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8 Characteristics of interaction and cooperation in immersive and non-immersive virtual environments

Carlo GALIMBERTI, Sabrina IGNAZI, Pietro VERCESI, and Giuseppe RIVA

Abstract. This research presents three studies that investigate the characteristics of the interaction and cooperation activities in immersive and non-immersive virtual environments. The first study explored the characteristics of the interaction during a cooperative task; the second one investigated the characteristics of the cooperation strategies used in the cooperative task; the final one verified if and how the level of immersion in the virtual environments influenced the performance and the characteristics of the interaction/cooperation. The results of the studies showed a substantial homogeneity between immersive and non-immersive VR environments. In both environments, partners produce a reciprocal influence on their actions and seem to be able to perceive their conjoint communicative work. However, the average time used to complete the task is significantly longer in the immersive phase instead of in the non-immersive one. Moreover, our experience showed that simulation sickness is a significant problem for the immersive experience.

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8.1 Characteristics of interaction and cooperation in immersive and non-immersive virtual environments

8.1.1 Introduction

Virtual Reality (VR) constitutes a three-dimensional interface that puts the interacting subject in a condition of active exchange with a world re-created via the computer. The possibility of not limiting the paradigm of interaction in a unidirectional sense represents the strong point of the new technology: man is not simply an external observer of pictures or one who passively experiences the reality created by the computer, but on the contrary may actively modify the three-dimensional world in which he is acting, in a condition of complete sensorial immersion [1, 2].

For these characteristics VR can be considered as the leading edge of a general evolution of present communication interfaces [3, 4]. But, what is a communication interface?

Biocca & Delaney [5] defined a communication interface as "the interaction of the physical media, codes and information with the sensorimotor channels of the user" (p. 59). Designers play a key role in defining the characteristics of this advanced communication interface. In order for a virtual environment to work the user has to have some idea about what the virtual reality system expects and can handle, and the environment has to incorporate some information about what the person's goals and behaviors are likely to be [6]. These two aspects, the user's "mental model" of the virtual reality system and the designer's "understanding" of the user, are just as much a part of the interface as its physical and sensory manifestations [7, 8].

However, understanding how to use virtual reality to support collaborative interaction presents a substantial challenge for the designers and users of this emerging technology. First, Virtual Environments (VEs) are designed to serve a purpose, so must be designed with intended users' tasks and goals explicitly considered [9]. Moreover, during the Internet experience the knowledge relevant to the goal should be distributed, and actions should be coordinated among the various actors. Particularly, to support collaborative activities VEs should provide task applicable information representation and communication tools embedded in the environment in which activities happen [10, 11].

Second, the possibility of negotiation, both of actions and of their meaning, has a key role in providing a satisfactory sense of cooperation. This is even truer for networked VEs where cooperation and collaboration are the key features of the experience. However, teams vary tremendously in their negotiation strategies as well as in their task achievement process [10].

Following this approach, it is rather complicated to study cooperation in VEs. Experts of the Computer Supported Cooperative Work area have tried to formalize and put in practice the structure of the human cooperation. But this approach failed when tried to model in an acceptable way the complexity of the situation and the variety of interests of the users.

Particularly, there are two basic difficulties in creating a suitable model for cooperation. The first difficulty lies in the ambiguity and unpredictableness typically present daily situations. Considering the world of experience as an open system, it soon becomes clear that it is impossible to foresee every type of situation which could be created in carrying out a series of tasks (a fixed mode if we want to build a suitable cooperation model). Another reason it is difficult to represent cooperation in a formal model is the basic diversity among the various points of views of the actors. "About rationale," says Gasser, "two agents cannot have identical representations… shared knowledge is impossible" [12]. Cooperation, according to Gasser, is simply a moment of

practical understanding because the actors are good at pragmatically tuning their own activities 'as if' they had common knowledge with other actors.

Mantovani [11] partially disagrees with this view: according to this author, "The actors manage to cooperate by combining the interpretative activity with the practical one, they can make plausible *inferences* about the *meaning* that they and their interlocutors give occasionally to the situations, which they change through their intervention. Simultaneously, they define, tentatively, in which world of principles both they and their interlocutors are moving" (p. 185).

In both visions the key content of communication is the interpretation of the situations which actors are involved in [13, 14]. So, the most effective way of clearing the meaning of messages is to connect them to a shared context of meaning. However, this is more difficult in VEs than in other computer-based activities. VEs forces individuals to deal with interface constraints and time delays, adding layers of complexity to an already-overwhelming set of social constructs.

The difficulty of managing negotiation has two consequences for the design of VEs [3, 15]:

- the only way to understand negotiation is by analyzing the subjects involved in the environment in which they operate. This means that the social context in which the Internet experience happens plays a crucial role [16];
- new processes and activities will develop during interactions which challenge and change the initial relationship between subject and context. So VEs have to be flexible enough to handle these changes without imposing constraints to the interaction [17].

This paper tries to understand the characteristics of cooperative activities in networked environments. In the research we used a specific form of networked environments - shared 3D virtual worlds (metaworlds) - in three different studies:

- in the first one we used the analysis of conversations to investigate the characteristics of the interaction during the cooperative task;
- in the second one we used the analysis of conversations to investigate the characteristics of the cooperation strategies used in the cooperative task;
- the final one analyzed how the level of immersion in the networked environments influenced the communication and the interaction process within the cooperative task.

The results are analyzed to identify the psychosocial roots used to support cooperation in a digital interactive communication.

8.2 The research project

8.2.1 The research plan

8.2.1.1 Setting

The experiment was conducted in the LICENT (Laboratory of Human Interaction and New Technologies) Virtual Reality Lab., Catholic University of Sacred Heart, Milan, Italy.

8.2.1.2 Setting Sample

The complete sample included 49 couples of university students, both male and female (see Table 8.1 for details) in the 20-28 age group (mean age for the 43 males: 24.2+/-1.5; mean age for the 55 females: 23.9+/-1.2). All the subjects in the sample had not used DOOM II or other first person 3D shooting videogames before the experiment.

Table 8.1 Breakdown of the overall sample (MM-male/male; FF-female/female; MF-male/female)

First phase	MM	MF	FF	Total
Immersive phase	14,3%	20,4%	18,4%	53,1%
Non immersive phase	12,2%	14,3%	20,4%	46,9%
Total	26,5% (13)	34,7% (17)	38,8% (19)	100,0%

8.2.1.3 Objective and Instruments

Objectives of the project were:

- to verify if cooperative activities in networked environments VEs are possible;
- if yes, to understand the characteristics of cooperative activities. We also tried to identify possible differences between *immersive* and *non immersive* virtual environments.

The cooperative process used for the research is the following: by moving freely in a three-dimensional maze (see Figure 8.1), each subject of the couple had to find a key - red for the first subject and blue for the second one.

