Collaboration in 3D Virtual Worlds: designing a protocol for case study research

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Abstract. Three-dimensional virtual worlds (3DVW) have been growing fast in number of users, and are used for the most diverse purposes. In collaboration, 3DVW are used with good results due to features such as immersion, interaction capabilities, use of avatar embodiment, and physical space. In the particular cases of avatar embodiment and physical space, these features support nonverbal communication, but its impact on collaboration is not well known. In this work we present the initial steps for creation of a protocol for case study research, aiming to assert itself as a tool to collect data on how nonverbal communication influences collaboration in 3DVW. We define the propositions and units of analysis, and a pilot case to validate them.

Keywords. virtual worlds, collaboration, immersion, interaction, communication, nonverbal, case study, pilot case.

1. Introduction

Three-dimensional virtual worlds (3DVW) have been used for collaboration in several areas such as education, training, and distance learning [1] [2][3][4][5], decision making and planning [6][7][8], project management [7][3], and information systems [9][3]. 3DVW possess features that promote interaction and an immersive environment making them suitable for collaboration [9][3], with the most diverse objectives such as work, social interaction or gaming, are found in World of Warcraft and Second Life [10][11][12][13].

The immersive environment, as well as other features of 3DVW, is also responsible for a sensation felt by users, known as Presence, which occurs when they experience the virtual world without acknowledgment of the mediation of the technology [14]. It is believed that Presence improves collaboration [15], and Romano et al. [16] affirm that collaboration is related to a strong sense of presence shared by collaborators. In the knowledge area that studies the phenomenon of Presence, it is recognized that immersion [17][18][19][20][21][16], nonverbal communication

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[22][23][24][25][26], and interaction [27][28][29] are important for Presence, with the potential for collaboration enhancement.

Nonverbal communication, including clues of presence related to social aspects, such as proximity, orientation of the avatar, focus, eye gaze, eye contact, physical appearance, and the use of avatar itself, strengthen the sense of presence and are important for collaboration [23]. Besides its importance for communication [23][25][26][29], nonverbal communication also improves awareness [23]. In the case of the field of vision, techniques of manipulation and navigation capabilities improve interaction, as well as the immersive environment created by 3DVW, and facilitate cooperative tasks [19]. These facts clearly show a relationship between collaboration and Presence since communication, awareness, interaction and cooperation are directly related to collaboration. Nevertheless, there is a lack of literature on how nonverbal communication cues influence collaboration.

The theoretical framework of the field of Computer Supported Cooperative Work (CSCW) provides a starting point for this work. However, as stated in a recent paper [30], CSCW taxonomies fail to properly address the key features of 3DVW, confounding them with other quite distinct systems. With this work, we want to present a research instrument that enables data collection on how nonverbal communication in 3DVW influences collaboration, and contribute to improve the theoretical framework of CSCW in its ability to classify 3DVW. Generally, we intend to observe a user's behavior and the effect it appears to have on other users' behaviors. With this, we expect to relate some behaviors to specific effects, within a collaboration context, thus achieving data that may contribute to a better understanding of how nonverbal communication cues in 3DVW influence collaboration. The focus on case study research is due to the complex nature of the analysis of users' behaviors. This proposal establishes the first two steps of the case study methodology according to Yin [31], as part of the case study protocol. These steps are Research Design (1) and Preparation for Evidence Collection (2). Further support of this choice is presented in the next section, as well as a summary of Yin's methodology. The third section refers to the design of the research with definition of propositions and units of analysis, and the fourth refers to the preparation for the collection of evidence, including a pilot case to validate propositions and units of analysis. We conclude in the final section with some reflections.

2. Methodology overview

Case study methodology studies phenomena, processes or behaviors in their real environment [32][33][31]. It allows the study of different aspects of the object of study and their relationships [33], namely the "how", the "why", and results [32][34]. This methodology is used to explore processes or behaviors that are new or poorly understood [35], characterized by a non-evident distinction between phenomena and context [31], or situations where it is very difficult, if not impossible, to use other methods besides qualitative ones [36]. Techniques of data analysis for case study may include distribution of data by different categories, creating flow charts or other synoptic, calculation of frequencies, means and variances, and organizing data chronologically [37].

In 3DVW, features such as gestures and emotions are used to produce behaviors reflecting social symbolisms like culture, ethnicity, and religion [6][7][8]. The environment is also used to influence the mood and humor of the users, helping them to socialize [6][7][8]. These behaviors are complex in nature, and are difficult to separate from context, being the spatial environment a good illustration of that fact. These reasons led us to choose the case study methodology for this study.

We follow Yin's [31] perspective on the case study methodology, which is well accepted and used in many case study research efforts. It comprises the following activities:

- Research Design
- Preparation for Evidence Collection
- Evidence Collection
- Evidence Analysis
- Sharing of Results

Research Design begins by defining the issues under study, or in other words, the research questions. After that, comes the definition of propositions, which helps focus the study in the core of the case. The third component of Research Design is the definition of units of analysis, that is, the definition of what concretely will be studied (the phenomenon, behavior, process, etc.). After this, the logical connection of propositions to the data should be made. Finally, the criteria for interpreting the results are defined. After the research planning, the next step is the Preparation for Evidence Collection (or data collection preparation). This implies developing a protocol for the case study – a tool that helps assure reliability in data collection. It includes objectives, framework and relevant literature, procedures for obtaining the data (access, method of collection, calendar), questions to ask, and format of the report with the results. The development of the protocol should be validated with a pilot case. These are the activities presented in this paper. The subsequent activities (evidence collecting, evidence analysis and sharing of results) comprise the future actions and are not the focus of this paper.

