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The Users' Avatars Nonverbal Interaction in Collaborative Virtual Environments for Learning

Adriana Peña Pérez Negrón[1], Raúl A. Aguilar[2] and Luis A. Casillas[1]
[1]*CUCEI-Universidad de Guadalajara*
[2]*Universidad Autónoma de Yucatán-Mathematics School*
Mexico

1. Introduction

In a Collaborative Virtual Environment (CVE) for learning, an automatic analysis of collaborative interaction is helpful, either for a human or a virtual tutor, in a number of ways: to personalize or adapt the learning activity, to supervise the apprentices' progress, to scaffold learners or to track the students' involvement, among others. However, this monitoring task is a challenge that demands to understand and assess the interaction in a computational mode.

In real life, when people interact to carry out a collaborative goal, they tend to communicate exclusively in terms that facilitate the task achievement; this communication goes through verbal and nonverbal channels. In multiuser computer scenarios, the graphical representation of the user, his/her avatar, is his/her means to interact with others and it comprises the means to display nonverbal cues as gaze direction or pointing.

Particularly in a computer environment with visual feedback for interaction, collaborative interaction analysis should not be based only on dialogue, but also on the participants' nonverbal communication (NVC) where the interlocutor's answer can be an action or a gesture.

Human nonverbal behavior has been broadly studied, but as Knapp and Hall pointed out on their well-known book (2007): "*…the nonverbal cues sent in the form of computer-generated visuals will challenge the study of nonverbal communication in ways never envisioned*".

Within this context, in a CVE each user action can be evaluated, in such a way that his/her nonverbal behavior represents a powerful resource for collaborative interaction analyses.

On the other hand, virtual tutors are mainly intended for guiding and/or supervising the training task, that is, they are task-oriented rather than oriented to facilitate collaboration.

With the aim to conduct automatic analyses intended to facilitate collaboration in small groups, the interpretation of the users' avatars nonverbal interaction during collaboration in CVEs for learning is here discussed. This scheme was formulated based on a NVC literature review in both, face-to-face and Virtual Environments (VE). In addition, an empirical study conducted to understand the potential of this monitoring type based on nonverbal behavior is presented.

1.1 Collaborative virtual environments for learning

Advances on technology, engineering, and instruction have enabled to diversify education and training support computer systems −see Table 1. Initially, the development of this kind of systems adopted the Computer Aided Instruction paradigm and was subsequently refined with Artificial Intelligence techniques implemented in the Computer Aided Intelligent Instruction paradigm. From the viewpoint of Artificial Intelligence, systems have been developed based on two rather divergent instructional approaches: Intelligent Tutoring Systems and Learning Environments (Aguilar, et al., 2010).

Computer Supported Collaborative Learning (CSCL) is probable the last of the paradigms emerged in the late nineteenth century. Koschmann (1996) referred to it as associated with instructional technology: "*This developing paradigm, for which the acronym CSCL has been coined, focuses on the use of technology as a mediational tool within collaborative methods of instruction*".

	Technology	Engineering	Instruction
T	Mainframes	Monolithic Programming	Behavioral Approach
I	Personal Computers	Structured Paradigm	Cognitive Approach
M	Networks & Peripheral Devices	Object Oriented Paradigm	Constructivist Approach
E	Virtual Reality	Agents Paradigm	Collaborative Learning Approach

Table 1. Advances on Technology, Engineering and Instruction

CSCL basis is the Socio-Constructivism theory, in which core idea is that human knowledge is constructed upon the foundation of previous learning and within the society. People, as social creatures, are highly influenced by the interaction with their socio-cultural environment, in such a way that this interaction contributes to the formation of the individuals.

CVEs for learning, the computer systems developed under the CSCL paradigm, can be described as a conceptual space in which a user contacts or interacts, in possibly different time and space conditions, with other users or their representation, or with elements of the environment such as data or objects. Thinking in CVEs in this way includes a conceptual asynchronous character that Churchill & Snowdon (1998) did not take into account.

According with the interface offered to the user, CVEs could be classified as:

- One-dimensional environments – based on text or text in combination with some symbols (e.g. emoticons).
- Two-dimensional environments – based on text and complemented with figures (e.g. comics).

- Three-dimensional (3D) environments – also known as Virtual Reality (VR) environments.

However, nowadays it is hard to imagine a multi-user VE without a graphical representation.

VR environments offer to their users different immersion degrees covering a wide range of possibilities that goes from the less immersive systems using only traditional desktop devices such as keyboard, mouse and monitor, to the highly immersive that use VR specific devices such as head-mounted displays (HMD), data gloves, or the CAVE™ .

The intend in using a CVE for instruction is to promote particular forms of interaction among the students inside the environment, by means of creating, encouraging, or enriching situations that would trigger learning mechanisms in the way Dillenbourg (1999) proposed.

CVEs provide the learner with a diversified set of computational features as well as a powerful context for learning in which time, scale and physics can be controlled; where participants can get new capabilities such as the ability to fly, or to observe the environment from different perspectives as an object or with any other virtual embodiment.

CVEs offer a space that brings remote people and remote objects together into a spatial and social proximity creating a natural interaction, which allows better communication awareness (Wolff et al., 2005) and where users are likely to be engaged in interaction with the virtual world and with other inhabitants through verbal and nonverbal channels. These characteristics make them a proper scenario for knowledge construction, concurrent with the socio-constructivist theory, as well as a proper tool for training in socio-technical tasks (e.g. in coordinated situation such as rescue operations or enterprise logistic).

For the multiuser condition, 3D CVEs represent a communication technology on their own right due to its highly visual and interactive interface character. They offer a learning context that may allow the trainees to practice skills and abilities, and to get knowledge in a situation that approximates the conditions under which they will be used in real life, but using a safe and flexible environment where materials do not break or wear out.

CVEs can be used to train one or more students in the execution of a certain task, mostly in situations in which training in the real environments is either impossible or undesirable because it is costly or dangerous.

1.2 Intelligent CVEs

In the Computer Aided Intelligent Instruction paradigm, there is a growing interest on the research aim of knowledge such as Intelligent Virtual Environments (IVE). VEs may incorporate in different degrees, characteristics of learning environments through an Intelligent Tutoring Systems (ITS). Where the intelligence skills generally fall into a Pedagogical Virtual Agent (PVA) to engage and motivate students along their learning process.

The traditional architecture for the ITS consists of four modules: the expert or domain module, containing the information to be taught; the student module, which maintains individualized information of the students; the tutoring module, which provides a model of the teaching process; and, the interactions with the learner controlled by the communication module. The ITS architecture adapted for an Intelligent Collaborative Virtual Environment (ICVE) (Aguilar et al., 2010) is shown in Figure 1.

