The length of an exchange corresponds to the number of successive speeches by each person in the same exchange, so it is a numerical value. It thus gives information on the quantity of each person's speeches and on the tendency to respond to the other person or not. This variable is essential to have a global vision of the communication between two participants. Speech cuts make it possible to translate certain modalities of the conversational exchange, such as speaking at the same time as the other person or not letting him/her finish the sentence.

Types of exchanges

In order to identify the dynamics of verbal conversation between two participants cooperating on the same cognitive task, we chose to characterize the initiated actions. The exchanges are categorized according to syntactic distinctions (use of the indicative, imperative, conditional), recipient distinctions (speaking to oneself or to the other) and vocal tone distinctions (certain or uncertain tone, authoritative or non-authoritative tone). The classification of actions follows the taxonomy identified by Searle (1972, 1990), based on research by Austin (1975). Indeed, it is partly a matter of specifying so-called directive performative language acts. Performative means that the speaker expects the listener to perform an action, which is why we speak of an initiator of action to designate the issuer of this type of statement. In addition, they are directive, i.e. they ask explicitly the listener to perform a specific action. In Vernant (1992), this categorization corresponds to the 'directional initiator'. Searle (1990) and Vernant (1992) group orders, advice, questions or requests for undertakings under these directive performative language acts.

In order to validate the categories with respect to the task of the cooperative Tetris game, we conducted focus groups and card sorting sessions. Fourteen students aged 20 to 30, including 8 men and 6 women, were divided into three groups, each of which participated in a focus group organized around the characterization of the categories, followed by a card sorting session. Each group sorted 28 exchanges extracted from a 10-minute audio recording from a pre-experimental cooperative Tetris game. They were instructed to form groups of excerpts focusing only on the instructions given in the excerpts - and not on the answers - and to form as many groups as they wished, within the limit of 7. Once the groups were formed, they were asked to carry out labelling work and to give a name to each of the categories created.

Category		Origin of the category
Types of exchange : directive vs non-directive action		**Searle (1990), Vernant (1992)**
Directive action	Order	Coming from the Focus group and card sorting sessions
	Instruction	
	Proposal	
Non-directive action	Soliloquy	Coming from the Focus group and card sorting sessions
	Comment	
	Non-verbal action	
Types of decision : assent vs dissent		**Bales (1950; 1972)**
Assent	Agreement	Adapted from Bales (decomposition cat. 3)
	Acceptance	
	Authorization	
	Dealership	
Dissent	Refusal	Adapted from Bales (decomposition cat. 10)
	Undetermined	
Qualifiers of interaction : task-related vs socio-emotional		**Bales (1950; 1972)**
Task-related	Communication of information	Adapted from Bales (merging cat. 5 et 6)
	Questioning	Adapted from Bales (merging cat. 7, 8, 9)
	Control	Bales (cat. 4)
	Positive game-oriented remark	Coming from the Focus group and card sorting sessions
	Negative game-oriented remark	
Socio-emotiional related	Positive feedback to the partner	Adapted from Bales (merging cat. 1, 2)
	Negative feedback to the partner	Adapted from Bales (merging cat. 11, 12)

Table 2 : Summary of the origin of the categories used in the ACDC model typology.

Based on the results, we formed three sub-categories under the heading of ***directive actions*** (i.e. *Directive Performatives* - see Table 2):

- orders, which include injunctions, orders and safe orders,
- instructions, which can be related to the notion of uncertain order because one addresses the other directly but not as certain and authoritatively as with an order,
- proposals, which include clear proposals awaiting confirmation, hesitant proposals requiring confirmation and suggestions.

Then our model considers ***non-directive actions***:

- comments, of a consensual (and no longer performative) type, which are used for description,
- soliloquies, which do not include the other and are therefore not illocutionary acts (the soliloquy being a discourse by a person who is talking to himself or thinking aloud),
- non-verbal actions, which are not acts of language.

Types of decisions

For the purpose of relevance, we are only interested in the final decision made by the original recipient. Thus, we note as a type of final decision the **assent of the addressee** to the initial directive with four sub-categories:

- agreement,
- acceptance,
- authorization,
- dealership,

And if not, the recipient's dissent to the original directive, in other words, refusal.

Qualifiers of interactions

We sought to characterize the nature of the interactions between the two individuals. Bales (1950; 1972) distinguishes task-related interactions from socio-emotional interactions. Furthermore, he classifies these two broad categories into two groups: "in question" and "in response" for task-related interactions and "positive emotional domain" or "negative" for interactions within the socio-emotional domain. Concerning the **task-related interactions**, we have collected those concerning:

- communication of information,
- questioning,
- negative game-oriented remarks,
- positive, game-oriented remarks,
- control.

Socio-emotional interactions are:

- negative feedbacks to the partner,
- positive feedbacks to the partner.

Events

Events allow transcription of context information (example: Tetris game finished, restart of a new game). This is information that is relevant for the analysis but that cannot be symbolized in the modeling.

3.2 - Development of a graphical representation of the exchanges and their temporal dynamics

Once the typology for characterizing conversational exchanges was defined, a graphical representation was proposed to account for the temporal dynamics. Several types of graphic proposals have been put forward (circular, frieze, etc.). A focus group enabled us to validate a symbology of the typology of exchanges (Table 3), then a representation in the form of a timeline (Fig. 3).

