Nonverbal Communication to Support Collaborative Interaction in Collaborative Virtual Environments for Learning

Adriana Peña Pérez Negrón[1], Angélica de Antonio Jiménez[2]

Universidad Politécnica de Madrid –Facultad de Informática
Campus Montegancedo s/n, Boadilla del Monte
28660 Madrid, España
[1] apena@alumnos.fi.upm.es [2] angelica@fi.upm.es

Abstract. When a group of students, placed around a shared workspace and working on an anticipated task is observed, the teacher or the facilitator intuitively can, to a certain extent, understand how collaboration is taking place within the group, without listening to the students' discourse. Following this analogy, we propose that some specific nonverbal communication cues should be useful to infer collaborative interaction to such an extent that collaboration can be automatically fostered. Some nonverbal communication cues selected for that purpose and the inferred collaborative learning indicators will be presented.

Keywords: Collaborative Virtual Environments (CVE) for Learning, Nonverbal Communication (NVC), collaborative interaction.

1 Introduction

An important advantage with Collaborative Virtual Environments (CVEs) is that they can display avatars' nonverbal communication (NVC). Most of the research in computer science related to NVC is address to create believable intelligent agents trying to make their avatars act more like humans in different situations, like in conversations (Padilha and Carletta, 2003), expressing emotions (Fabri, Moore and Hobbs, 2004), or as a partner in learning sessions (Ieronutti and Chittaro, 2007), among others. But although avatars controlled by users can also express NVC (Johnson and Leight, 2001), this characteristic has not been much exploited, probably because of its complexity and extension.

Users' avatars are their visual embodiment, their means for interacting with the VE and for sensing various attributes of the world (Guye-Vuillème et al., 1998). In a collaborative situation, the avatar should perform other important functions such as perception, localization, identification and visualization of the focus of attention of other users (Capin et al., 1997). Here the expression of NVC by the avatar is a helpful mechanism to support awareness.

NVC is a wide field; it comprises all wordless messages people interchange and includes communication using objects like clothes or hairstyle, or how the decoration of the daily spaces are; NVC is also about what is communicated through our body, like gestures, facial expressions or speech characteristics other than verbal content. Regarding interactions NVC involves three factors: environmental conditions, physical characteristics of the communicators, and behaviors of communicators (Knapp and Hall, 2002), all of them clearly restricted in CVEs to computer conditions.

In a CVE for learning, environmental conditions have to do with pedagogical strategy, which determines the session purpose, like a theme of discussion, solving a problem or accomplishing a task. Based on the purpose of the learning session, the environment emphasis will be put on the communication media, the conditions of the workspace, the surrounding objects and/or the features of the scene.

Physical characteristics are determined by the avatar's appearance which in learning environments usually is established by the developer, without possibilities of being changed by the student; and they also include those more interesting related to the avatar's possibilities of expressing NVC via facial expressions, navigation or some specific body movements. While natural human communication is based on speech, facial expressions and gestures, interaction also depends heavily on the actions, postures, movements and expressions of the talking body (Morris et al., 1979).

As far as NVC features are automatically digitized, they should be more revealing and spontaneous. There are three different approaches to transmit NVC to a VE: directly controlled –with sensors attached to the user; user-guided –when the user guides the avatar defining tasks and movements and; autonomous –where the avatar have an internal state that depends on its goals and its environment, and this state is modified by the user (Capin et al., 1997). Although, we believe that even if NVC is transmitted to the computer by a simple keyboard or a mouse, it gives significance to communication and resources to understand collaborative interaction. Succinct metaphors for the visualization of NVC can contribute to the user's immersion feeling; the degree of being present in a virtual world depends more on the person's own attitudes and not mainly on the technology (Tromp, 1995).

The behaviors of communicators on which we will focus are those related to collaborative interactions, this is, those behaviors that transmit something about how the group members collaborate in order to achieve the common goal, where the main NVC areas related are Proxemics, Kinesics and Paralinguistics. The study of proxemic analyses the chosen body distance and angle during interaction (Guye-Vuillème et al., 1998). Kinesics is the study of what is called "body language", all body movements except physical contact, which includes gestures –movements of the limbs, postural shifts and movements of some parts of the body like hands, head or trunk (Argyle, 1988). Finally Paralinguistics comprises all non linguistic characteristics related to speech like: the selected language or the tone of voice or voice inflexions, among others.

Our focus is on synchronous collaborative interactions for learning tasks, that is, on the NVC cues useful to foster these collaborative interactions as described by Martínez (2003): "*an action that affects or can affect the collaborative process. The main requirement for an action to be considered a possible interaction is that the*

action itself or its effect can be perceived by at least a member of the group distinct of the one that performed the action", in order to get an effective learning session.