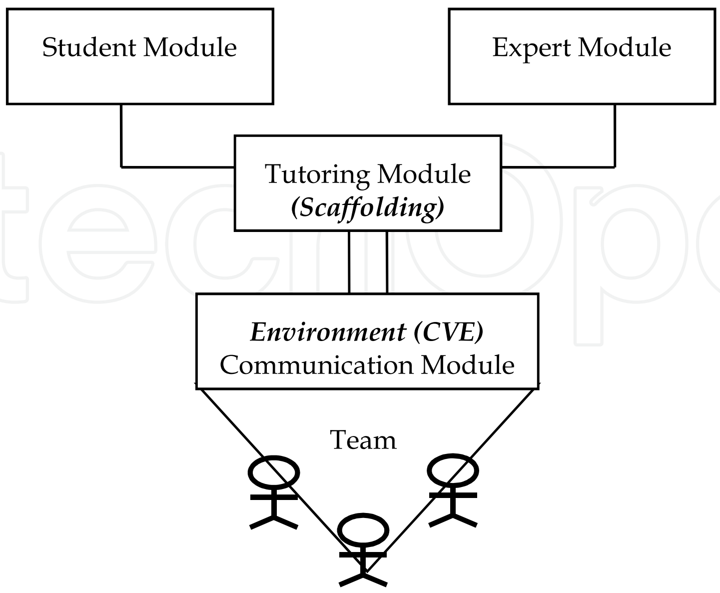

Fig. 1. ICVE Architecture

The systems for training developed to date may be classified depending on the issue they emphasize as: simulation processes, generation of believable environments, and collaboration processes; three aspects that can be integrated in a single system, an ICVE for learning.

The component in charge of the domain of the application has the capacity to execute the simulations of the task to be trained as they are executed in the present systems. VR technology allows recreating environments with believable features (Youngblut, 1998) offering the possibility of being trained in tasks that may be expensive, risky, or even impossible to reproduce in the reality.

Regarding the collaboration process, in an ICVE by including virtual agents to replace team members (Rickel, 2001), the trainees can have a team training experience when the complete human team is not available. It is also possible to integrate into the environment personified PVAs to offer them support, in the same way an instructor or a human peer would do.

Within VR technology, a PVA may assume a 3D representation similar to that used by a human in the environment; they can be embodied through an avatar. The PVAs personification seems to generate positive effects in the perception of the apprentices during their learning experiences (Lester et al., 1997), with two key advantages over earlier work: they increase the bandwidth of communication between students and computers; and they increase the computer's ability to engage and motivate students. Some early empirical results on PVAs embodied effectiveness are on the topics of (W. L. Johnson, Rickel, & Lester, 2000): interactive demonstrations, navigational guidance, gaze and gesture as attentional guides, nonverbal feedback, conversational signals, conveying and eliciting emotion, and virtual teammates.

A PVA can be defined as an intelligent agent that makes decisions about how to maximize the student learning process. PVAs as a result of its goal can function within the ICVE as tutors, mentors, assistances (Giraffa & Viccari, 1999), learning peers (Chou, Chan, & Lin, 2003) or as proposed in here, as a collaborative facilitator with the aim of enhancing the collaborative process; as mentioned, by the analysis of the nonverbal behavior of the users' avatars.

2. Nonverbal interaction in CVEs

Broadly defined, nonverbal behavior might include most of what we do; it even includes certain characteristics of verbal behavior by distinguishing the content, or meaning of speech, from paralinguistic cues such as loudness, tempo, pitch or intonation (Patterson, 1983). Moreover, the use of certain objects like our decided outfit, or the physical environment when used to communicate something, without saying it, has traditionally being considered as NVC. Nonverbal behavior can be used to substitute, complement, accent, regulate or even contradict the spoken message (Knapp & Hall, 2007).

In real life, nonverbal interaction involves three factors (Knapp & Hall, 2007): *environmental conditions, physical characteristics of the communicators,* and *behaviors of communicators*, all of them clearly restricted to the computer scenario conditions.

The *environmental conditions* that will probably affect the most during interaction in a computer scenario are given by the architecture and virtual objects around, what Hall (1968) defined as fixed-features, space organized by unmoving boundaries such as a room, and semi-fixed features, the arrangement of moveable objects such as a chair.

In a computerized environment, the *physical characteristics* of the interactants will be given by the users' avatar both appearance and body movements. While the appearance typically is given by a set of characteristics for the user to choose, like male or female avatar, and maybe a set of different cloths, skin or hair colors for example. As of body movements, Kujanpää & Manninen (2003) presented a considerable set of possible elements an avatar can include to manage the transmitting of NVC.

The avatar's body movements are usually restricted mainly due to their associated technology cost. Typically, in CVEs the users' avatars are naturalistic (Salem & Earle, 2000), with a low-level details approach and humanoid-like, they can display some basic humans' actions or expressions.

Other important consideration is that the means offered by the CVE to the user, in order to transmit NVC to his/her avatar, interfere with its spontaneity and therefore its revealing. The three different approaches to transmit nonverbal behavior from the users to his/her avatar in a VE (Capin et al., 1997) are:

1. directly controlled with sensors attached to the user;
2. user-guided, when the user guides the avatar defining tasks and movements; and
3. semi-autonomous, where the avatar has an internal state that depends on its goals and its environment, and this state is modified by the user. For example, when in a video game, the player achieves a goal and his/her avatar celebrates it.

The *behaviors of communicators* relay on the context that in a CVE will be given by its purpose. For example, in a video game, the users' interaction will be controlled by their intention on getting the goals of the game, while in a social CVE the participants interaction will be more likely to be directed to those they feel socially attracted −see Table 2.

Nonverbal interaction influential factors	Constrained in a CVE to	
Environmental conditions	• the fixed-features of the scenario • the semi-fixed features of the scenario	
Physical characteristics	the users' avatars	• appearance • body movements
Behaviors of communicators	according to the CVE purpose	

Table 2. Conditions of the nonverbal interaction factors in a CVE

Specifically *for a CVE for learning*, the *environmental conditions* will most likely to be constrained by the domain to be taught and the selected pedagogical strategy. The pedagogical strategy will determine the session configuration, like a theme of discussion, solving a problem or accomplishing a task.

Consistent with Collaborative Learning theories the participants' interaction should be implied in the CVE, and recommendable for learning purposes can be to solve a problem through the accomplishment of a task; considering that one of their main advantages is the spacial space with shared objects they offer. Within the CVE, the entities on it with the faculty of being manipulated by the users, the semi-fixed features, will take part of their verbal and nonverbal interchange on being the means to the accomplishment of the task.

As mentioned, the *physical characteristics* of the communicators in a computer-generated environment are determined by his/her avatar's stipulations. The avatar appearance in a learning scenario may represent the apprentices' role. For example, if a firefighter will be trained, his/her avatar will be most likely to use the firefighter's uniform to distinguish him/her from other users.

In order to accomplish the learning purpose in the CVE, the apprentices will control their avatars to communicate, navigate and modify the environment. For that, the mainly related areas of NVC are:

Paralinguistics that comprises all non-linguistic characteristics related to speech like the selected language, the tone of voice, or the voice inflexions, among others.

Proxemics, the analyses of the chosen body distance and angle during interaction (Guye-Vuillème et al., 1998).

And **Kinesics,** the study of what is called "body language", all body movements except physical contact, which includes gestures, postural shifts and movements of some parts of the body like hands, head or trunk (Argyle, 1990).

As of the *behaviors of communicators* in a virtual learning scenario, of special interest should be those related to collaborative interaction, that is, those behaviors that transmit something about how the group members collaborate in order to achieve the common goal; and they will be consistent with the nonverbal behavior carried out for the service-task function (Patterson, 1983).