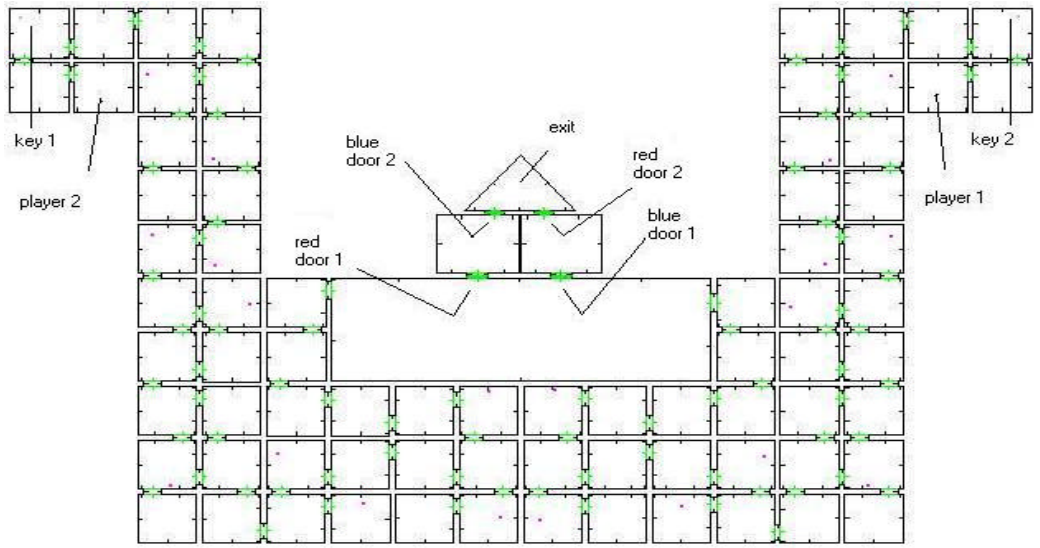

Figure 8.1 Basic maze structure. Starting point (*Player 1* and *2*); position of the keys (*Key 1* and *2*); *exit*. The smaller squares indicate the doors/passages.

After having found the right key, the subjects had to reach together the 'exit door'. No subject could reach the exit without the key found by the other one. So the couple was forced to cooperate for finding both keys.

The couples performed two consecutive phases separated by a brief pause; half of the couples were asked to do first the immersive phase and then the non immersive phase; the

other half of the sample first performed the non immersive phase, then the immersive one. To avoid the possible learning effect between the phases, we used two mazes, identical in the structure and positioning of the objects, but different in visual appearance.

For this experiment two versions of the 3D Maze were built: one for each phase (immersive - non-immersive). The *layout* of the maze remains unchanged in its structural features: shape/structure of the walls, arrangement of the objects in the rooms, position of the doors to allow a comparison between the two phases. Changes were made to the starting point of each player (and therefore to the directions they would follow), the colours of the maze walls and the types of objects.

The structure is specular: the two *players* start from the two opposite sides of the *maze*, following a semi-fixed route which does not allows many variations (see Figure 8.1).

In implementing the maze structure, we referred to existing literature on the subject of creating virtual environments and the problems encountered in using virtual *hardware*. In more detail, consideration was given to the difficulty of coordinating the movements of the head and eyes. To avoid this problem we used textures on walls and objects that were highly distinguishable from one another.

8.2.1.4 Experimental procedure

For each couple of subjects, chosen in a random manner, a standard execution procedure was used:

- Welcome and presentation of the VR system.
- Assignment of codes and filling out the experiment summary sheet (performed by the experimenters).
- The signature of the informed consent.
- Handing out of the experiment - Presentation of the *Samples*.
- Phase1 - First cooperative task in the maze. During the test the experimenter took care of possible technical problems and filled out the individuals' forms.
- Phase 2 - Second cooperative task in the maze with inverted level of immersion. During the test the experimenter took care of possible technical problems and filled out the individuals' forms.
- Dismantling and completion of the data.
- Thanks and greetings.

The total duration of the experiment was about one hour.

8.2.1.5 Methods

Given the peculiar aims of this research we used as framework for our analysis the Complementary Explorative Multilevel Data Analysis (CEMDA) that integrates qualitative and quantitative procedures [18]. CEMDA incorporates complementary use of both methods, depending on the particular research stage or the initial assumptions that need to be taken in consideration. As underlined by Sudweeks and Simoff [19], "the rationale is that the weakness of any single method… is balanced by the strengths of other methods… However, the qualitative and quantitative analyses are usually distinct, mutually exclusive component of the research… The result is an integrated view that narrowly focuses on a particular social phenomenon" (p. 37). Following this approach we collected the following data during the experiment:

- codes about the subjects, personal data and remarks by the experimenter.

- transcripts of the verbal interaction of the couple during the two phases of the experimental session.
- digital recording of the behavior of the subjects within the maze.

The obtained data were analyzed separately in three different Studies. The first and the second ones investigated the cooperative process through the analysis of the transcripts (analysis of conversations - qualitative method). The second one studied the differences in the dialogical productivity between the immersive and non-immersive environments through a statistical procedure (ANOVA - quantitative approach).

A preliminary analysis of how many couples could end the proposed collaborative task, was used to verify whether networked environments could support the formation of actual cooperative processes.

8.2.2 Description of hardware

Starting from the above rationale, we used a Thunder 650/C networked virtual reality system for the studies. The Thunder 650/C is composed by two Pentium III based VR system (650mhz, 128 mega RAM, graphic engine: Matrox MGA 400, 32Mb WRam).

We used a two-button mouse to provide an easy way of motion: pressing the left button the operator moves forward; the different rotations are produced by the movement of the mouse. In the immersive phase, however, the direction of the movement is given by the rotation of operator's head. For the immersive and non-immersive phases the following hardware was also used:

8.2.2.1 Immersive phase.

For the immersive phase we used two I-glasses head mounted displays (one for each subject) from Virtual I-O, USA. The I-glasses uses LCD technology (two active matrix colour LCD's) displaying 180000 pixels each. Virtual I-O has designed its I-glasses so that no optical adjustment at all is needed, aside from tightening a two ratchet knobs to adjust for the size of the wearer's head. There's enough "eye relief" (distance from the eye to the nearest lens) that it's possible to wear glasses under the head mounted display. The motion tracking is provided by an included gyroscopic tracker (Azimuth: ±180 degrees; Elevation: ±80 degrees, Refresh rate: 256Hz, Latency time: 38ms ± 2).

8.2.2.2 Non-immersive phase.

For the non-immersive phase we used two SVGA Compaq Plug and Play (VESA DDC) 14'' monitors (the resolution used, 640 x 480, is the same supported by the head mounted displays).