Categories	Sub-categories and symbology			
Initiator of the exchange	Participant 1 or participant 2		P1 P2	
Initiator of the action	Participant 1 or participant 2		P1 P2	
Length of the exchange	From 1 to n			
Speech cuts	Yes or no			
Event	Yes or no		EI	
Type of exchange	Directive actions		Non-directive actions	
	Order		Comment	
	Instruction		Soliloquy	
	Proposal		Non-verbal action	
Type of decision	Assent		Dissent	
	Agreement		Dissent : Refusal	
	Acceptance		Undetermined	
	Autorization			
	Dealership			
Qualifier of interaction	Task-related interaction		Socio-emotional interaction	
	Communication of information	i	Positive feedback to the partner	+
	Questioning	?	Negative feedback to the partner	-
	Negative game-oriented remark	-		
	Positive game-oriented remark	+		
	Control			

Table 3 : Typology symbols of the ACDC model.

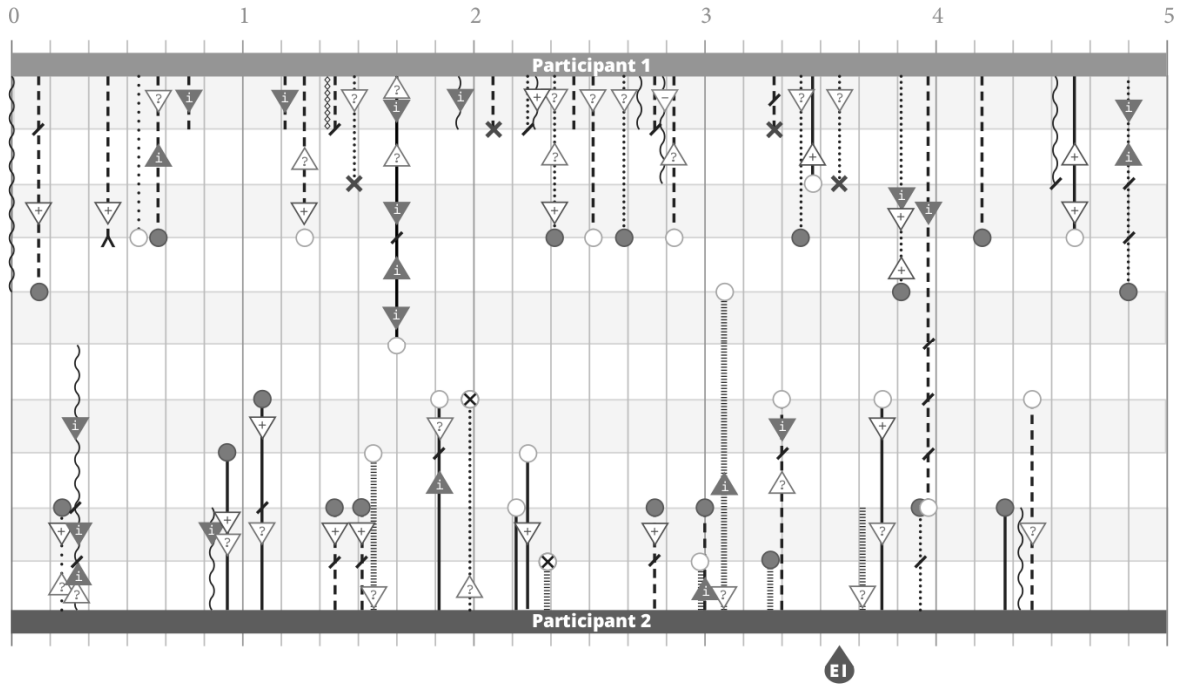

Fig. 3 : Graphical representation of the ACDC model for the first 5 minutes of conversational exchanges for the dyad BH3 (jury alpha : 2 experts). Refer to the typology symbols of the ACDC model (Table 3).

Fig. 3 shows the evolution of conversational exchanges observed for 5 minutes. It is characterized as follows:

- The time course is on a horizontal axis, the time unit is 10 seconds.
- The grey bars at the top and bottom of the timeline position each person of the dyad (participant 1 at the top and participant 2 at the bottom).
- The middle part characterizes the exchanges according to the previously defined categories.

The graphical representation of the ACDC model (Fig. 3) corresponds to a joint display (Guetterman et al, 2015) and combines qualitative and quantitative data in the same visual plane. The qualitative data are accessible through the symbology of types of exchanges, types of decisions and qualifiers of interactions (Table 3). The quantitative data are also visualized at a glance in the graphical representation (Fig. 4) we can observe :

On the horizontal axis: the timing and distribution of exchanges during the conversation.
On the vertical axis: the distribution of the actions initiated between the participants, the duration of the exchanges and the distribution and quantity of the interactions.