The nonverbal behavior in collaborative interaction is expected to be mainly intended for the accomplishment of the task. Following the Miles L. Patterson (1983) Sequential Functional Model for nonverbal exchange, people's interaction behavior is the consequence of a sequence of related events. At the foundation of this model is the distinction made between the interaction behavior on itself and the functions served by them. Distinguishing the function served by the interaction behavior means to recognize that the same behavioral patterns can serve very different functions in an interaction.

In the service-task function proposed by Patterson (1983), the service component refers to interaction determined by a service relationship between individuals, for example, a physician-patient interaction. While the task function, influential for a CVE for learning, identifies focused or unfocused interactions that require people to relate others through a particular task or activity.

According to Patterson (1983), the necessity for variable involvement in task-oriented focused interactions, such as when people collaborate to accomplish a task, seems relatively straightforward. Understanding this type of nonverbal interaction keeps the interpretation of nonverbal behavior to an acceptable extent from cultural and personality influences, since the service-task function identifies determinants of nonverbal involvement that are generally independent of the quality of interpersonal relationships. Accordingly, the nonverbal interaction conditions for a CVE for learning are presented in Table 3.

Nonverbal interaction influential factors	**Their conditions in CVEs for learning**
Environmental conditions	• an scenario according to the domain to be taught • operable objects for the learning purpose
Physical characteristics	the users' avatars • appearance • allowed body movements
Behaviors of communicators	consistent with the service-task function

Table 3. Conditions of the nonverbal interaction factors in CVEs for learning

In order to make use of a nonverbal communication cue to monitor collaboration, it needs to have the faculty of being transmittable to the CVE and recognizable by the computer system. With this in mind, the nonverbal communication cues suggested for the interaction analysis as described in Peña & de Antonio (2010) are:

Talking turns - the paralinguistic branch that studies, not what or how people talk but amounts and patterns of talk and that have been use for the comprehension of interaction in different ways as in (Bales, 1970; Jaffe & Feldstein, 1970).

Proxemics – to understand the users' position within the environment and related to others.

Facial expressions – in real life, they might be difficult for interpretation, but when transmitted to a VE not directly controlled by the user, their intention is usually predefined by the system as in the case of the emoticons.

Artifacts manipulation – when they are part of the collaborative interaction.

Body movements - such as gaze direction, deictic gestures, head movements and some body postures.

In the next section the analysis of nonverbal behavior from the participants in a collaborative task within a CVE are discussed. Afterwards, a model for an intelligent tutor based on nonverbal behavior with the intent to facilitate collaborative sessions is presented.

3. Case of study

Working together to accomplish a task does not necessarily mean that the outcome is due to collaboration. It could be, for example, the result of splitting the task and then putting the parts together, or the task could be accomplished by some participants giving orders while others just follow them. In consequence, if Collaborative Learning is expected some factors have to be observed like the maintained focus on the task, the creation of shared ground, division of labor, and the Plan-Implement-Evaluate cycle.

A collaborative learning session usually begins with an initial introductory social phase, especially if the members of the group do not know each other; students tend to socialize before initiating collaboration in the strict sense (Heldal, 2007). This social conduct can be repeated in the session to maintain a balance between the social and the task aspects of the meeting. Nevertheless, even the fact that this social behavior is necessary for the proper function of a work group, it is also important that it is kept in due proportions, and *focus on the task* has to be maintained.

In order to achieve collaboratively a task, participants have to share information or common ground, that is, mutual knowledge, mutual beliefs, and mutual assumptions; and this *shared ground* has to be updated moment-by-moment (Clark & Brennan, 1991). This mechanism is the individual attempt to be understood, at least to an extent that the task can be accomplished.

Division of labor may appear during the whole session or in parts of it; the kind of task will determine its convenience.

In addition, whereas a maintained balance between dialogue and action is desirable, it is also expected an appropriate approach to problem solving, based on the *Plan-Implement-Evaluate* cycle (Jermann, 2004).

The study was conducted with the purpose of understanding the participation of the members of a group, in both dialogue and implementation; and the group process phases: Planning, Implementation, and Evaluation, by identifying patterns derived from selected NVC cues extracted from the group behavior during a session while they carry out a task in a CVE.

3.1 Observing NVC cues

In trying to understand the use of some NVC cues, an experimental application was developed. The VICTOR (VIrtual Collaborative Task- Oriented) application allows three users net-connected to work in a collaborative task, in which the three users' avatars are placed around a table, their workspace.

The NVC cues available in the environment were narrowed to those observed in a study conducted in a real life situation where three people seated around a shared workspace were asked to place a set of drawn furniture on an apartment sketch –see (Peña & de Antonio, 2009) for further details.

These NVC cues are talking turns, objects manipulation, gazes to the workspace and to peers, and pointing to objects, next described for collaborative interaction:

Talking turns and amount of talk. The idea of taking the time that group members speak to understand group process is not new. In 1949, Eliot Chapple created the chronograph interaction; a device to measure persons' amount of talk with the intention of analyzing talk-turns structure (Chapple, 1949). Since then, frequency and duration of speech have been useful tools for the analysis of group interaction in a number of ways, for example to create regulatory tools for meetings as in (Bergstrom & Karahalios, 2007). The students' rates of speech will help to determine if they are participating during discussion periods and to what extent.

Artifacts manipulation and implementation. When the group's common goal implies implementation, it is desirable a maintained balance between dialogue and action (Jermann, 2004). Artifacts manipulation is an object form of nonverbal behavior, as it can be part of the answer to an expression. The amount of work a student realizes, aside of its quality, is a good indicative of that student's interest and participation on the task.

Gazes. The eyes direction is a reliable indicative of a persons' focus of attention (Bailenson et al., 2003). Via the students' gazes, it can be determined to what they are paying attention.

Deictic Gestures. Deictic terms such as "here, there, that", are interpreted resulting from the communication context, and when the conversation is focused on objects and their identities, they are crucial to identify them quickly and securely (Clark & Brennan, 1991). Consequently, deictic gestures directed to the shared objects or the workspace should be useful to determine whether students are talking about the task.

In the application, the user does not see his/her own avatar −see Figure 2. The users' avatars do not have a natural behavior; they are just seated representations of the user that need a metaphorical representation of their actions in the environment.

The significant entities associated to the avatars actions are: colored arrows coupled to their hair color (yellow, red, or brown) that take the place of their hands, and can be used to point the objects or grab them to be moved; by a mouse click, the arrow is activated. To move the objects once they have being selected, the WASD keys can be used to direct them.