8.2.3 Description of software

As 3D engine for the shared virtual environment we used DOOM II, a first person 3D *shoot'-em-up* videogame, produced by ID-Software.

During the game the player can explore the 3D environment in the following ways: circular movement from left to right; forwards-backwards movement. To interact with the objects (weapons, keys, *bonus*) in the 3D environment the player just has move over them.

This software supports networked play (up to 4 users) through a simple null-modem connection. DOOM II also allows the recording the games (all the movements and actions performed by the players) thus allowing them to be examined in detail later.

The two 3D virtual mazes in the experiment were developed using three different editing programmes: Deep 97 (vers. Shareware); Doom Easy Edit 2; Windeu 32 vers. 5,25 beta3.

8.3 Is collaboration possible? A positive answer with some limits

The question of whether networked environments can support the formation of real cooperative processes was the first addressed in this paper. To verify this possibility we checked how many couples of our sample could end the proposed collaborative task.

Most of the couples (41 - 83,7%) of the sample managed to complete at least one phase; 63,3% of the sample (31 couples) completed both phases (Table 8.2).

We then analysed the couples that did not manage to complete even one phase (8 - 16,3%). 62,5% of them (5) broke off while were experiencing an immersive networked environment, the other ones (3 - 37,5%) during the non-immersive experience. In this situation the main reason was a drop in interest resulting in their leaving the experiment.

The main problem for the immersive experience was simulation sickness: in each leaving couple one of the subjects, usually the female one, experienced some form of side-effects. These side-effects, usually defined "simulator sickness" [20], were characterised by three classes of symptoms: ocular problems, such as eyestrain, blurred vision and fatigue; disorientation and balance disturbances; nausea. The experienced symptoms are similar to those which have been reported during and after exposures to simulators with wide field-of-view displays [21]. The higher sensibility of female subjects to simulation sickness in our sample is a common datum in literature. In fact, females tend to be more susceptible to VR side-effects than males [22].

Table 8.2 Outcome of the couples (n=49)

Phase	1ª immersive	1ª non immersive
At least first phase	40,8%	42,9%
First and second	38,8%	24,5%
The first one only	2,0%	18,4%
No phase	12,2%	4,1%

Generally, our empirical findings suggest that networked environments support the cooperation process. A detailed analysis of the characteristics of this process will be done in the following three Studies. However, the results also underline the need, for the researchers and for the users of immersive networked environment, of addressing the effects of simulation sickness.

Table 8.3 Percentage of couplet who finished/completed: both phases, only the first one or none.

Successful Phases	1° Immersive	1° Non Immersive	Total
First and second	62,1%	37,9%	100,0%
Only the first one	10,0%	90,0%	100,0%
No phase	75,0%	25,0%	100,0%

Although there is much potential for the use of immersive virtual reality environments, this problem has still limited their application. In different studies users have experienced side-effects, during and after exposure to virtual reality environments [23]. Specifically, exposure duration of less than 15 minutes to immersive virtual reality environments has

been shown to lead to significant incidences of nausea, disorientation and ocular problems [24].

8.4 Study 1: Characteristics of the cooperative process: conversation analysis of the interaction in shared environments

8.4.1 Objective and characteristics of the sample

The sample used was composed of 39 out of the 41 couples of subjects (79.6% of the original sample) who had completed at least the first phase (Table 8.4). Two couples were not in the final sample for problems with the records of their interactions.

The analysis of conversations was focussed on the structure of the interactions. In particular, main goal of this study was in to identify a series of characteristic sequences which could be considered "typical" of the cooperative process. The communicative exchanges were also analysed to identify:

- the exchanges in which the content was of an informative or collaborative nature;
- the exchanges expressing the relationship between the two subjects when one of them took the lead.
- the expressions which explain the position of the subjects in relation to the objects encountered along the path, the colour of the walls and the ability of mentally representing the environment in its specular structure.

Table 8.4 Characteristics of the sample according to the "sex" variable.

Immersive			**Non immersive**		
MM	**MF**	**FF**	**MM**	**MF**	**FF**
15,4% (6)	17,9% (7)	15,4% (6)	15,4% (6)	12,8% (5)	23,1% (9)
Total immersive on total Couples considered			**Total non immersive on total Couples considered**		
48,7% (19)			51,3% (20)		

8.4.2 Methodology

The sequence can be defined as a block of exchanges linked by a strong relationship of semantic and/or pragmatic coherence [25]. Hudelot [26] stated that the sequence is not well defined, which is difficult to limit at formal level. For this precise reason the distinction between the various sequences is done largely by intuition, producing different results according to the aspects that are chosen. In this specific case, to identify the sequences, we followed the same approach used in previous studies on negotiation [27].

The analysis of the interactions is concentrated specifically on four indices: 1) general information about the keys, wall and object colors; 2) spatial indications, with particular attention to the deixis; 3) collaborative exchanges; 4) the roles assumed by the two subjects in performing the task [28].

From a preliminary analysis of the conversations of the subjects in the two consecutive phases, a strong effect of habituation was noticed from the first to the second phase, due basically to three components:

- Familiarity with the game.
- Latent learning of the maze structure: in some subjects, an "instinctive" improvement of the individual performance was noticed.
- The subjects understood that the two mazes were conceived in the same way, and therefore, they no longer needed to negotiate the strategy to be used.

To eliminate the influence of the habituation process, we focussed our analysis of conversations on the first phase experienced by each couple. However, to check any possible change in the roles between the phases, we also decided to consider the interactions of the second phase (if reached).

8.4.3 General structure of the interaction

The first part of the interaction includes the first descriptive remarks exchanged by the speakers. The second part, which is more extensive and heterogeneous, includes the exchanges aimed at cooperation and solving the task. During this part the speakers become familiar with the environment, elaborating a cognitive map both through their direct experience and the information offered by the partner. Finally, the third part coincides with the end of the cooperation. This type of structure can be attributed to all the interactions taken into examination, although the proportion between the parts and their content can vary greatly. The first sequence opens usually with a brief description of the environment.

(43 IM)
G2,1(...) I'm in a wooden wall room.
G1,2 So am I (-) in a wooden wall room.

In the first sequence, just as it is normal when specifying the characteristics of a specific location, it is possible to highlight some specific features. The subjects, in this sample, find a bookcase almost immediately.

(C1 IM)
G2,1 Come in the next room (-) there should be the bookcase (.) right?
G1,2 I'm coming with pleasure (xxx).

The bookcase is a few rooms after the players' starting point and the keys have been placed in front of the furniture. When the study was handed out it was clearly specified that each player must collect the key of a certain colour and that therefore, it is never the first one which is encountered along the route.

(C42 NI)
G1,2 I've found a blue key and as it's the first I meet here I don't want pick it up
G2,2 Therefore you don't have to pick it up (.) 'cause I have the red key.