An especial advantage of our proposal, using NVC as means to determine collaborative interaction, is that it can be retrieved from the CVE without regard to the domain, making it appropriate for a generic analysis.

2 NVC in Collaborative Learning Interaction

After a careful review of NVC behaviors, our hypothesis is that through them we can get indicators of member's participation rates; of students maintaining the focus on the task; of students making shared grounding; of division of labor and; of an adequate group process for the task, including the plan, implement and evaluate phases.

Participation is the students' intervention in the collaborative environment. When it grows, the potential of sharing learning also grows. In a collaborative situation, participation is expected to have symmetry (Dillenbourgh, 1999).

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 strict sense (Heldal, 2007). This social conduct can be repeated during the learning session to maintain a balance between social and 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 during the learning session.

In order to achieve collaboratively a task, students 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 and Brennan, 1991). This mechanism is the individual attempt to be understood, at least to an extent that the task at hand can be accomplished (Resnick, 1991). Computer context in a CVE is the means to support common grounding by its shared workspace that allows grounding by references.

During the learning session, it is possible that division of labor appears in the whole session or in parts of it. The kind of task will determine its convenience.

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

We believe that these features of a learning session are good indicatives of collaboration, and all of them can be deduced through the retrieval of NVC cues, with the aim of automatically fostering collaboration.

2.1 NVC on its Task-related Function

Patterson (1982) proposed what he called "nonverbal involvement behaviors" to operationally define the degree of involvement manifested between individuals, and he classified them within specific functions. These functions for NVC are: to provide information or to regulate interactions –these two are useful to understand isolated behaviors; and to express intimacy, to exercise social control, and to facilitate service or task goals –these last three more useful to understand behavior over time. The first two are independent of the last three in such a way that a given behavior can be either informational or regulatory and, at the same time, be part of an overall pattern serving to intimacy, social control, or service-task functions.

Of special interest to our proposal is the service-task function, helpful to understand NVC impersonal behavior. By impersonal we mean not engaging with personality or emotions. The interpersonal involvement in these kinds of exchanges is delimited to the service or task regulations. When in a social event, the person you gaze and talk is usually the one you are interested in, but when taking care of a task, talk and gazes are directed to the person who is needed to accomplish the task. In that same manner NVC such as proximity or the touch between persons are perceived different when the behavior is serving to a specific task. For example, when an unknown person approaches us more than what is socially accepted, it is very likely that we feel uncomfortable and try to move away; nevertheless, if this approaching person is a dentist who is going to check our teeth, this same proximity should not bother us.

3 NVC Cues selected to extract Collaborative Learning Indicators

Without pretending to be exhaustive we will select those NVC cues we consider useful to get the aforementioned indicators –participation rates; focus on the task; the making of shared grounding; division of labor and; the plan, implement and evaluate phases, to automatically foster a task learning session. This possibility, as far as we know, has not been explored on its relation to CVEs for learning.

Two NVC cues closely related to participation rates are amount of talk and implementation. Also, these two cues can be retrieved from a simple desktop-based CVE with no especial hardware required. Oral communication seems to be more appropriate for a VE (Imai et al., 2000), but written text can be a substitute to retrieve the amount of talk.

A) Amount of Talk. The paralinguistic branch of NVC that studies patterns of talk has been useful for the study of interaction. With respect to collaborating groups, researchers have found that talkative group members seem to be more productive (Norfleet, 1948), more task dedicated (Knutson, 1960) and more likely to assume task leadership (Stein and Heller, 1979). Frequency and duration of speech have been useful for group process analysis, generally based on Hidden Markovian Models (Brdiczka et al., 2005; McCowan et al., 2004).

In a collaborative learning session, discussion allows getting and maintaining shared understandings, getting agreements, conducting negotiation and creating strategies, among others, in order to achieve the group's common goal. In this context, the communication process serves the learning purpose by: 1) externalization, when a student shares knowledge; 2) elicitation, when a student by externalization gets what other student(s) contributes; and 3) reaching consensus about possible actions to achieve goals (Fischer et al., 1998).

A collaborative learning session can be fostered according to students' rates of speech, that help to determine whether students are participating and if that participation is or it is not symmetric −for example, if a student is too quiet with respect to others. On the other hand, even if no statements can be done for sure about an utterance without content comprehension, if a student is an initiator –a person that initiates conversations– together with other indicators of task accomplishment, chances are this student is externalizing. An initiating utterance followed by an answer could be understood as elicitation, and a growing speech rate with group turns could be understood as getting consensus. Periods of empty turns could be due to the fact that the students are working on ideas too ill-formed or complicated to be introduced into the shared work, followed with intense interaction to incorporate the individual insights into the shared knowledge (Roschelle and Teasley, 1995).