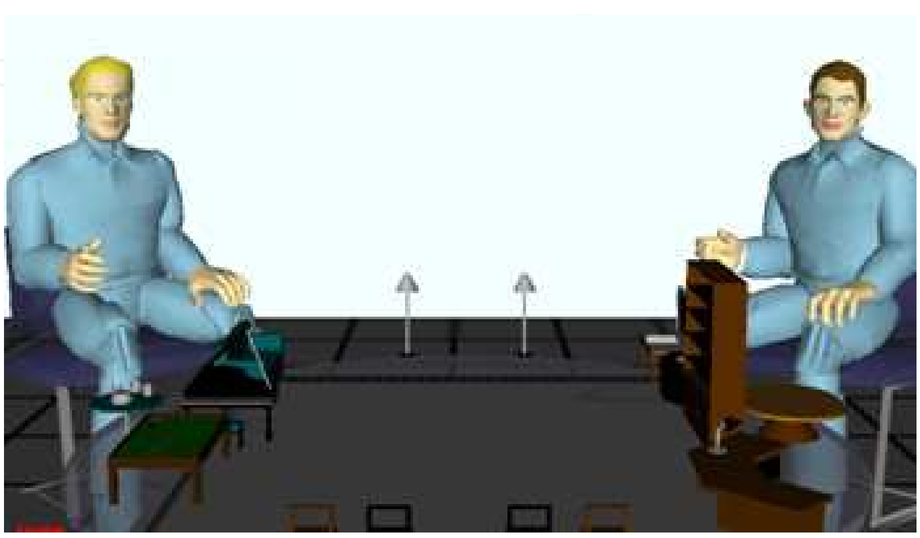

Fig. 2. Experimental application

The avatars' head is another entity that can take four positions to change the user field of view; to the front where the other two peers can be seen, to the right or left to see directly one of the peers, or down to see the workspace –see Figure 3, for that the arrow keys are used.

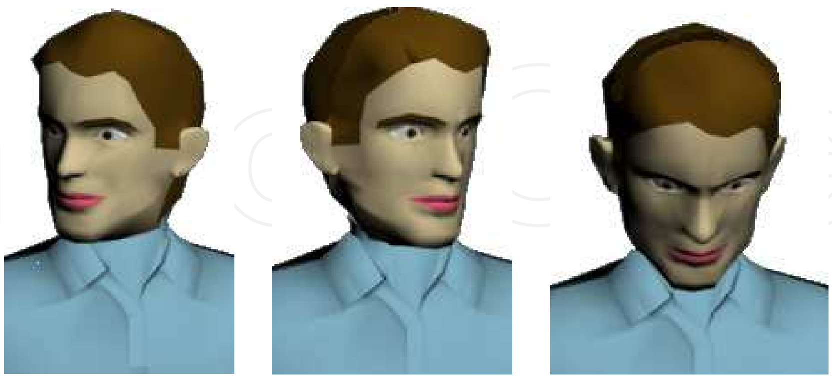

Fig. 3. The avatar head movements

And, when the user is speaking a dialogue globe appears near his/her right hand as showed in Figure 4., when the user wants to speak he/she needs to press the spacebar key.

This first trial was conducted with the aim of modeling a virtual tutor to facilitate collaboration. In the next session, the tutor implementation is discussed.

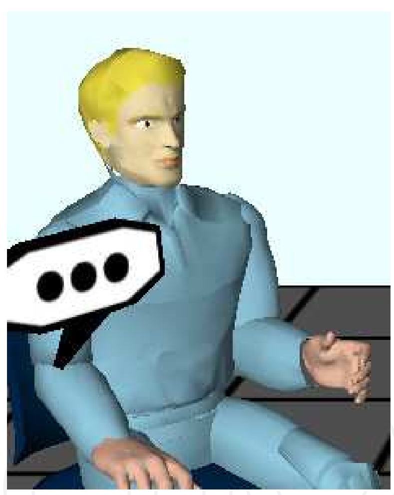

Fig. 4. The dialogue globe

3.1.1 Method

Subjects. Fifteen undergraduate students, 14 males and 1 female from the Informatics School at the Universidad de Guadalajara were invited to participate. Five groups of triads were formed voluntarily.

Materials and Task. The task consisted on the re-arrange of furniture on an apartment sketch to make room for a billiard or a ping-pong table; the group decided which one of them.

Procedure. A number of rules with punctuation were given regarding on how to place furniture such as the required space for the playing table, spaces between furniture and restriction on the number of times they could move each piece of furniture. The instructions were given both verbally and in written form.

Participants were allowed to try the application for a while before starting the task in order to get comfortable with its functionality. The time to accomplish the task was restricted to 15 minutes. Sessions were audio recorded.

Data. Every student intervention within the environment was recorded in a text log file. The logs content is the user identification; the type of action , i.e. move furniture, point furniture, a change in the point of view of the environment, when speaking to others; and the time the intervention was made in minutes and seconds. Data was manipulated to identify discussion periods and the session stages.

Discussion periods

Discussion periods are important in a collaborative session because when they occur, planes, evaluation and agreements are settled. A number of talking-turns involving most of the group members seems to be an appropriate method for distinguishing them from situations like a simple question-answer interchange, or the statements people working in a group produce alongside their action directed to no one in particular (Heath et al., 1995).

A talking turn, as defined by Jaffe and Feldstein (1970), begins when a person starts to speak alone, and it is kept while nobody else interrupts him/her. For practical effects, in a computer environment with written text communication, the talking turn can be understood as a posted message, and in oral communication as a vocalization.

Discussion periods for these trials were established as when each one of the three group members had at least one talking-turn. Because for automatic speech recognition the end of an utterance is usually measured when a silence pause occurs in the range of 500 to 2000 ms (Brdiczka, Maisonnasse, & Reignier, 2005), and the answer to a question usually goes in a smaller range, around 500 ms (A. Johnson & Leigh, 2001); to determine the end of a discussion period, pauses of silences were considered in the range of three seconds.

Initial-Planning-Implementation-Reviewing stages

The collaborative stages can be established by nonverbal cues in different ways, although it also has to relay on the specifications of the task and the instructor strategy for the session. For example, the initial phase could be the introduction to the problem within the environment.

In this case, because the task was explained in person, instruction were delivered to participants in written paper and they had an initial session to try the application, the initial stage was expected to be brief, more likely to be used to get the initiative to start. Then, the Planning stage was expected to start almost immediately; to identify it, the first discussion period was used.

The restrictions posted for the objects manipulation makes to expect that participants will not move objects if they have no implementation intention; therefore, the initiation of the stage was determined with the first movement of an object.

Once the group starts to implement, the discussions periods should mean that they are making new plans or changing them, because there is no way to differentiate new plans from reviewing those already made through the available nonverbal communication, the discussion periods within the Implementation stage were considered as Reviewing stages.

By the end of the Implementation, a final Reviewing stage to agree on the final details of the task was expected. The collaborative stages were then determined based on data logs as follows:

- *Initial stage* – starts with the session and ends when the Planning stage starts.
- *Planning stage* – starts with the first discussion period and ends when the Implementation stage starts.
- *Implementation stage* – starts when participants move the first piece of furniture.
- *Reviewing stage* – when discussion periods occur during the Implementation stage, and at the end of it.

3.1.2 Results

At a first glance to the data it could be overseen that the pointing mechanism was barely used; the speech content revealed that the users' had to make oral references to areas where there were no furniture because they could not point them. Due to this misconception in the design of the environment, pointing gestures were left out.

The changes in gazes were expected to be used to manage talking-turns. The number of times subjects directed their gaze to their peers while they were talking or listening, was relatively small compared to the number of times they were gazing to the workspace as shown in Table 4. A first attempt to understand gazes was to identify possible problems for the participants not using the mechanism as expected.

The possible identified problems in the experimental application were that when the user was viewing the workspace area, he/she did not receive enough awareness about the other users' gazes −see Figure 5. Users had sometimes to specify verbally whom they were addressing if not to both members. Also, sometimes even if they knew their peers names, they did not know which of the two avatars represented each of them.