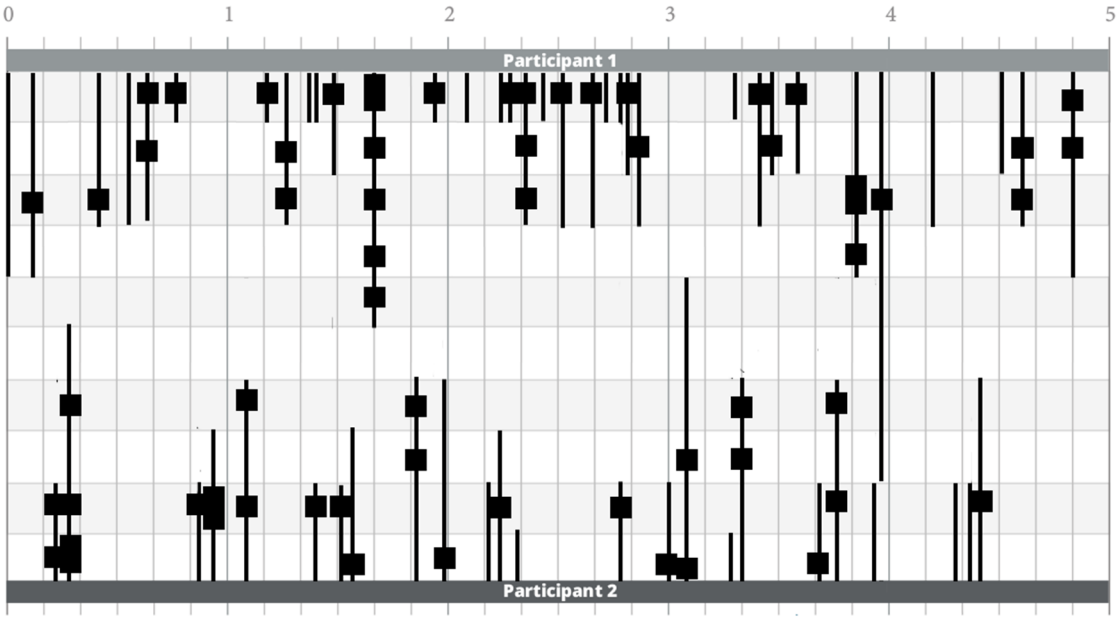

Fig. 4 : Illustration of quantitative data visible in an example of graphical representation of the ACDC model (Fig. 3). Vertical full lines indicate any type of exchange. Full squares represent any type of interaction. Refer to the typology symbols of the ACDC model (Table 3).

4 - Application of the analysis model to a Corpus

4.1 - Constitution of the corpus

4.1.1 - Description of the pre-test in an individual situation

64 students aged 20-30 years, 37 women and 27 men, participated in the pre-tests. The participants were divided into 3 groups and supervised by 2 observers. Each individual had a computer with a version of the Tetris game coded under MATLAB. The difficulty of the game is progressive with the level increasing every 5 completed lines. After a short presentation of the context of the experiment, they are asked to play Tetris individually. All individuals started playing simultaneously and raised their hand when they lost so that observers could note the score and the level reached; the game then restarted. All participants played for a total of ten minutes, regardless of the number of games lost. The students then completed an anonymous Google Forms online questionnaire which included their assigned participant code. This questionnaire (i) collected personal data, (ii) self-assessed performance on Tetris, and (iii) had 5 questions on the practice of video games.

4.1.2 - Constitution of dyads for the task of cooperative Tetris.

The formation of the dyads for the experiment was carried out using the data collected during the pre-tests. Men and women were separated to form non-mixed dyads. In order to have subjects with homogeneous game performances (neither too weak nor too strong), we excluded subjects with performances in the first and last quartile. In total, we obtained a sample of 8 dyads: 3 male and 5 female.

4.1.3 - The Cooperative Tetris experience

The 8 dyads formed participated in the experiment as follows: The participants were informed individually of their schedule without knowing that they were in dyads. The observers received them in a room equipped with two computers with the version of Tetris developed on Matlab and used in pre-test (see Fig. 1). The two participants were placed at tables next to each other and separated by a screen. They each had a screen and a keyboard with which they could use two keys to play Tetris. The participant "P1" of each dyad was always in charge of the rotation of the pieces and their rapid descent, via the "up arrow" and "down arrow" keys of the keyboard. Participant "P2" was always in charge of horizontal movements using the "O" (left) and "P" (right) keys of the keyboard.
The difficulty was not progressive and the level was set at 5 to simplify score comparison among the dyads. Participants were told that they could communicate verbally as much as they wished and that their goal was to achieve the best possible score in Tetris. As in the pre-tests, they were told that they must play for 10 minutes and that the game would be restarted if they lost. Two audio recordings were made for each participant throughout the experiment. In addition, observers took notes according to an observation grid. They observed the distribution of the exchanges in 2-minute increments and the general dynamics of the exchanges. They also noted events that would not appear in the audio recordings, such as intermediate scores in case of failure. The experiment was completed when the 10 minutes were up.

4.1.4 - The corpus

The results of 7 dyads (out of 8) were collected due to technical problems encountered during the experiment for the first dyad.
All audio files were transcribed word-for-word and then a re-transcription of each, exchange by exchange, was carried out by a jury of two experts who had already mastered transcription as well as the model we propose.
The exchanges were treated according to our model of Analysis of Communication in Dyad Cooperation (ACDC) (examples in Table 4).