The end of the first sequence coincides with the entrance of the players in the second sector. At this point, in fact, they already reach certain conclusions. They understand that their key, and their partner, are in a zone of the maze which is similar to the one they have already left, situated elsewhere though. This hypothesis is confirmed by the description of the objects found along the route, different objects for each sector of the environment.

(C4 NI)
G1,56 Where are you?
G2,56 I'm in the wooden (-) I'm at the door (-) I'm where there are the rock and the wood, but you are not here.
G1,57 Sorry (.) don't move (-) are you halfway between wood and rock?
G2,57 Yes (-) I'm at the door.
G1,58 Ah no (.) then you must be close to another rock (-) (xxx) (.) all right (-) that's the reason way I can't find the key (.) we are talking about two different things.

The part of the maze in which the subjects pay more attention is surely the central part, where there are the exit doors.

(C1 IM)
G2,72 Excuse me (.) what are these doors (-) then (.) let's see (-) ah (.) I've found the exit doors.

The content of the central sequence is extremely varied. Typical themes are the description of the walls/objects and the hypotheses on the structure of the maze. Often the two players, after their meeting, progress together along the route that separates them from the missing keys.

(C21 IM)
G1,92 Do we go together?
G2,92 Yes (.) come with me.
G1,93 Let's go together (.) I bring you to the blue key and you bring me to the red one.

The last sequence includes the route from the key to the exit through the doors. The players, here, have crossed the entire environment. They know the sectors and the objects that appear, and they know where the doors are situated.

8.4.4 General information referring to the environment

Within the different conversations it was possible to distinguish between:

- simple monologues, during which one of the two speakers takes turns in speaking rather extensively providing extensive information;
- the alternation of interventions that are not very coherent among themselves, especially in terms of dialogue and real exchanges.

The turn that follows is an example of the first category: the speaker gives a long description of the walls and objects he encounters while he proceeds in the environment.

(C20 IM)
G1, 29
(xxx) I' m arrived (.) oh boys (.) that path (xxx) I must go back where is the blue wall (.) because there are no other ways (-) and you, you must go along the walls (.) in sequence you'll find a brown wall (.) the little wall (.) then the blue wall (.) red wall then and at his end you'll find the key at your right (.) the blue key (.) wher the bookcase is (.) (xxx) (.) the bookcase is so little (.) it's only one wall long.

The commitment of the speakers in taking so many turns in speaking seems to violate the basic general rule which says that they have to be pre-announced. In the case of a traditional conversation, in fact, such a behavior is considered a prevarication of one speaker on the other, who is not allowed to enter conversation. Here, the presence of such a phenomenon is mitigated by two considerations. The first one refers to the frequency which the speakers introduce the pauses in which the other interactor may begin to speak.

The second one concerns the particular task in which the two subjects are engaged. In fact, this needs the ability of putting at the partner's disposal the greatest amount of information possible.In this sense of a lack of intention is not reflected by the most 'exuberant' speaker but by the one who restricts his interventions to the bare minimum, inhibiting, in this way, the other partner's initiative.

The next level of analysis considers the interventions of the two speakers. While an exchange can be defined as the smallest dialogue unit, an intervention consists of a monologue-type unit emitted by a single speaker [25]. Although an intervention can be considered as a contribution by a speaker to an exchange, it is possible that a first intervention will not be followed by a second. The conversations under review often present interventions by a speaker in which exchanges are not satisfied by the other interactor.

(C1 IM)
G1,60 The other side is closed.
G2,60 The candelabrum with a green flame.
G1,61 Then (.) I think that there are two different sections (xxx)

In this example, the two speakers, in three turns, conduct a "two-some monologue". G1, is describing the room in which he finds himself. G2 is referring to the presence of a green flame candelabrum. Finally, G1, in his second intervention expresses his opinion, referring to his first intervention and not to the intervention from the other speaker. It is a well-acknowledged phenomenon, known as "connection by leaping" [29] usually typical in interviews. In current practice an interaction, composed of different apparently interconnected interventions, can be considered dysfunctional. However in the study such a behavior can in some way "support" the conversation. Speakers, in fact, are not engaged in a traditional interaction, which would call for both logical and dialogical coherence between the interventions. They are rather performing a problem solving task by trial and error, which, because of its unusual nature, puts the speakers in the position of establishing a common ground to conversation.

Following Clark and Schaefer [30] we can affirm that the two interactors are defining a common ground specifically suited for the situation they find themselves in. The commitment of the two speakers in solving the task and, indirectly, their degree of collaboration, cannot simply be inferred from the coherence of their interventions. Kerbrat-Orecchioni [25] although showing dialogic coherence as a basic requisite of dialogue, recognises to this kind of cooperative interaction the status of a gradual and ongoing phenomenon. When a question is posed, for instance, there is a whole series of intermediate possibilities between the reply that perfectly satisfies the question itself and the one that is clearly incoherent with it. In this sense it is useful to bring into the picture also the idea of conditional pertinence: once a statement is made, a system of expectations is created around the following statement. Going back to the previous example, it is greater in the case of directive speech acts rather than assertive ones. Thus the speakers, faced with a first assertive act, continue with a second one whose coherence with the previous one can be recognised in terms of its content and in relation to one's own particular situation. Following this analysis it is possible to identify a first cooperative strategy in which each

of the two players attempts to make himself useful to his partner immediately, simply by describing the environment encountered in the maze route.

8.4.5 Space/time indications

This category includes interventions in which the speakers explicitly refer to their position within the environment regarding the sector in which they find themselves, an information they infer from the colour of the walls or the objects they encounter.

> (C1 IM)
> G1,54 Listen (.) I am in the blue room (.) no excuse me (.) brown bricks with this green can.

Almost all the interactions examined showed a significant use of the temporal and spatial deixis. Deixis refers to the way in which languages code the parts of the context of speech and the communication event [31]. Deixis of place or of a spatial kind concerns the indication of the positions referring to the anchor points in a communication event. There are two basic ways of referring to objects: describing them or naming them on one side and placing them somewhere, on the other [32]. The positions can be indicated in relation to the other objects or fixed reference points.

> (C40 NI)
> G1,11 My god (.) I have two doors (.) one with a tree the other with a lamp (.) I am entering the one with the tree.

Or they can be specified compared to the actual position of the participants.

> (C1 IM)
> G1,121 There is where I met you and here there is the blue door and now I wait for you (.) I stay here in front of it.

The use of the adverb here in the previous example can be considered to be symbolic and can be explained as “a pragmatic spatial unit which includes the place where the speaker is situated at the time of the statement” [32]. The adverbs *here* and *there* can be conceived in terms of contrasts on a dimension of closeness/distance, starting from the place in which the speaker is situated. In this case, *here* indicates unequivocally the place in which the speaker finds himself at the time of the statement while *there* refers to a different point, probably not far away and however, visible from the point of observation. These adverbs, as the demonstrative pronouns *this, that*, are words with a purely spatial deixis value.