An external person was asked to determine through the audio recorders, for each talking-turns interchange whether the students were having an episode in which they were taking decisions, making plans or reviewing one of those, that is, discussion periods. Only two interchanges involving two of the three members had these characteristics and the rest of them included the 43 discussion periods identified following the specifications. That is, almost 96% of the talking-turn interchanges with the three members involved were discussion periods.

Gazes	**While Talking**		**While Listening**	
Group	Workspace	Peers	Workspace	Peers
1	93	29	172	89
2	270	19	474	36
3	108	4	217	10
5	188	45	369	68

Table 4. Number of gazes to the workspace or peers while talking or listening

Fig. 5. Seeing down to the workspace

The team got points when its participants followed the given instructions, but if they did not, their punctuation was decremented. Other way to measure the group effectiveness was by comparing the number of movements required to get each piece of furniture where it was last placed, against the number of movements the team actually made; the more effective use of movements is then represented by a 0 difference. The game table was not taken into account for this effectiveness score because a group could not get to that point. In Table 5, the first and second rows show the score given for correctly following instructions as "Instructions Score", and the effectiveness in moving furniture as "Movements score".

The percentage of time each group spent in each session stage is also presented in Table 5, the row that follows the stage is the discussion time the group spent in that specific stage, and the final row presents the total percentage of time they used for discussion periods.

Regarding a collaborative intelligent tutor, a clear opportunity to intervene is the fourth team presented in Table 5. This team started almost immediately –after 2 seconds, with the implementation and then they had very short discussion periods; through the data, it seems that they worked almost in silence. In the audio tape at some point they commented "–remember that we are not supposed to talk" with apparently no reason and they worked to the end of the task in silence. However, they faked talking, that is, they pressed the talking-turn key probably to bring the others attention.

Stages / Group	1	2	3	4	5
Instructions score	39	93	22	-15	-17
Movements score	112	61	33	747	49
Initial	0.012	0.009	0.039	0.002	0.009
Planning	0.227	0.119	0.048	-	0.084
Discussion	0.194	0.115	0.025	-	0.071
Implementation	0.553	0.776	0.854	0.998	0.676
Discussion	0.366	0.574	0.277	0.043	0.178
Reviewing	0.209	0.097	0.058	0.002	0.231
Discussion	0.092	0.097	-	-	0.110
Total Discussion	0.651	0.786	0.303	0.043	0.360

Table 5. Percentage of time elapsed in session stages

This is a very small sample of data, and then it was decided not to treat it statistically. Even though it is worth mentioning, that the best scored groups in following the instructions, were those with the highest percentage of time in discussion periods.

The group 5 low score in following instructions was due to a misunderstanding about the task, they tried to put both gaming tables. With a PVA regarding the task during the session, it is probable that the collaborative process could be more attached to the task results.

This trial was meant to understand, the users' nonverbal behavior in order to model a PVA to facilitate collaboration. In the next session, how the tutor was modeled in this same application is presented.

3.2 Modeling the virtual tutor

The PVA model here propose, as already mentioned, aims to facilitate in time, understanding facilitation as guiding the group process, a collaborative 3D virtual session of a small group of participants. While they synchronously accomplish a task with an open-ended solution that implies the manipulation of objects, through monitoring their users' avatars NVC cues displayed during their collaborative interaction.

The experimental CVE was modified to implement the PVA and to correct some identified problems (see section 3.1.2). To solve the abovementioned misconception about the pointing mechanism, in this version, the arrow can be placed at some parts of the table, see Figure 6.

Then, to solve the awareness of others change of view when the user was viewing to the workspace, the avatars were shrunk in order to show a biggest part of their faces. For the participants to know whom to address verbally when talking, the name of the participant is now displayed in blue letters near his/her avatar – see Figure 6. Finally, the log files now include milliseconds in the timing.

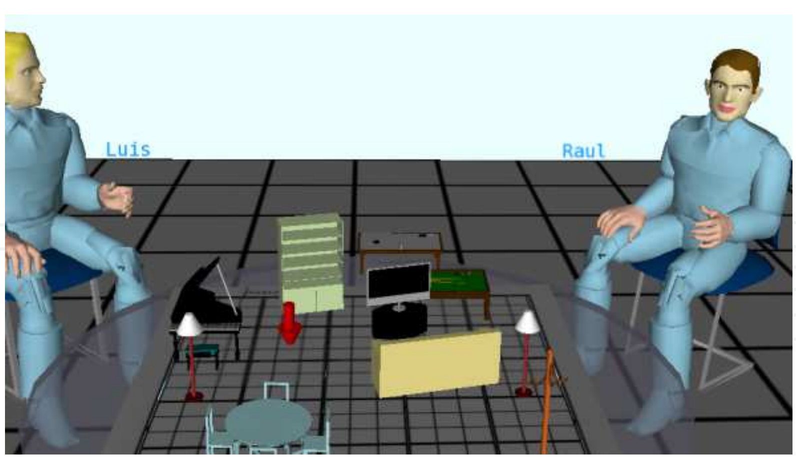

Fig. 6. Experimental application, pointing to the table

Modeling the facilitator

The virtual facilitator has no graphical representation within the environment. Because the PVA is not meant to give feedback but in the collaborative process, it was considered that it might not need a body. The PVA advices are delivered via text messages posted at the bottom of the screen in black letters –see Figure 7.

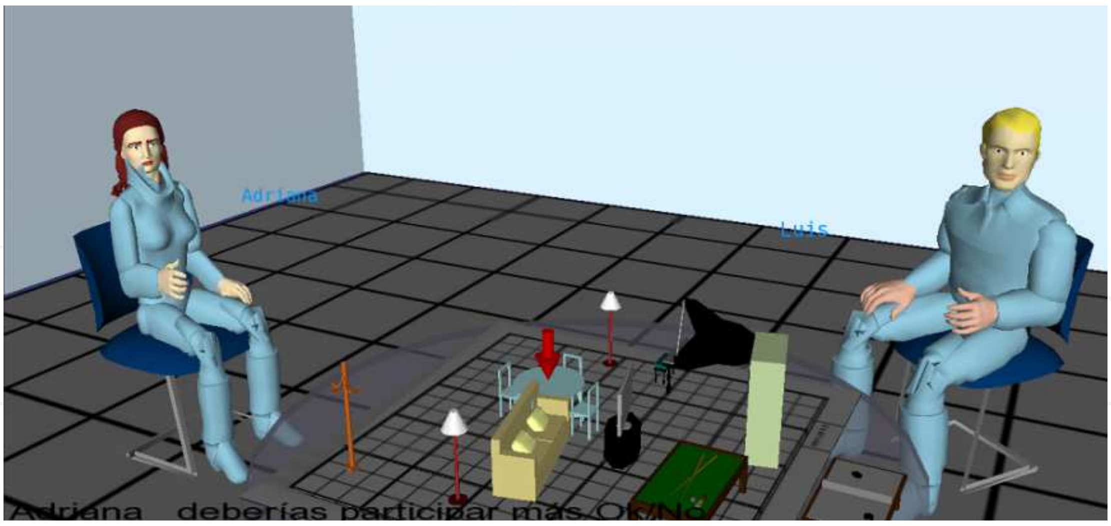

Fig. 7. A message from the IVA

Based on the participants' nonverbal behavior, the tutor makes recommendations regarding their participation and the expected stage sequence (i.e. Initial–Planning–Implement–Reviewing). The "F" key was activated, and when the participants end the session, one of them has to press it. The PVA messages regarding the stages are five and they are triggered under the circumstances described in Table 6.