	Example 1
1. Retranscription	*P2 : "How do you want it?"* *P1 : "Flat, I'll move it to the left"* *P2 : "There, like that ?"* *P1 : "Yeah"*
2. Characterization	P2 speaks first, but to involve the other participant ***-> questioning P1***  P1 answer by a directive ***-> initiator of the action***  P1 give a directive, P2 answer, P1 answer ***-> length of the exchange = 2*** P1 says what he/she would do ***-> proposal*** P2 does not conflict ***-> agreement*** 
3. Formalization	

	Example 2
1. Retranscription	*P1 : "You can put it on the edge, at the far right"* *P2 : " 'Fuck you're good !"*
2. Characterization	P1 initiates the exchange  P1 speaks to P2 to tell him/her what to do ***-> instruction*** P1 gives a directive, P2 answers ***-> length of the exchange = 1*** P2 compliments P1 ***-> positive feedback to P1***  P2 answers positively to P1 ***-> agreement*** 
3. Formalization	

Table 4 : Detail of the re-transcription of two exchanges : re-transcription, characterization and formalization according to our ACDC model

4.2 - Application of the model to our corpus: example of a dyad (BH3)

For an easier understanding, we will illustrate the application of our model through a single dyad, the one named BH3.

Once the transcription is done, we characterize and formalize the exchanges with a timeline (Fig. 5).

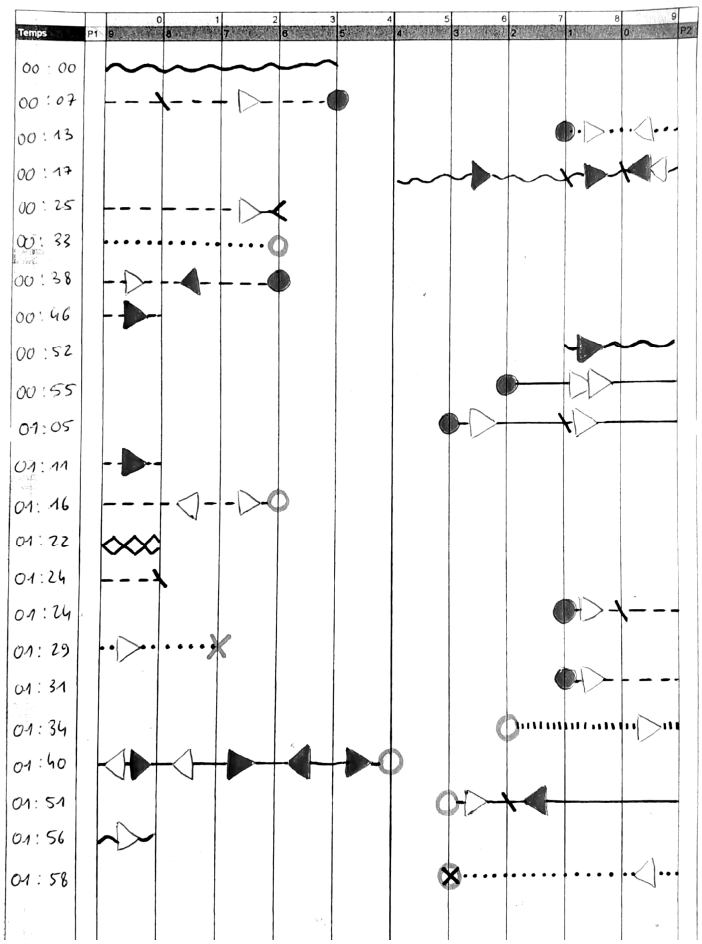

Fig. 5 : Completed paper timeline of the first 2 minutes of conversational exchanges for the dyad BH3 (jury alpha : 2 experts). *Refer to the typology symbols of the ACDC model (Table 3).*

From the timeline, a matrix of temporal data collects and characterizes all conversational exchanges. The matrix form is intended to facilitate statistical processing and interpretation (Table 5).

						P1 to P2								P2 to P1							
Start time (mm:ss)	Init. action	Init. exchange diff	Lengh	Type of exchange	Type of decision	Questioning	Information	Control	P feedback	N feedback	PGO remark	NGO remark	Speech cuts	Questioning	Information	Control	P feedback	N feedback	PGO remark	NGO remark	Speech cuts
00:00	P1	0	3	comment	null	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
00:07	P1	0	3	instruction	acceptance	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
00:13	P2	0	1	proposal	acceptance	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0
00:17	P2	0	4	comment	null	0	2	0	0	0	0	0	1	1	1	0	0	0	0	0	0
00:25	P1	0	2	instruction	undetermined	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
00:33	P1	0	2	proposal	agreement	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
00:38	P1	0	2	instruction	acceptance	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
00:46	P1	0	0	instruction	null	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
00:52	P2	0	1	comment	null	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
00:55	P2	0	2	order	acceptance	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
01:05	P2	0	3	order	acceptance	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
01:11	P1	0	0	instruction	null	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
01:16	P1	0	2	instruction	agreement	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0
01:22	P1	0	0	soliloquy	null	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
01:24	P1	0	0	instruction	null	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
01:24	P2	0	1	instruction	acceptance	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0
01:29	P1	0	1	proposal	refusal	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
01:31	P2	0	1	instruction	acceptance	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0
01:34	P2	1	2	non-verbal	agreement	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
01:40	P1	1	4	order	agreement	0	3	0	0	0	0	0	0	1	1	0	0	0	0	0	1
01:51	P2	0	3	order	agreement	0	1	0	0	0	0	0	1	1	0	0	0	0	0	0	0
01:56	P1	0	0	comment	null	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
01:58	P2	0	3	proposal	dealership	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0

Table 5 : Time matrix of the first 2 minutes of conversational exchanges for the dyad BH3 (jury alpha : 2 experts).