Lyons [32] on this same subject specifies that the demonstrative pronouns are organized according to a linear dimension of closeness/distance where this means "the object of an area near the place where the speaker finds himself at the time of the statement" and that "the object beyond the area close to the place where the speaker finds himself at the time of the statement". The verbs of motion are another combination of deittic elements: Italian uses coming vs. going to describe the direction of movement of the participants of the communication event.

> (C1 IM)
> G2,1 Come in the next room (-) there should be the bookcase (.) right?
> G1,2 I’m coming with pleasure (xxx).

In the first turn, G2 finds himself in a room and invites G1 to join him. G1, with his intervention, shows his movement in the direction of the speaker, or rather, is moving to the place in which the interlocutor finds himself at the time of the statement. The analysis of spatial deixis is more complex when the speaker is moving and it is possible to use temporal terms to refer to places where he is positioned.

(C1 IM)
G1,109 No (.) excuse me (.) the red doors were besides the blue ones (.) so I've to go back (.) right?

Levinson [31], in this regard, raises the question if the temporal or spatial deixis has a certain priority. According to Lyons [32] the spatial deixis has the priority over the temporal one, because the spatial deittics like this and that can be used in a temporal meaning.

(C40 NI)
G2,30 No (.) I'come back to a blue bricked room but I don't know whether it is the one I was before (.) you are still in the brown?

(C40 NI)
G1,29 I (xxx) brown bricks and an eye (.) I found another eye (.) I suppose hope it is not the one I saw before (.) but I believe it is not because it is in a different position in the room (.) no and anyway in this room (xxx) the exit.

In these two examples the adverb before shows both the precedence in time, as opposed to after, and in space. The speakers, in fact, refer at the same time to a situation which happened before, both from a temporal and spatial point of view. The objects and the rooms were encountered earlier in a different place to where they are at the time of the statement, and this was possible only thanks to the speakers' movements in the environment. According to Levinson [31] the spatial deixis always includes an implicit temporal deixis, while the contrary is not true.

8.4.6 Cooperative exchanges

The dialogic coherence is seen in our analysis as the main index of the real intention to collaborate. In the conversations under examination the dialogic coherence is shown by two behaviors:

- one of conversational nature dealing with the exchange of information,
- the other as a 'practical' intervention - the two subjects accompany each other to find the keys - which is however reflected in communication.

The coherence of the subsequent exchange is proven by the fact that all the speech acts are satisfied, and the conversation proceeds in a linear manner.

(C1 NI)
G2,14 And you, what did you find?
G1,15 Wall of steel (-) with fire.
G2,15 Fire and what colour is it?
G1,16 Yellow.
G2,16 Mine is green.

G1,17 Oh yes (.) there is a can with green fire (-) no it's not a can (-) yes it's a can.

Linear exchanges of this kind are not very common. More often, different information is intertwined and the subjects show great communication skills in following the direction taken by the conversation. The exchanges are usually focused on the route. What follows is an example of negotiation on the right direction to take to get to the key.

(C10 NI)
G1,62 Where are you?
G2,62 In the brown bricked room.
G1,63 Now you have to search for green.
G2,63 No for blue (-) no (.) wait.
G1,64 No (.) I think you have to search for the green.
G2,64 Green?
G1,65 Yes.
G2,65 Oh no (.) really? Now let's go and search for green.
G1,66 'cause the blue is linked to the one of the key.

The last phenomenon taken into account happens when the two subjects, on meeting, decide to continue together to collect the two keys. Regardless of the roles assumed by the two players, it is interesting to check how, during the movement, they ensure that they do not lose sight of each other, seeking eye contact besides actually conversing. What follows is a very simple example of this behavior. Here is G1 who supports the conversation, seeking contact with G2. This is probably resulting from his position in front of G2, who can see G1 while the contrary would require G1 to turn around.

(C21 IM)
G1,159 Yes (-) here it is (.) here (.) then are you here?
G2,159 Yes I'm.
G1,160 Are you behind me? Can you see me?
G2,160 Yes I can.

As a conclusion the conversations analyzed clearly show an intention to collaborate to solve the mutual objective. This intention is witnessed and sustained by a whole series of strategies which the speakers exchange information and try to maintain contact with one another.

8.4.7 The configuration of roles

During the analysis a series of conversational indices was identified which could register the different roles assumed by the subjects. Normally, during an interaction, one of the two players is faster, or reaches a series of conclusions first and is more skilled in developing a mental image of the environment. Often, this difference is translated into greater level of conversation by the subject who is more skilled and who, during the interaction, has more turns in speaking than the other speaker. At a pragmalinguistic level, moreover, the player who has more difficulty tends to perform directive speech acts used to induce the other player to supply more information. In the brief sequence that follows the dominant role is assumed by G2 who, already from turn 78, has started to supply indications on the route

that G1 must follow. In this first intervention G2 ensures that the other player sees him to better understand the information and to be able to follow him as requested in G2,79.

(C1 IM)
G2,78 Well (.) now I tell you where you have to go (-) then (-) can you see me?
G1,79 Yes I can.
G2,79 Follow me (.) can you see a door over there?
G1,80 Wait (.) don't go too fast (.) yes go.
G2,80 Well (.) these are the doors we have to get out.
G1,81 Ah.
G2,81 Well (.) you see over there is a door.
G1,82 Yes.
G2,82 You have to go through it and look for the blue brick area and the red one and when you arrive there you'll find the key.
G1,83 OK fine (.) you go in the opposite direction,
G2,83 I go the opposite direction.
G1,84 And then we meet here (-) it's non easy.
G2,84 And then we meet here coming from the opposite direction.

The next sequence is drawn from the second phase of the study by the same couple. In this example, it is clear that the roles of the subjects didn't change in moving from one phase to the next. The collaboration in the actual situation is more difficult. In fact the two subjects no longer find themselves in each other's presence and the directions that G1 asks to G2 must also bear in mind the movement of G1 in space and therefore the direction he is following. The first two turns show that G2, although not leaving his leading role, is having problems. G1, in fact, asks for some information three times, as shown by the long pauses during G1,35. At first, he simply expresses his perplexity. Then his request for help becomes more explicit, although remaining generic. In the end, he turns to G2 with a very specific question.

(C1 NI)
G1,35 Damn! (.) I don't remember if I am coming back or going on (-) I need some help (-) wait (.)
G2,35 Yes (.) I am in the steel area and I'm lost, me too.
G1,36 Look (xxx) if you where in the steel and there was the blue,
G2,36 No (.)you find the blue before and then the steel.
G1,37 But to go to the very centre of the maze?
G2,37 Then (.) if you go to the central part you find the steel before and then the blue area (.) if you come back you are likely to,
G1,38 I am going to the beginning of your maze.
G2,38 So you should find the steel after the blue.
G1,39 Ah.
G2,39 Now the blue and then the steel.
G1,40 Well and so I let the blue behind me and I am in the steel.
G2,40 Yes yes yes you are in the steel.