The facilitator also displays other six messages regarding participation, two for each group member. The PVA verifies the percentage of participation from each member compared to the whole group participation, and applies a formula that implies a tolerance range to an exact equal participation.

Stage	Number / Message	Triggered when
Initial	0. "First step should be to talk about what to do"	Elapsed time *A* (3000 ms) from the beginning of the session in which participants do not initiate either a discussion period or implementation
Initial	1. "You should discuss before starting the implementation"	If they start implementation without having at least one discussion period, which implies they did not make a plan
Implement	2. "A review of what you have until now is advisable"	Elapsed time *B* (3000 ms) without a discussion period
Implement	3. "You should try to work as a team"	When the three of them were doing implementation at the same time
Implement	4. "Before leaving the session you should review your outcome"	Participants finish the session without having at least one discussion period after they finished the implementation.

Table 6. Messages from the facilitator to foster collaboration

The applied formulas were extracted from a real life situation (Peña & de Antonio, 2009) by a regression model. When the participants are in the Planning or a Reviewing stage the formula is based only on the subject talking time as follows:

1. subject's participation = −0.711 + (7.990 * percentage of talking time)

When the group is at the Implementation stage the applied formula includes the subject implementation as follows:

2. subject's participation = −1.759 + (6.742 * percentage of talking time) + (4.392 * percentage of manipulation time)

If the participant has an under participation (according to the formulas 1 or 2), that is when the result is under 1, this message encouraging him/her to increase his/her participation is sent: “<<participantName>>, you should try to increase your participation”.

If the participant has an over participation, when the formula result is more than 3, the sent message is: “<<participantName>>, you should try to involve more your peers”.

Message No	addressed to	with the intention to
5/6/7	SS / SA / SB	encourage his/her participation
8/9/10	SS / SAB/ SB	diminish his/her participation

Table 7. Messages from the facilitator regarding participation

The number of the triggered message corresponds to the user to be encouraged for participation or to diminish it as shown in Table 7; the three users were denominated SS, SA and SB. All the messages, although they have a participant target, are sent to the three group members.

When a message appears on the screen, the group members can agree or disagree with it by pressing the keys “O” for OK to agree or “N” for NO to disagree. Although users are not forced to answer the messages, when they do, a number of actions are taken: the message disappears from the screen; the chronograph of elapsed times is set to 0; the participant times are also set to 0; the participants’ answers are included in the log file; and, if at least two of the three participants disagree with the message, it is deactivated, that means it will not appear again.

The log file has now information regarding the facilitator as another actor in the scenario, when the PVA sends a message and which one is sent by its number. There is an 11th message just to say “Good bye”.

This second trial followed the same method as the first one, with the next differences:

Subjects. Twelve undergraduate students, 13 males from the Informatics School and a female from the Chemistry School at the Universidad de Guadalajara participated. Four groups of triads were formed voluntarily.

Procedure. Participants filled out a questionnaire at the end of the session.

Data. The starting time is now considered when the three computers are connected and not when the first action takes place as in the first trial.

Discussion periods were identified same as in the first trial, when the three group members have had at least one talking-turn, but now the pauses were considered in the range of 2000 ms since the system registers now the milliseconds.

3.2.1 Results

About pointing, in Table 8 is presented the number of times the group pointed a piece of furniture or to the table during each stage, the third row correspond to the Reviewing periods during the Implementation stage. Groups 2 and 3, same with the better performance in both collaborative process and the scores about the task, used the pointing mechanism during the Planning and the Reviewing stages, but Group 2, the highest score, pointed during Implementations most of the time during Reviewing periods.

Group	**1**	**2**	**3**	**4**
Planning	0	6	2	0
Implementation	13	8	10	13
Reviewing	2	14	0	0
Reviewing	0	2	1	0

Table 8. Pointing to the furniture and the workspace.

Gazes were now observed under a different perspective. It was detected that the change of view mechanism was being used, although as mentioned not while the user was talking or speaking, the users usually change their viewpoint repeatedly before doing something else, an average of 4.02 movements.

Because in real life people change the direction of gaze in a regular fashion notably associated with utterances (Kendon, 1990), it was decide to observe what the users were doing after they changed their viewpoint. For that, only the groups that went through the four stages were included. Results are shown in Table 9 for Groups 1 and 2 of the first trial; Table 10 for Groups 3 and 4 of the first trial; and Table 11 for Groups 2 and 3 of the second trial.

Group 1 without IVA										Group 2 without IVA									
Plan			Implement				Review			Plan			Implement				Review		
#	NA	GT	#	NA	GT	DP	#	NA	GT	#	NA	GT	#	NA	GT	DP	#	NA	GT
4	T	P	6	T	W					4	T	W	17	T	W		1	T	P
1	T	P	5	T	W	D							6	T	W	D	9	T	P
			5	M									18	T	W	D	12	T	P
			2	M									1	T	W	D	6	T	P
8	T	P	7	T	W	D	1	T	P				1	M		D	11	T	P
4	T	P											1	T	W		14	T	P
3	T	P								7	T	W	3	T	W	D	7	T	p
2	T	P								1	T	W	5	T	W		19	-	
5	T	W											2	T	W	D			
11	T	P	2	T	W	D	13	-					1	T	P	D			
4	T	P	2	M		D							4	T	W	D			
1	T	W											2	T	W	D			
2	T	W											3	T	W	D			
1	T	P																	
1	K	W																	

Table 9. Groups 1 and 2, of the first trial, gazes and the followed action

Group 3 without IVA										Group 4 without IVA									
Plan			Impement				Review			Plan			Impement				Review		
#	NA	GT	#	NA	GT	DP	#	NA	GT	#	NA	GT	#	NA	GT	DP	#	NA	GT
1	T	W	20	K	W	D	14	-		2	T	W					3	T	p
15	T	P	6	T	W		16	T	W								25	T	p
8	T	w	3	M	P												3	T	W
			4	T	W												1	-	
20	T	W								1	T	W	1	T	P	D	6	T	P
1	T	W											1	T	W		2	T	P
													1	T	P	D	1	T	W
													1	T	W	D	3	T	P
													7	T	W		1	T	P
										1	T	W	1	M	W		2	T	P
													2	M	P		2	T	P
													1	M	W	D	6	T	P
													3	T	W		1	T	P
													4	T	W		5	T	P
													4	T	W		3	T	P
																	4	T	P
																	8	T	P
																	4	T	W
																	6	T	P
																	10	T	P
																	4	-	