Fig. 6 shows the ACDC model's final graphical representation of the exchanges of BH3 dyad, constructed from the data collected in the time matrix (Table 5).

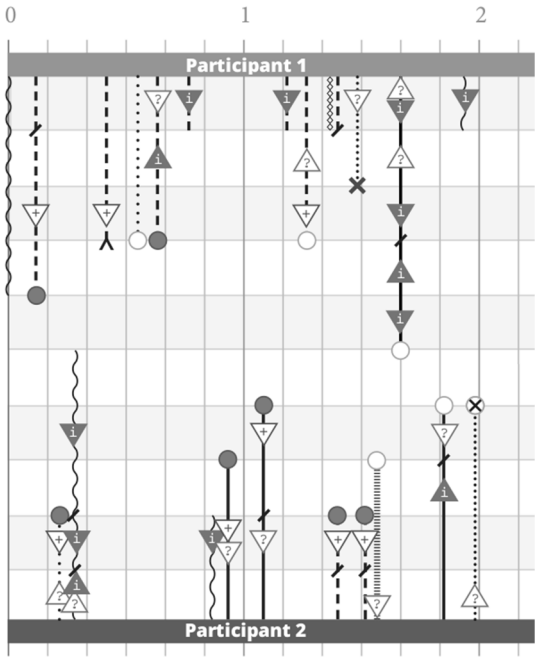

Fig. 6 : Final graphical ACDC model representation for the first 2 minutes of conversational exchanges for the dyad BH3 (jury alpha : 2 experts). Refer to the typology symbols of the ACDC model (Table 3).

5 - Validation of the model

Human interrater agreement represents one of the gold standard against which we measure natural language processing performance (Campbell, 2010). Therefore, we chose to calculate interrater agreements between judges and juries in order to validate the ACDC model and its reliability.

5.1 – Interrater agreement between judges

Initially, we compared decisions made individually. Two experts in the analysis model separately analyzed and modeled the conversational exchanges of the same dyad: the BF1 dyad. This dyad was chosen by the two experts as they judged the exchanges of this dyad to be dense, rather complex and exhaustive in terms of the representation of the different components of the model.

Results

Tables 6 and 7 compare the analyses proposed by the two expert judges.

For dichotomous variables, we compared the responses of the two judges. We first identified the number of common exchanges with the same timing (+/- 3 seconds). Then, for those exchanges, we noted the percent agreement between the two judges for the following scores:

- % of actors in common: percentage of times the judges identified the same actor (possible answer: participant 1 or participant 2)
- % of initiators of the exchange in common: percentage of times the judges identified the same initiator of the conversational exchange (participant 1 or participant 2)

- % of speech cuts in common: percentage of times the judges identified the same speech cuts
- % of interactions in common: percentage of times the judges identified the same qualifier of interaction (questioning, providing information, positive feedbacks to the partner, etc.).

Percentage agreement	% of common exchanges	% of common actors	% of common initiators of the exchange	% of common speech cuts	% of common interactions
expert 1 vs expert 2	90,71 (***)	100 (***)	97,70 (***)	88,60 (**)	94,50 (***)

Table 6 : Interrater agreement between judges on dichotomous variables: moderate concordance between 70 and 79% (*) / strong concordance between 80 and 89% (**) / very strong concordance >90% (***)

For qualitative variables, agreement between the two expert judges was analyzed using Cohen's (1960) kappa statistic: a coefficient to measure agreement between two qualitative variables, and commonly used to measure degree of agreement between two judges. The specificity of this coefficient is that it considers the theoretical proportion of "random" agreements. We used the Cohen's kappa coefficient interpretation grid proposed by Landis and Koch (1977):

- < 0: Disagreement
- - 0.20: Very low agreement
- 0.21 - 0.40: Weak agreement
- 0.41 - 0.60: Moderate agreement (*)
- 0.61 - 0.80: Strong agreement (**)
- 0.81 — 1.00: Almost perfect agreement (***)

The specificity of Cohen's (1960) kappa coefficient is that it considers the theoretical proportion of "random" agreements.

We calculated interrater agreement on length, type of interaction, type of directive, type of decision and type of other action. In the case of perfectly ordered sub-categories, serious disagreement is more likely to be sanctioned than slight disagreement between two contiguous sub-categories (Cohen 1968; Bakeman et al. 1997; Bakeman and Gottman 1997). Thus, for the linear variable length of interaction, we used a linearly weighted Cohen's kappa. A quadratic-weighted measure of kappa was applied to directive actions with the following ordering: order, instruction, and proposal. We used an unweighted version of the kappa calculation for the other categories, which have sub-categories that are too different to be ordered. Namely: the type of final decision and the type of non-directive action (non-verbal, soliloquy and comment).