The two previous examples show how the same subject can have the leading role in both phases and for the entire interaction. However, not all the conversations are structured in such a rigid way and sometimes one of the two players is more skilled in carrying out a certain phase rather than another, meaning a complete reversal of their positions. In this

regard, the brief exchange that follows not only explains such a phenomenon but it shows that the two subjects were aware of this fact.

(C10 NI)
G1,28 I'm starting twisting on me.
G2,28 If you need it I can come and help you and bring you back.
G1,29 Yes (.) as usual .
G2,29 No (.) you too did bring me for a while eh,

The configuration of turns of this type of interaction is not static, but tend to be a constantly changing phenomenon. Although sometimes one of the two players was more skilled than the other, this is not always true and often the roles are reversed different times during the interaction.

8.5 Study 2: Characteristics of the cooperative process: conversation analysis of the interaction in shared environments

8.5.1 Characteristics of the sample

As in the previous study the sample was composed of 39 couples of subjects who had completed at least the first phase (Table 8.4). To reduce the influence of the habituation process, we focussed our analysis of conversations on the first phase experienced by each couple. However, to check any possible change in the roles between the phases, we also decided to consider the interactions of the second phase (if reached).

8.5.2 Objective and methodology

We noticed from the transcriptions produced in the first study, that in the examined interactions the cooperation process occurred mainly in two situations:

- when the subjects met for the first time (CO1): after the meeting they tried to sum up the data acquired and agreed a strategy for the search of the keys.
- when they met in front of the doors after finding both the keys (CO2): the players began to negotiate a strategy for opening the external doors at first, and then the internal ones.

This second study aims at analysing, using Content Analysis and the Analysis of Conversations, the structure of interactions to individuate common features of cooperation in the Cooperative Parts (CO1 and CO2) considered. To identify the CO1 and CO2 sequences, we followed the same approach used in previous studies on negotiation As in the first study the sequence can be defined as a block of exchanges linked by a strong relationship of semantic and/or pragmatic coherence [25].

8.5.3 Results

From the analysis three conversational cooperative *microstrategies* [28] have been isolated:

1) ASSOCIATION (A): the first subject proposes a possible solution that he thinks suitable to solve the problem. The partner accepts this strategy and uses it as starting point for further reasoning, bringing new contributions that *do not clash* with the previous ones.

Example 1: CO1-IM.

G2, 79 follow me, do you see there's a door over there?
G1, 80 wait, don't go too fast, yes, go
G2, 80 so these are the exit doors
G1, 81 oh
G2, 81 you see, there's a door over there
G1, 82 yes
G2, 82 you must go there and look for the area with blue bricks and red bricks and when you reach the red bricks you'll find the key
G1, 83 all right, take the opposite direction...
G2, 83 I'll take the other direction
G1, 84 and we'll meet here again... it's easier said than done!
G1, 84 and we'll meet here again from the opposite direction
G1, 85 tell me
G2, 85 take that direction and I'll pass from here

G1 proposes the strategy and G2, *after* considering the details, accepts G2,82 in G1,83 and in turn proposing G2 to take the other direction. This passage is a still more evident example of association cooperative *microstrategy*:

Example 2: CO1-NI

G1, 26 we met at last
G2, 26 Hi
G1, 27 Here we are
G2, 27 so I have to take the opposite direction
G1, 28 I'm taking yours then
G2, 28 yes

2) NEGOTIATION (N): the different starting positions are compared and one of the two parts conforms itself to the solution proposed by the other.

Example 3: CO1 IM

G1, 40 you're over there
G2, 40 hi, there are the doors...
G1, 41 we found a door....
G1,42 it is blue
G2, 42 ...it is blue
G1, 43 here it is
G2, 43 here it is
G1, 44 (...)
G2, 44 yes, there's the red door behind you, go
G1, 45 here it is (...)
G2, 45 Are you going on?
G1, 46 where are we going?

G2, 46 I don't know
G1, 47 what did you find in your area?
G2, 47 more or less the same things you saw
G1, 48 shall we take this direction? shall we continue together or...
G2, 48 why don't we exchange/swap directions? I'll take yours and you'll take mine
G1, 49 so we would find, we already found them at the beginning of the game, wait, you should, you should try to turn and it seems to me that the key was in the brown, wooden scratched walls
G2, 49 you must come back too...
G1, 50 where was your key?
G2, 50 my key was in the wooden walls at the beginning, the one I mentioned, can you remember?
G1, 51 mm
G2, 51 at least it seems to me (...), wood, I think

Example 4: CO2-NI

G1, 35 all right
G2, 35 here you are (...) you're beautiful, I can see you, shall we follow this direction, can you see me?
G1, 36 no, but I think you should take my direction to get to the key and I'll take your direction... that's right, in fact I see now the green pillars If I'm not wrong
G2, 36 yes, the green pillars in the beige wall
G1, 37 that's right
G2, 37 I'm getting into the grey stones
G1, 38 yes, it's right, the two doors are there
G2, 38 there are two doors, I can see them, I see the doors but the keys are not there
G1, 39 no, you must reach the area I'm coming from, go through a green area, then a beige area... did you have seen the red torches before?
G2, 39 yes

3) DOMINANCE (D): one of the two subjects clearly prevails over the other. Dominance has two patterns:

- the person who decides, *forces* his partner to follow the strategy he proposes without giving any explanation
- the second subject accepts the suggested strategy, verbally expressing his total inability to solve the problem, thus relying on the other.

Example 5: CO1-NI

G1, 67 Hi
G2, 67 let's take this direction
G1, 68 take me out
G2, 68 just a moment, the keys, where did you come from? why did you have my key and I had yours?
G1, 69 turn and look at me... can you see me? no, let's take that direction to go out...
G2, 69 no, Chiara, Chiara, listen, we are coming from opposite directions
G1, 70 yes

G2, 70 so we must now take opposite direction, I have to take your direction, in my opinion, to get to my key, and you must take the direction I was coming from
G1, 71 is that right?
G2, 71 mhh
G1, 72 .....
G2, 72 yes, and remember, is that right?
G1, 73 I don't know
G2, 73 well, let's have a try and remember... I know where the doors are
G1, 74 let's go then...
G2, 74 grey walls, let's go, take the other direction
G1, 75 which direction?
G2, 75 the opposite of the direction you were coming from

After presenting the three strategies, we codified the different interaction to calculate how many times the sample used every strategy employed (see Table 8.5).