Table 10. Groups 3 and 4, of the first trial, gazes and the followed action

Group 2 with IVA										Group 3 with IVA									
Plan			Impement				Review			Plan			Impement				Review		
#	NA	GT	#	NA	GT	DP	#	NA	GT	#	NA	GT	#	NA	GT	DP	#	NA	GT
8	T	W	2	M	W								3	T	w		2	-	
1	T	P	2	K	W								3	T	w				
1	T	W	2	T	W								2	T	W				
			3	M	W								2	T	W	D			
			2	K	W	D				1	T	W	3	M	W				
			4	K	W	D							3	M	W				
			2	K	W	D							2	M	w	D			
13	T	P	2	T	P					3	T	W	1	M	P				
2	T	W	3	K									1	T	W	D			
1	T	P											2	M	W				
3	T	P											1	T	p	D			
2	T	W											1	T	w	D			
2	T	P																	
2	T	P																	
3	T	W																	
2	T	W	3	M	w		2	T	W										
3	T	P	3	M	w														
1	T	W																	

Table 11. Groups 2 and 3, of the second trial, gazes and the followed action

In these Tables (9, 10 and 11), for each group the first, second and third columns correspond to the Planning stage, columns 4, 5, 6 and 7th are for the Implementation stage, and the last three columns (8 to 10) are for the Reviewing stage. The first columns (#) of each group correspond to the number of times the user changed his/her point of view. The second column represents the next action (NA) after the viewpoint was changed as follows: "T" for talking, "K" for taking and "M" for moving a piece of furniture. In the third column is the final gaze target (GT) with a "P" when it was a peer and a "W" when it was the workspace. The same description can be applied for the 4, 5 and 6th columns, but the 7th column (DP) contains a "D" when the viewpoint changes were made during a discussion period. In the Reviewing stage, when the next action (NA) is a dash, it means that the user did nothing else afterwards. Each user has a different tone of gray.

Table 12 shows the messages sent by the PVA during the four group sessions. The number identifying the message is in the first column of each group. In the second column, the elapsed time of the session when it was sent, then the stage of the session in which it was sent. Columns 3, 4 and 5th contain the answer of the participant (SS, SA and SB). In the 6th column the tutor assumption regarding to the sent message, if two participants agreed with

Group 1							**Group 3**						
Msg	**Elapsed Time**	**stg**	**SS**	**SA**	**SB**	**participants**	**Msg**	**Elapsed Time**	**stg**	**SS**	**SA**	**SB**	**participants**
1	01:24.428	Imp	OK	OK	NO	accepted	9	01:00.824	Pl	OK	OK	OK	accepted
8	02:00.292	Imp	OK	OK	OK	accepted	8	03:33.946	Imp	OK	OK	-	not answered
8	03:04.611	Imp	-	OK	-	not answered	5	05:08.022	Imp	OK	-	-	not answered
8	04:05.592	Imp	OK	OK	-	not answered	5	05:17.445	Imp	-	-	-	not answered
8	05:14.902	Imp	OK	OK	-	not answered	5	05:24.917	Imp	-	OK	-	not answered
8	06:00.018	Imp	OK	OK	-	not answered	6	06:04.775	Imp	-	OK	-	not answered
8	07:03.245	Imp	OK	OK	-	not answered	5	07:00.779	Imp	-	-	-	not answered
8	08:01.651	Imp	OK	OK	-	not answered	5	08:00.091	Imp	-	-	-	not answered
8	09:03.039	Imp	OK	OK	-	not answered	6	09:01.539	Imp	-	OK	-	not answered
8	10:02.895	Imp	OK	OK	-	not answered	6	10:02.972	Imp	-	-	-	not answered
8	11:00.661	Imp	OK	OK	-	not answered	5	11:23.765	Imp	OK	NO	OK	accepted
8	12:00.051	Imp	OK	OK	-	not answered	5	12:00.893	Imp	NO	OK	-	not answered
8	13:00.719	Imp	OK	OK	-	not answered	5	13:05.846	Imp	OK	-	-	not answered
8	14:00.299	Imp	OK	OK	-	not answered	6	14:00.467	Imp	OK	OK	OK	accepted
Group 2							**Group 4**						
Msg	**Elapsed Time**	**stg**	**SS**	**SA**	**SB**	**participants**	**Msg**	**Elapsed Time**	**stg**	**SS**	**SA**	**SB**	**participants**
5	01:00.075	Pl	OK	NO	OK	accepted	0	01:19.576	Ini	OK	OK	-	not answered
5	03:11.334	Imp	OK	NO	OK	accepted	0	03:17.621	Ini	OK	OK	OK	accepted
6	04:06.059	Imp	-	OK	OK	not answered	1	03:48.618	Imp	OK	OK	OK	accepted
6	05:01.626	Imp	-	NO	OK	not answered	5	05:02.890	Imp	OK	OK	-	not answered
6	06:02.076	Imp	OK	OK	OK	accepted	5	06:20.266	Imp	-	-	-	not answered
9	07:04.133	Imp	-	OK	OK	not answered	9	07:00.936	Imp	OK	-	NO	not answered
9	08:04.147	Imp	OK	OK	OK	accepted	8	08:03.414	Imp	OK	OK	OK	accepted
5	09:08.122	Imp	-	OK	OK	not answered	7	10:00.648	Imp	OK	OK	NO	accepted
5	10:01.707	Imp	OK	OK	OK	accepted	5	11:02.028	Imp	OK	OK	OK	accepted
							5	12:05.268	Imp	OK	OK	OK	accepted
							5	13:04.828	Imp	OK	-	-	not answered
							9	14:02.870	Imp	OK	OK	NO	accepted

Table 12. Facilitator messages sent during the sessions

it, the message is considered as "accepted". When one of the three members did not answer a message, it was considered as "not answered".

The resending of the same message responds, at some extent, to the fact that if the participants did not answer the message, the numbers were not cleared. None message was rejected, but there were many messages that were not answered by the whole group, and some participants ignored most of them.

Table 13 shows the scores each group got for following the instructions, the effectiveness in their furniture movements and the time each group elapsed in the stages.

Two of the four groups did no go through a Planning stage, Group 1 and 4. As can be seen in Table 13, the Group 4 had a very small amount of discussion time; this group did not finish the task.

Stages / Group	1	2	3	4
Score	-47	97	41	-18
Effectiveness	288	160	55	100
Initial	0.098	0.066	0.065	0.254
Planning	-	0.219	0.126	-
Discussion	-	0.090	0.081	-
Implementation	0.872	0.630	0.753	0.746
Discussion	0.064	0.282	0.230	0.077
Reviewing	0.030	0.085	0.056	-
Discussion	0.002	0.064	0.056	-
Total Discussion	0.066	0.397	0.367	0.077

Table 13. Percentage of time elapsed in session stages with the facilitator

3.2.2 Discussion

Most of the messages from the facilitator were to try to balance participation, 45 of 49 as can be seen in Table 12. From the 135 expected answers, almost a third (28.8%) did not arrive.

In Group 1, participant SB accepted the first two messages and then ignored the rest of them, but they were all the same message addressed to SS asking to diminish his participation. A similar condition can be found in Group 3 where participant SB ignored 11 messages, 7 of them addressed to encourage SS participation and 3 to encourage SA for participation, while in this same Group 3, SS ignored 7 messages from which 4 were addressed to him.

In summary, and although the answer to the specific question about the PVA that was "How proper do you consider the posted messages were?" in a scale of 1 to 4 got a 2.57 average score, there is not a clear perception from the participants of the PVA.

Did the facilitator affect the collaborative process?