Inter-rater agreement	Agreement on the type of decision	Agreement on the length of the exchange	Agreement on directive actions' sub-categories (order, instruction, proposal)	Agreement on other sub-categories of actions (non-verbal, soliloquy, comment)
Cohen's kappa coefficient	Unweighted Kappa	Kappa with Linear Weighting	Kappa with Quadratic Weighting	Unweighted Kappa
expert 1 vs expert	0.48 (*)	0.70 (**)	0,67 (**)	1 (***)

2				

Table 7 : Interrater agreement between judges on qualitative variables: 0.41 - 0.60: Moderate agreement (*); 0.61 - 0.80: Strong agreement (**); 0.81 - 1.00 : Almost perfect agreement (***)

The results of interrater agreement between the two expert judges (percentage agreements and Cohen's kappa coefficients) show primarily strong and very strong, agreements, except for "type of decision" where agreement was moderate.

5.2 - Interrater agreement between juries

Previous interrater agreements were on decisions made individually. We also compared decisions made in pairs, as the confrontation of subjectivities could make it possible to partially neutralize them, and to conform more closely to the established grids. We compared the decisions by a pair of non-expert judges with those by a pair of expert judges on the same dyad : the BH3 dyad.

We set up 3 juries (X, Y and Z), made up of non-expert pairs and composed of people aged 21 to 25. Jury X was a pair of men. Jury Y a pair of women. Jury Z mixed. Jury (alpha) was made up of two judges expert in the analysis model and constituted a reference.

Each jury was placed in a separate room and had unlimited time to re-transcribe the verbal conversations of the BH3 dyad using the audio recording, according to the previously described methods. They had the following resources available: a step-by-step guide to re-transcription, presentation and explanation grids for the different elements, decision support trees, detailed and didactic examples, a blank paper timeline and markers.
Participants were free to ask as many questions as they wished during the discovery phase. When they said they were ready, the observers started the audio recording and left the room. The sound was lateralized to improve voice distinction (the first participant BH3P1 was heard to the left of the sound output, and BH3P2 to the right). Juries could pause and leave the room at their discretion as long as they did not talk to others about the current experience.

After about 40 minutes of reading the transcription documents they had prepared, the juries took between 2h00 and 3h30 to model the exchange on paper. It should be noted that the BH3 dyad was chosen for modelling by the pair of experts (alpha jury) because it is dense, rather complex and exhaustive in terms of representation of the different components of the model.

Results

The results of the interrater agreement validation among juries are presented in Tables 8 and 9. We compared the results obtained by the 3 non-expert juries (jury X, Y and Z) with the reference alpha expert jury. The percentages agreements and Cohen's kappa coefficients were calculated between each combination of two juries, i.e. a total of 3 interrater agreement comparisons :

- jury X versus jury alpha,
- jury Y versus jury alpha,
- jury Z versus jury alpha.

Percentage agreement	% of common exchanges	% of common actors	% of common initiators of the exchange	% of common speech cuts	% of common interactions
X vs alpha	83,43 (**)	85.26 (**)	95.79 (***)	85.40 (**)	84.70 (**)
Y vs alpha	78,37 (*)	89.41 (***)	92.94 (***)	84.70 (**)	84.40 (**)
Z vs alpha	83,06 (**)	88.54 (**)	90.63 (***)	83.30 (**)	88.40 (**)
% agreement average	*81,62 (**)*	*87,74 (**)*	*93,12 (***)*	*84,47 (**)*	*85,80 (**)*

Table 8: Interrater agreement between juries for dichotomous variables: moderate concordance between 70 and 79% (*) / strong concordance between 80 and 89% (**) / very strong concordance >90% (***)

For most parameters, the % agreement was very high (>80%) between each of the 3 non-expert and the expert jury suggesting that agreement between juries is verified.

Interrater agreement	Agreement on the type of decision	Agreement on the length of the exchange	Agreement on directive actions' sub-categories (order, instruction, proposal)	Agreement on other sub-categories of actions (non-verbal, soliloquy, comment)
Cohen's kappa coefficient	Unweighted Kappa	Kappa with Linear Weighting	Kappa with Quadratic Weighting	Unweighted Kappa
X vs alpha	0,37	0,24	0,58 (*)	0,46 (*)
Y vs alpha	0,14 ( )	0,26	0,63 (**)	0,47 (*)
Z vs alpha	0,38	0,44 (*)	0,48 (*)	0,50 (*)
Average Cohen's kappa coefficient	*0,30*	*0,31*	*0,56 (*)*	*0,48 (*)*

Table 9: Interrater agreement between juries for qualitative variables: 0.0 - 0.20: Very low agreement ( ); 0.21 - 0.40: Low agreement; 0.41 - 0.60: Moderate agreement (*); 0.61 - 0.80: Strong agreement (**); 0.81 - 1.00 : Almost perfect agreement (***).

Results show that for the type of decision and the length of the exchange there was little or no agreement between expert and non-expert juries. For length of the exchange, this disagreement does not have a decisive impact on exchange typology but may reflect a difference in precision e.g., judges did not end the exchange in the same place because they aggregated two instructions or separated a single exchange into several. Conversely, concerning the type of directive and the type of other action, interrater agreements between juries were mostly moderate with one strong agreement.