Table 8.5 Percentage of Microstrategy used during the Cooperative Parts (CO1 e CO2)

Microstrategy used	*CO1 Cooperative part/Phase/Level of Immersion*		*CO2 Cooperative part/Phase/Level of Immersion*
	CO1 (1st Phase Immersive)	->	CO2 (1st Phase Immersive)
ASSOCIATION	63,16%		68,42%
NEGOTIATION	21,05%		21,05%
DOMINANCE	15,79%		10,53%
TOTAL	100,00% (19)		100,00% (19)
	CO1 (1st Non-immersive)	->	CO2 (1st Phase Non-immersive)
ASSOCIATION	50,00%		70,00%
NEGOTIATION	30,00%		25,00%
DOMINANCE	20,00%		5,00%
TOTAL	100,00%		100,00%
	CO1 (indipendently from level of immersion)	->	CO2 (indipendently from level of immersion)
ASSOCIATION	56,41%		69,23%
NEGOTIATION	25,64%		23,08%
DOMINANCE	17,95%		7,69%
TOTAL	100,00% (39)		100,00% (39)

If we check Table 8.5 we can verify that *Association* is the favourite strategy both in CO1 and in CO2 (in this case, the use of *Association* strategy is a little higher): the subjects listen to the other's proposal, respecting his/her experience in terms of/as being the result of a greater knowledge of the labyrinth. This choice is essentially due to two reasons: an "economic" one (finding an agreement on the *modus operandi* saves time), and a "conversational" and "cooperative" one (keeping in touch helps reaching the main aim).

The reduced importance of the *Dominance* and "*Negotiation* strategies, seems to underline the strong cooperative nature of the task (less time devoted to discussion means more time to devote to the exploration of the labyrinth).

Also interesting is the influence of the level of immersion on the cooperation strategy. The data show that in CO1 we have a significant reduction in the choice of the Association strategy counterbalanced by an increase in the *Dominance* and in the *Negotiation* ones. The influence of the level of immersion is not significant in CO2.

We also verified whether the subjects who used the *Association* (the most used) strategy in the CO1 also used it in CO2 (Tables 8.7, 8.8, 8.9). In general the sample maintained in CO2 the strategy previously chosen, independently from the level of immersion: percentages of conservation of strategy A are respectively 75% (IM) and 80% (NI).

Table 8.6 Changes of strategy from CO1 to CO2 (only first phase – Immersive VR - n. 19)

First Phase: Immersive	*From Association in CO1 to Association in CO2*	*From Association in CO1 to Negotiation in CO2*	*From Association in CO1 to Dominance in CO2*	*Total* %
ASSOCIATION (A)	75,00%	16,67%	8,33%	100,00
	From Negotiation to Association	*From Negotiation to Negotiation*	*From Negotiation to Dominance*	*Total* %
NEGOTIATION (N)	50,00%	50,00%	0,00%	100,00
	From Dominance to Association	*From Dominance to Negotiation*	*From Dominance to Dominance*	*Total* %
DOMINANCE (D)	66,67%	0,00%	33,33%	100,00

Table 8.7 Changes of strategy from CO1 to CO2 (only first phase – Non Immersive VR - n. 20)

First Phase Non-Immersive	*From Association in CO1 to Association in CO2*	*From Association in CO1 to Negotiation in CO2*	*From Association in CO1 to Dominance in CO2*	*Total* %
ASSOCIATION (A)	80,00%	20,00%	0,00%	100,00
	From Negotiation to Association	*From Negotiation to Negotiation*	*From Negotiation to Dominance*	*Total* %
NEGOTIATION (N)	50,00%	33,33%	16,67%	100,00
	From Dominance to Association	*From Dominance to Negotiation*	*From Dominance to Dominance*	*Total* %
DOMINANCE (D)	75,00%	25,00%	0,00%	100,00

Table 8.8 Changes of strategy from CO1 to CO2 (only first phase - n. 39)

Independently from level of immersion	*From Association in CO1 to Association in CO2*	*From Association in CO1 to Negotiation in CO2*	*From Association in CO1 to Dominance in CO2*	*Total* %
ASSOCIATION (A)	77,27%	18,18%	4,55%	100,00
	From Negotiation to Association	*From Negotiation to Negotiation*	*From Negotiation to Dominance*	*Total* %
NEGOTIATION (N)	50,00%	40,00%	10,00%	100,00
	From Dominance to Association	*From Dominance to Negotiation*	*From Dominance to Dominance*	*Total* %
DOMINANCE (D)	71,43%	14,29%	14,29%	100,00

8.6 Study 3: The influence of the level of immersion on the communication and the interaction process

8.6.1 Objective and characteristics of the sample

As in the previous study the sample was composed of 39 couples of subjects who had completed at least the first phase (Table 8.4). The Main goal of Study 2 was to verify if a significant change in the dialogical productivity (turns in speaking) happened between the immersive *and* non-immersive *phases.*

8.6.2 Methodology

On a preliminary basis, we divided each of the 39 transcriptions of the verbal comments made by the couple during the first phase into six parts (PA), three of which referred to the turns in speaking of the first player (G1), three referring to the second one (G2).The single PAs included respectively:

PART 1 *(P1): P1 included the route from the moment the subjects "enter" the maze, to they arrive to the central part (where the doors are situated).*
PART 2 *(P2): P2 includes the route from the doors to the required key (on the opposite side of the maze).*
PART 3 *(P3): P3 includes the route from the key back to the doors. The players had to follow all three PAs* at least *once.*

8.6.3 Results

Objective 1: verifying if there are significant differences in the time that took the couples to get out of the maze with reference to:

- Order of presentation (First phase/Second phase);
- Level of immersivity.

Conclusion: there is a significant difference (Sig.=.001; df =1; p =.05) in the time used to get to the end of the maze regarding the order of presentation. Specifically, the average time used is significantly longer in the first presentation instead of in the second one (learning process).

There is a significant difference in the time used to reach the end of the maze with reference to the type of immersivity. Particularly, the average time used is significantly longer in the immersive phase instead of in the non-immersive one.

There is a quite significant interaction (Sig.=.089; df = 1; p =.05) between the two independent variables (order of presentation and level of immersivity). In particular, the time necessary to get to the end of the maze is significantly shorter in the phase of immersion, when the couple tests the phase of non-immersivity first (learning process, from immersivity to non-immersivity).

The simple survey of the time used doesn't allow to estimate the differences in the communicating process. Therefore, we have proceeded to further series of analysis:

Objective 2: verifying if there are significant differences between the immersive and non-immersive situation with reference to the inducement of the activity of speaking. The comparison is made using an index that expresses the relation between time of speaking and total time of the performance. The relation "dialogue over the totality" expresses a

measure free from the temporal variations of performance among the couples on the basis of the hypothesis that anyhow there is a relation between word and action, between speaking(recording) and time of decision.
Conclusion: the difference immersive/non-immersive has no influence on the determination of the percentage of time of speaking, calculated on the overall time of the test (coherence with substantial homogeneity).