B) Artifact Manipulation and Implementation in the Shared Workspace. When the group's common goal implies some implementation, it is desirable a maintained balance between dialogue and action (Jermann, 2004). Artifacts manipulation is an object form of NVC; it can be the answer to an expression. Even if there are no artifacts in the learning session, the shared workspace could play the role as part of group's collaborative interaction. Participation can be obtained from the amount of manipulation in the shared workspace. Independently of its quality, how much work a student realizes within the workspace is, by itself, a good indicator of that student's interest and participation on the task.

According to Jermann (2004), a combination of participation in the shared workspace with amount of talk allows establishing participation patterns with regards to division of labor: 1) symmetry in dialogue with asymmetry in implementation, when all participants discuss the plans but only some of them do the implementation; 2) asymmetry in dialogue and in implementation, when some give orders and some others follow them and; 3) symmetry in dialogue and in participation when there is no division of labor.

The strategies to solve the problems can also be showed by participation patterns: 1) alternation in dialogue and implementation reflects an approach plan-implement-evaluate and; 2) almost null dialogue and continuous implementation reflects a brute force trial. In consequence, besides participation rates, patterns composed of amount of talk and manipulation in the shared workspace should be useful for the analysis of the collaborative interaction within a learning scenario.

The way to retrieve other NVC cues depends on the design of the environment. Gazes, deictic gestures and proxemics can be retrieved by head or hand trackers, but gazes can also be retrieved through the avatars' point of view, the deictic gestures can be compared to mouse pointing and proxemics can be obtained from the avatar's

navigation in such a way that these three NVC cues can be transmitted to the environment also through a simple keyboard or a mouse.

C) Gazes. When people are working on a task, gazes serve as a means of collecting information. Through gazes people get feedback about contact, perception, understanding and attitudinal reactions (Allwood, 2001). Gaze is an excellent predictor of conversational attention in multiparty conversations (Argyle and Dean, 1965) and the eye direction is a high indicative of a persons' focus of attention (Bailenson, et al., 2003). Then, via students' gazes it can be determined if they are paying attention to the current task and/or to which other students. Observing gazes it can be overseen if the group maintains focus on the task, and they also could be helpful to measure the degree of students' involvement.

D) Deictic Gestures. Gestures have narrative–iconic, and grounding–deictic functions (Roth, 2002), but while it can be difficult to automatically distinguish between iconic gestures from the very common meaningless gestures people use when they are speaking, deictic gestures can be compared to mouse pointing. 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 the objects quickly and securely (Clark and Brennan, 1991). Consequently, deictic gestures, especially those directed to the shared workspace, should be useful to determine whether students are talking about the task.

Before continuing with the selected NVC cues, let's see how the already commented ones help with the identification of the group process, plan–implement–evaluate phases.

In order to accomplish a task it would be desirable first to plan how, who and when things are going to be implemented, then to make the implementation or execution, and finally to evaluate what was implemented. This is a cycle, and its phases are not always entirely separated. It is not necessary to have everything planed to make some implementation, implementation can be interrupted by new or redesigned plans, or by evaluation, and evaluation can need implementation or new plans. These phases can be distinguished by different NVC cues.

Planning. The discussion of the strategies to be followed helps students to construct a shared view or mental model of their goals and required tasks to be executed. During this phase students need to talk, look at each other to be convincing or searching for feedback, and they could also use pointing to the workspace as a tool.

Implementation. In this task accomplishment phase, activity in the shared workspace must appear. Implementation can be a joint effort where there has to be discussion and negotiation about what students are doing. If implementation is decided to be conducted by dividing activities, then activities have to be split in the shared workspace, and less discussion should be required. Students' focus of attention has to be on the shared workspace with spare gazes at each other.

Evaluation. After reviewing the plans or the implementation, students have to decide if some changes are needed. Discussion here can imply pointing, and gazes have to be directed to the shared workspace.

E) Proxemics. VEs have been used by sociologists for the research of Proxemics because results have demonstrated that users keep some proxemic behavior on them (Bailenson et al., 2003). When people are standing they tend to form a circle in which they include or exclude other persons for interaction (Scheflen, 1964). In learning environments, students' proxemic behavior can be used to indicate the creation of subgroups and division of labor; proxemics is also helpful to indicate partners' inclusion or exclusion in task activities.