6 - Discussion

The objective of this work was the formalization of a model to analyze conversations in dyad cooperation situations. Two points are essential in this model: 1- determining a typology to characterize the nature of conversational exchanges (in terms of type of exchange, final decision,

interaction, etc.) and 2- proposing a visual representation to illustrate the exchanges and their temporal dynamics.

In order to achieve this goal, we used different methods from the field of psychology, ranging from user-centred design to psychometric and an ecological approach to method validation. The design process (Fig. 2) begins with the development of a model and then with its validation using focus groups and card sorting sessions. Then the model is validated experimentally. The results are analyzed by several experts and the different points of view are compared by means of inter-rater measurements. This process allows the model to be validated in the analysis.

What motivated the development of this methodology is the observation that there is no satisfactory methodology for modelling conversational activity. Indeed, the existing methods are not easily usable and their manipulation is complex. Here we have a process for designing and validating a new analysis model adapted to a particular situation and accessible to non-expert experimenters.

To validate the model, we applied it to a dyad cooperation situation - the Tetris game - and choose to use a mixed methods approach. We performed two validation steps : a qualitative one to validate the categories of our typology and their wording, and a quantitative one to test the ease of use and reliability thanks to statistical analysis on our qualitative data.

The following characteristics of a conversation exchange were included in the model: performative, directive or non-directive type, type of decision, assent or dissent, the type of interaction, socio-emotional or task-related. The model considered the most relevant theories from the literature in order to have a theoretical framework for each of the categories of analysis model typology.

For the first validation, we refined the typology using qualitative methods derived from user-centered design (ISO 9241-210:2019, 2019; Zarour and Alharbi, 2017), namely focus group and card sorting sessions. These qualitative methods made it possible to measure the degree of usability of our model and to guarantee a consensus on the choice of categories and their wording. As illustrated in Table 2, this allowed defining the types of exchange precisely by clearly separating directive actions (order, instruction and proposal) from non-directive actions (soliloquy, commentary, non-verbal action). This first stage of validation also made it possible to enrich the typology by adapting theoretical names and categories to a concrete analysis situation. This showed that theoretical models may be far from field work and may need refinement by considering the users' point of view to adapt to a particular situation.

Concerning the second validation, we performed statistical analysis on our qualitative data to test reliability and degree of transferability of the analysis model, i.e. whether it could be used by people other than its designers and lead to similar results. We used Cohen's kappa coefficient as a concordance index, this allowed precise measurement of interrater agreement on qualitative variables. Since Cohen's kappa (1960) considers the theoretical proportion of "random" agreements, it is possible to measure the degree of true agreement between two raters based on the distribution of their responses (Santos, 2018).
We measured two types of interrater agreement: between two expert judges and between two juries, one composed of a pair of experts and the other of a pair of novices. These interrater

agreement validations allowed us to specify the conditions of use of our analysis model according to the expertise of the raters. Thus, an expert judge will be able to use the model alone whereas for novice juries it is preferable to be in pairs to obtain satisfactory results. In all cases, a training and an understanding of the typology of the exchanges and the graphical representation was necessary before using the model.

Without this quantitative arm to the study, we would have been left with inconclusive results on the reliability and degree of transferability of our model.

Using the mixed-method technique called joint display, we combined qualitative and quantitative results to find possible improvements. We compared some final graphical representations to capture and understand the dissonance and congruence between disagreeing judges. Although the analysis model was validated, the typology could be further improved, especially concerning the length of the exchanges and the type of final decision. The disagreements seen here did not have a decisive impact on the typology of exchanges but may reflect a difference in precision: judges may aggregate two directives or, on the contrary, detail an exchange into several. It would be interesting to adjust the transcription grid, either by making the calculation of length of the exchange more objective, or by modifying the type of final decision variable so that it is no longer dependent on the length of the exchange.

The analysis model detailed here allowed us to objectively characterize the dynamics within a dyad in a simple and experimental cooperation situation, namely a cooperative Tetris game. The model could likely also be used as an analytical framework in characterizing the emergence of social roles in a group dynamic such as leadership, followership, etc.

One of the strengths of this analytical model is the consideration of temporality, which allows observation of the dynamics of leadership within a dyad. The fluctuations and the eventual transitions of decision-making power are important and could be lost in a more global approach that did not consider the time variable. Similarly, the possibility of adding events in this model contextualizes exchanges and their associated fluctuations making it possible to observe whether leadership changes hands when the situation becomes complicated or after a failure. The qualifiers of interaction (positive or negative remarks) and the type of final decision allow determination of type of leadership and followership associated with the observed dyad.