Objective 3: verifying if there are significant differences between the first and the second phase (when the first one is immersive) regarding the activity of speaking. The comparison is made using an index that expresses the relation between time of speaking and total time of the performance. The relation "dialogue over the totality" expresses a measure free from the temporal variations of performance of the same couple between the two tests on the basis of the hypothesis that anyhow there is a relation between word and action, between speaking (recording) and time of decision.
Conclusion: when the first test is immersive, there is no significant difference between time of speaking of the first phase and time of speaking of the second one (we suppose the exclusion of the effect of getting used to).

Objective 4: verifying if there are significant differences between first and second phase (when the first one is non-immersive) regarding the inducement of the word activity. The comparison is made using an index that expresses the relation between time of speaking and total time of the performance. The relation "dialogue over the totality" expresses a measure free from the temporal variations of performance of the same couple between the two tests on the basis of the hypothesis that anyhow there is a relation between word and action, between speaking (recording) and time of decision.
Conclusion: when the first test is non-immersive, there is a significant difference (Sig. 0,26; p = .05) between time of speaking of the first phase and time of speaking of the second one (in the immersive phase they talk less: 0,64 VS 0,49); this fact shows that starting with the non-immersive phase, the subjects have a better perception of the structure of the environment. This hypothesis has to be examined more closely.

Objective 5: verifying if there are significant differences between the number of turns of speaking produced by every single subject in each of the three parts of the maze. Particularly, we tried to verify if the turns of speaking were influenced by the level of immersivity (immersive/non-immersive), by the order of presentation (First phase-Second phase) and by the interaction of the two variables.
Conclusion: A) There is a significant difference between the number of turns of speaking produced by every single subject in the three parts. Specifically, the average of the turns of speaking produced in the First Part (Average PA1= 40,76) is more than the double of the turns of speaking produced in the other two parts (Average PA2= 18,56 - Average PA3= 16,1). So, It seems confirmed the hypothesis that the subjects interact using the first part of the way both to get used to the new environment and to co-construct a common ground *to be based on for the following conversations, also in absence of physical co-presence.* B) There is a significant difference (Sig.=.02; p=.05) between the number of turns of speaking produced by every single subject in the three parts, with reference to the order of presentation. In particular, apart from the parts taken into consideration, the number of turns in speaking of the first phase is significantly greater than that of the second phase.
Finally, there is no significant difference between the number of turns of speaking produced by every single subject in the three parts. Particularly, apart from the parts taken into consideration, the number of turns of speaking of the immersive mode is always greater than that of the non-immersive mode, even if it is not significant. However, the

analysis of the statistical power (0,237) let us suppose that the lack of significance should be resulting from the limited size of the sample.

8.7 Conclusions

In this chapter we tried to reach two different goals:

- to verify if cooperative activities in networked virtual environments are possible;
- if yes, to identify the characteristics of the cooperation process. We also tried to identify possible differences between immersive and non immersive virtual environments.

We used as framework for our analysis the Complementary Explorative Multilevel Data Analysis (CEMDA) that integrates qualitative and quantitative procedures [18]. In particular, the obtained data were analyzed separately in three different Studies:

- Study 1 investigated the cooperative process by means of the analysis of the transcripts of the verbal interaction of different couples (analysis of conversations - qualitative method);
- Study 2 investigated the characteristics of the cooperation strategies used in the cooperative task;
- Study 3 analyzed the differences in the dialogical productivity between the immersive and non-immersive environments by means of a statistical procedure (ANOVA - quantitative approach).

The question of whether networked VEs can support the formation of real cooperative processes was the first addressed in this paper. To verify this possibility we checked how many couples of our sample could end the proposed collaborative task: most of the couples (41 - 83,7%) of the sample managed to complete at least one phase; 63,3% of the sample (31 couples) completed both phases. These empirical findings can be interpreted as an indication that in networked environments cooperation is possible even if individuals have to deal with interface constraints and limited interaction.

However, the results of Study 1 clearly stated that the couple has to tune its communicative approach to the characteristics of the experienced environment. For example, simple monologues, in which one of the two speakers takes turns in speaking rather extensively providing extensive information, are very common. If in traditional conversations, we can consider such a behavior a prevarication of one speaker on the other, in this situation simple monologues "support" the conversation: the specific collaborative task calls for the ability of putting at the partner's disposal the greatest amount of information possible.

Other characteristic of the specific communicative approach is a significant use of the temporal and spatial deixis. As a conclusion the conversations analyzed clearly show an intention to collaborate to solve the mutual objective. As showed in the second study, this intention is witnessed and sustained by specific strategies – Association, Negotiation and Dominance. Using them the speakers exchange information and try to successfully reach their common goal.

On the basis of the results of the studies, both quantitative and qualitative analysis showed a substantial homogeneity between immersive and non-immersive VR environments. In both environments, partners produce a reciprocal influence on their actions and seem to be able to perceive their conjoint communicative work. However, the

average time used to complete the task is significantly longer in the immersive phase instead of in the non-immersive one. Moreover, our experience showed that simulation sickness is a significant problem for the immersive experience: in each leaving couple one of the subjects, usually the female one, experienced some form of side-effects. These side-effects were characterised by three classes of symptoms: ocular problems, such as eyestrain, blurred vision and fatigue; disorientation and balance disturbances; nausea. The experienced symptoms are similar to those which have been reported during and after exposures to simulators with wide field-of-view displays [21]. The higher sensibility of female subjects to simulation sickness in our sample is a common datum in literature. In fact, females tend to be more susceptible to VR side-effects than males [22].

In the end, our empirical findings suggest that networked environments can support the cooperation process. The way the description of the environment and space and time indications are shared, the co-construction of roles, and the characteristics of the exchanges, are examples of how social interaction can be mastered in virtual environments. We can consider them paradigm of cooperative action facing complex tasks. On the basis of results we can argue that studies in this field are worthwhile and useful to reach a sufficient knowledge about ways to control and master complexity of interaction in virtual environments.

However, the results also underline the need, for the researchers and for the users of immersive networked environment, of addressing the effects of simulation sickness. Although there is much potential for the use of immersive virtual reality environments, this problem is still limiting their real-life applications.

8.8 Acknowledgment

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8.9 Appendix: transcription codes

In the transcriptions the capital letter followed by a full stop indicates the name of the subjects, which is omitted for confidential reasons.

* o # (in both turns)	start of a superimposition
+ o / (in both turns)	end of a superimposition
(.)	pauses up to 2"
(-)	pauses between 2" and 5"
,	slightly raised intonation
?	interrogative intonation
.	ending or downward intonation
x-	incomplete words
(xxx)	incomprehensible words
(word)	uncertain interpretations
(...)	omission

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