Related to a balanced participation some observations can be done. Based in the personal messages responded by the target member, some members corrected their participation rate. For example, in Group 2, SA received three messages encouraging his participation, one of them was rejected, and then he received two messages asking him to involve more his peers, a clear change in his rate of participation. This type of change can be also observed, in Groups 3 and 4. Unfortunately, not all members corrected their participation rate, in that same Group 2, SS received two messages encouraging his participation and by the end received other two with the same advice.

A more concerning part could be regarding to the stages. Only four messages were sent, one to Group 1 and three to Group 4. The Group 1 received a message suggesting them to settle a plan before starting the implementation, members SS and SA agreed, but member SB who was the one who started the implementation, disagreed with the message and continued with it.

Group 4 received two messages suggesting to agree on decisions as a starting point. The group answered until the second one and agreed with it, but instead of having a discussion period as expected, they started the implementation. Thus, the facilitator sent a third message encouraging them to get an agreement before implementing, and even that the group agreed with the message, they kept moving furniture instead of having a discussion period as expected.

3.2.3 Learned lessons

As mentioned, the pointing mechanism can be used to monitor whether participants are talking about the task, to understand their involvement on it. In this case, the participants were video recorded and physically observed while they were carrying out the sessions; therefore, they were involved in the task no doubt. In these trials, the intention was its observation in order to incorporate data coming from it to the facilitator in the future, same as gazes.

In the accomplishment of a task like the one presented here, a mechanism to point objects or some areas is an advantage to identify them quickly; deictic gestures during collaboration in real life are more likely to appear during Planning and Reviewing phases. Although, we are completely aware that this is a very small data sample, in Table 13 can be observed that the Group 2 used it the most during these stages, and it is the one with the better scores regarding the task accomplishment and a more proper use of the collaborative stages. A first thought is to suggest its use during the collaborative session, especially during the Planning and Reviewing stages.

The change of gaze direction was used in a very particular way, see Tables 9, 10 and 11, a number of them (4.02 in average) usually preceded a talking turn, 81% of the times. This behavior may correspond to the fact that people try to get feedback from facial expressions when speaking or listening, but the avatars in the environment do not have them, then the users' change of gazes seem to be as an "announcement" that they were about to speak.

In the Planning stage, only one time the action following to the gaze changes was pointing. The final gaze target during the Planning stage to the peers was 43%, in the Implementation stage only 15%, and in the Reviewing stage, it was the 71 %. In the Reviewing stage, the followed action to the changes in the viewpoint, in 5 of the 34 times was the end of the session, this is consistent with a last look to verify what had been done. The change of gaze that ended in a moving action may be because of the user trying to see the workspace from other perspectives. Curiously, Group 2 from the first trial without facilitator, used these changes of gaze by the end of the session during the Reviewing stage, which imply head movements on their avatars, to say yes or not to the others.

In reserve of confirming these observations with a biggest sample of data, they may represent an adaptation of the users' nonverbal behavior facilities in a CVE, as awareness of their interaction with others.

Regarding the facilitator, it seems that the messages were sent very frequently, see column 2 in Table 12, it might be better to spread them, especially those regarding participation rates; also, statistics should be cleaned once a message is triggered regardless the users' answer to avoid repetitions. This, as an attempt of improving the number of answered messages, without forcing the participants to do so.

Other method to make the facilitator advices more acceptable could be to present them in a more attractive way like changing the color of the letters, or maybe in an imperative form, to give them via voice, or to give the facilitator a body.

Finally, following the logs files a kind of story can be tell about what is going on in the environment, the next lines were composed based on them and it correspond to a SS user:

Results from Loading: keyStrokeLog - 1.txt
SS(1)

Look at Both at 9:40:29
Look at Nobody at 9:40:29
Look at SB at 9:40:30
Look at SA at 9:40:31
Talk to SA at 9:40:31
Look at SB at 9:40:32
Talk to SB at 9:40:32
Talk to SB at 9:40:35
Talk to SB at 9:40:42
...
Take Dining Table at 9:44:14
Talk to SB at 9:44:32
Move Dining Table at 9:44:43
Move Dining Table at 9:44:44
Move Dining Table at 9:44:45
Move Dining Table at 9:44:46
…
Talk to SB at 9:44:52
Talk to SB at 9:44:58...

This information could be used in a number of ways such as to establish nets of communication or to oversee some participants' collaborative characteristics such as being implementers or leaders. For example, it has been found that talkative group members are more likely to be task leaders (Stein & Heller, 1979), and to receive more gazes and send less than their peers (Peña & de Antonio, 2009).

4. Conclusions and future work

Base on the nonverbal behavior of the users' avatars in a CVE for learning, an IVA was modeled within an experimental application with the intent to scaffold the collaborative process. The model used only two NVC cues, talking turns and artifacts manipulation, to give two types of advices: one regarding a balance in the group members' participation rates in both talk and implementation; and, the other regarding an expected sequence in the Plan-Implement-Review stages.

Two trials were presented, the first without the facilitator or IVA and the second one with it. In the second trial, the observation of other two NVC cues was conducted, deictic gestures and gazes, while some indications on this regard were pointed out.

Although in this chapter only nonverbal behavior took part in the facilitator modeling, our final intention is to incorporate the scheme to a verbal analysis, an example, can be found in (Peña, Aguilar, & de Antonio, 2010). In trying to avoid a restricted interface like the Sentence Opener approach, the analysis in (Casillas & Daradoumis, 2009) will be adapted to the model.

How people nonverbally behave in graphical environment through their avatars and how they will adapt the CVE facilitations for that, are big open issues. The analysis in here was narrowed to collaborative interaction during the accomplishment of a task in a small group through only a few nonverbal communication cues, barely a small brushstroke of what is suggested as a complete area for research.

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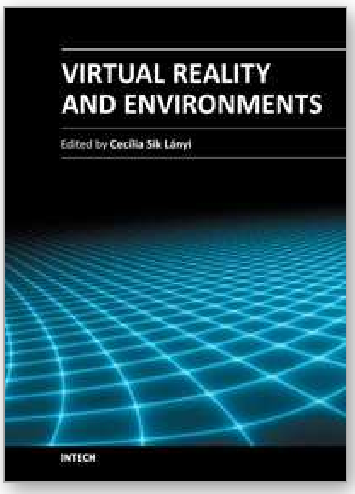

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Virtual Reality is clearly interdisciplinary research. It has, not only Information Technology importance but social, educational, economical importance too. It combines multiple disciplines for the development of virtual reality systems in which the user has the immersive feeling of being in the real world. Virtual reality has several applications in almost all fields of real life. The most typical fields for the application of virtual reality are health-care, engineering and game industry. This book may be a solid basis for the novice and advanced engineers who would like to develop user friendly Virtual Environments for education, rehabilitation and other applications of Virtual Reality. Our book provides a resource for wide variety of people including academicians, designers, developers, educators, engineers, practitioners, researchers, and graduate students.

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University Campus STeP Ri
Slavka Krautzeka 83/A
51000 Rijeka, Croatia
Phone: +385 (51) 770 447
Fax: +385 (51) 686 166
www.intechopen.com

InTech China
Unit 405, Office Block, Hotel Equatorial Shanghai
No.65, Yan An Road (West), Shanghai, 200040, China
中国上海市延安西路65号上海国际贵都大饭店办公楼405单元
Phone: +86-21-62489820
Fax: +86-21-62489821

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