It is quite possible to associate our analysis model with other tools such as personality tests.
For example, the Big Five Inventory test developed by John et al. (1991) combined with our model would make it possible to study the emergence of leadership. Authors such as Judge et al. (2002), for example, have used the Big Five Inventory and shown the link between the notion of leadership and the personality traits of extroversion, openness and awareness, making this type of personality test an interesting and relevant analytical tool for studying the emergence of leadership. Similarly, the desire for control scale developed by Burger and Cooper (1979) could be combined with our model. Burger (1990) explores the relationship between desire for control and interpersonal interaction style. In a study on the behavior of students with high and low desire for control during a structured interview, Dembroski et al. (1984) had already highlighted the tendency of individuals with a high desire for control to express themselves more strongly, with a more explosive and rapid intonation

and to be more competitive in their verbal interactions. Burger (1990) showed that people with a high desire for control can also adopt a reserved interaction style in order to control the information communicated. The link between the degree of desire for control and the style of interaction adopted seems relevant to an analysis of leadership dynamics.

7 - Conclusion and perspectives

Our model has so far only been applied to a dyad cooperation situation, in a controlled context and on a simple cognitive task. A next step is to model a cooperation situation on a more complex task with less clearly defined roles for each participant. Games designed as collaborative such as cooperative board games or escape games, could be a good support for experimenting with the application of the method to another task. If adaptation of the method to more complex interactions is possible, it could then be applied to other real-life situations.

Real situations of dyad cooperation are not lacking in teaching and learning contexts. Authors such as Johnson et al. (1990) and Slavin (1990) have shown that working in small groups with a common goal optimizes learning. In the area of learning team sports in school, authors such as Doise and Mugny (1997) and Gilly, Fraisse and Roux (1988) have studied the impact of exchanges between game sequences on the tactical skills developed. In these situations, two players must coordinate their actions in the game and cooperate in conversational exchanges in order to conceptualize their actions and develop tactical problem-solving strategies. It would be interesting to test our model with this type of real dyad cooperation.

The extension of the method to the modelling of conversational exchanges of more than two people seems more complex. The ACDC model would be suitable with some adjustments, such as e.g., adding categories for identity of the recipient(s). On the other hand, the proposed graphical representation is for the moment limited to the modelling of a dialogue within a dyad and will therefore have to be rethought if it is to be extended to larger groups.

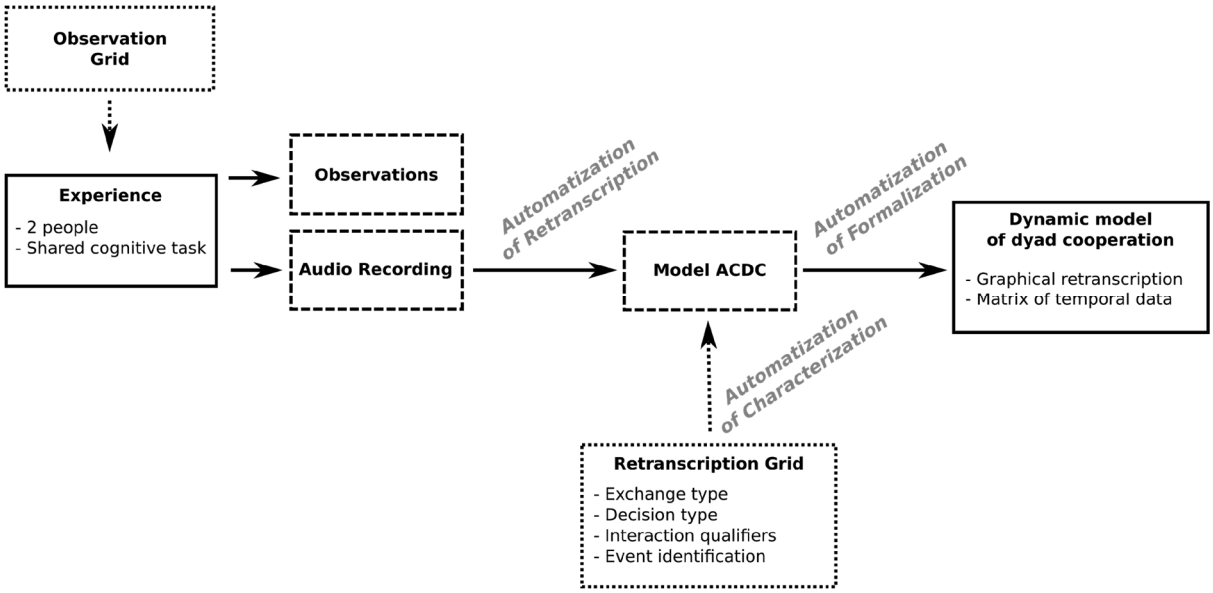

Fig. 7: Diagram describing the ACDC method with steps that can benefit from automation or semi-automation

In the longer term, we can envisage automating all or part of the process as illustrated in Fig. 7. The temporal visualization in chronological form could be directly generated by a software program from the data matrices. We could automate / semi-automate the modelling process by inputting the sound file and asking an artificial intelligence software program to cut out and characterize the exchanges on the basis of the proposed symbolism and according to rules imposed beforehand. Currently, the rules are understandable by a human, but there is probably still too much subjectivity to obtain a systematic result. The use of learning neural networks, supervised or not, could open interesting perspectives in the classification of exchanges. This could allow us to eventually optimize the model, but more importantly, it could perhaps shed light on variables common to certain leadership profiles that humans would not have identified.

In future research we will focus on two aspects, the transfer of the method from other situations and the automation of the different steps.

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Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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