The next and last two selected cues present ambiguities, for their interpretation in the real world, although for different reasons as we will see. However, they could present other means to understand collaboration.

F) Head Movements. Head position can provide a very close approximation to eye direction. Head position could be useful to replace gaze tracking when it is not possible to follow the exact direction of a person's sight (Parkhurst, Law and Niebur, 2002).

There are multitude of head movements during interaction that have to do with the nature, the purpose and the organization of it. The different patterns of head movements for conversation can be found in Heylen (2005). The automatic comprehension of head gestures becomes complex since they can carry out different functions and/or meanings that depend on the context in which they are produced. In spite of this difficulty, there are some semantic head movements that can be easily distinguished and are helpful for collaborative interaction analysis accompanied with other NVC behaviors, such as the very common nodding to show agreement or comprehension, or the side to side movement to indicate disagreement or incomprehension. Nods and jerks are typical movements involved in providing feedback (Cerrato and Skhiri, 2003).

G) Body Postures. Body postures are movements that spread throughout the body, visibly affecting all parts and usually involving a weight shift (Bartenieff and Davis, 1965), in contrast to gestures that are movements of only a part of the body.

This type of NVC poses a more complex challenge than head movements because there is not yet a clear association between postures and their interpretation (Mota and Picard, 2003). However, for seated people there seems to be some consensus. When people are seated around a table –the most common position for a task accomplishment, the degree of orientation between the speaker's torso and the listener can show agreement, liking, and loyalty when aligning with him/her (Mehrabian, 1969) and when not, a parallel orientation reveals neutral or passive moods (Richmond et al. 1991). In learning scenarios, it has been found correlation between postures and the students' level of engagement in the lesson, there is also an association between patterns of postural behaviors and the interest of a child working in a learning task (Mota and Picard, 2003).

Finally, about facial expressions, we would like to add only that although we believe they carry on more emotional and personal features than those related to the task, as mentioned, they are a helpful mechanism for feedback.

4 Discussion and Future work

In a collaborative learning situation interaction is expected to occur, but the degree of interweaving between reasoning and interaction is difficult to define operationally. The environment then should increase probabilities for collaborative interactions (Dillenbourg, 1999).

In an effective learning task situation, we expect a symmetric students' participation to create shared plans, make the implementation and continuous evaluation either for plans or implementation. We propose that some NVC cues could be useful in determining the fulfillment of these expected conditions.

Amount of talk and manipulation in the shared workspace can be retrieved from any CVE, even desktop-based, and they can be used to extract participation rates and some patterns formed by their combination which can also be used to infer division of labor or problem solving strategy (Jermann, 2004). Gazes are useful to analyze students' focus of attention. Deictic gestures can be a tool to determine the topic of the discourse. The combination of these four NVC cues can explain when the plan-implement-evaluate cycle is taking place. Observation of Proxemics can also be used to determine division of labor and subgroups. Some semantic head movements could be used, among other NVC cues, to establish agreement or comprehension and disagreement or incomprehension. Body postures could also provide agreement or disagreement, and students' interest on the current task.

These are only some of the characteristics of effective collaborative learning that can be studied based on NVC behaviors. Which NVC cues have to be selected will depend on the technology to digitize them and the task conditions, what data needs to be collect and how to interpret it needs to be put in context and empirically confirmed. A lot of work has to be done in order to prove the potential uses. Nevertheless, we believe this is an important and promising field of study to automatically foster collaborative interaction in learning situations. Selected NVC cues can be retrieved without regard to the domain, which makes this approach appropriate for reusability.

At present we are developing a desktop-based CVE application derived from an exploratory study in which we observed a real life situation of three students seated around a table working in a simple task accomplishment (see Peña and De Antonio (2007) for details). Four NVC cues: time of talk, time of objects manipulation, number and direction of gazes or head movements, and number of objects pointed were analyzed. These NVC cues are consistent with the aforementioned selected ones when there is no navigation in the environment and they are retrieved from the CVE through the keyboard and the mouse. Data was statistically manipulated with two points of view, first to compare NVC cues with participants' contribution to the task where major result was that the time of talk and the time of manipulation in the shared workspace explained expert tutors' opinion about participation rates, the second one consisted in a segmentation of the session, with the classification of each segment with the group process phases –plan, implement, evaluate, we found that a combination of the aforementioned NVC cues is useful to distinguish them. In the developing application each of the three users has an avatar, oral communication is applied, it allows manipulation of objects, pointing in the shared workspace, and changing the point of view from the shared workspace to one or to the two other

group members by avatars' head movements. And it automatically records the NVC cues for each user in text files for further analysis.

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