3. Research design

In our case, the research questions are concerned with how nonverbal communication affects collaboration in 3DVW. This general concern can be specified as two questions:

RQ1   How does the use of an avatar influences collaboration 3DVW?
RQ2   How does the virtual spatial environment influences collaboration 3DVW?

As for the definition of propositions, in this study they are related to expectations generated by the theory of Presence [15]. Thus, we propose the following set of propositions related to nonverbal communication and the impact it may have on collaboration, based on expectations from previous research on virtual worlds [15]:

P1 The aesthetics of the avatar influence the perception by others of the role of the avatar's user and/or his attitude.

P2 The gestures and sounds that the avatar does influence the perception by others about how the avatar's user wants to collaborate or how he or she wants others to collaborate.

P3 The eye gaze/face direction, direction of movement, and avatar placement provide cues about what the user is paying attention to, or what the user would like to direct others' attention towards.

P4 Interaction of the avatar with specific objects provides cues about which objects are intended to be used by others in the collaboration process.

P5 The arrangement of objects (e.g., their grouping or alignment) provides cues of their purpose for collaboration.

P6 The exchange of visual artifacts (i.e., "objects", "clothes", "tools"), with specific visual features and explicit purposes, helps define the team, contributing to group awareness and perception of collaboration roles.

P7 The virtual spatial environment, including lighting, sound or music, and visual effects, influences the attitudes of collaborators.

We also defined the units of analysis both for avatars and for the virtual spatial environment. Referring to the research questions, the units of analysis for avatars we used were:

- Appearance
- Gestures made
- Sounds emitted
- Eye gaze
- Facial demeanor
- Facial orientation
- Direction of movement
- Body position
- Avatar placement
- Visual artifacts used for interaction

And the units of analysis for the physical space were:

- Animated visual artifacts (animated objects) or artifacts for interaction (i.e. pose balls)
- Non-animated visual artifacts
- Non-visual artifacts (e.g., scripts)
- Visual environment (e.g., what kind of place the action is taking place in)

These units of analysis are the observation targets of the case studies, and their relations with the research questions will be obtained by applying Yin's recommended criteria [31].

4. Preparation for Evidence Collection

4.1. Pilot case

Second life is being used for collaboration in several different tasks, with learning and training as one of the most common [15]. This case was selected for convenience, because we had easy access to it for observation. In the pilot case used, the data was obtained by direct observation. The pilot case is an example of collaboration on an initial training class, where new participants of a group in Second Life learn the basics of building. The group's theme is the Star Trek television series. The group has several activities, among which stands out the construction of objects related to the series, with particular emphasis on the production of spaceships. Thus, it is of great importance for the group's goals to teach newcomers how to build a variety of objects.

4.2. Scenario

For the scheduling of the class, a Second Life group notice was used with date and time (this is a typical text message that is broadcast to all group members). The class was held in an empty space, commonly called "sandbox" in the context of Second Life (regardless of whether it has any actual sand or whether it is an actual box or – most likely – not), large enough to build even space stations. This sandbox space had many participants moving around, positioning themselves close to some of the objects, and often facing them. It was possible to observe beams of light balls coming out from the hands of some of the avatars towards some of those objects. These are Second Life's cues to indicate that an avatar is editing an object, so it was no surprise that the presence of those beams coincided with striking visual changes in the objects to which they were emitted. The class consisted of several avatars, dressing uniforms and bearing titles visible as text hovering above their heads, identifying them as several cadets, two junior officers who constituted the instruction team, and a senior official responsible for the supervision, as explained by one of the instruction team members. Participants unaware of the significance of titles and uniforms could check them in a text file, which alongside others (with rules, schedules, activities, etc.), as well as uniforms, titles, and other objects, are available to group members at a dedicated warehouse. Usually, these resources are informed to newcomers by a host.

4.3. The class observation summary

As soon as all participants gathered around the instruction team, forming roughly a circle, the instructor used the voice channel to present himself, welcoming everyone, and to transmit certain operating rules for the class. Besides rules, the roles of each instruction team member were also transmitted to the group, as well as a summary of the program for the class. The instructor offered to explain while demonstrating, and began to do so. While explaining, an object came up in front of him. A beam of light balls coming out of his hand towards the object pointed out he was editing it, and indeed changing as mentioned by the instructor. Students emitted similar beams towards objects that appeared before each of them. This indicated which object each one was editing, and those objects started to change shape as the instructor's had. After explaining using voice communication how to control the most basic properties such as shape, position,

and dimensions, and a few others, the instructor started to talk about the control of color and texture of objects. He mentioned that he would render a chair, and a chair appeared in front of his avatar, after which he urged the group of cadets to make an equal one as an exercise. He also said he would distribute a texture to be used in the chairs, using Instant Messaging (IM) as a means of distributing the resource containing the actual texture. Several objects came up on the ground near each other, as a sort of grouping, before each student. Again, beams of light balls were emitted from the hands of the avatars towards the objects that began to change shape, position, or texture. Further along in the class, the overall position of those groups of objects relative to each other revealed them to be chairs similar to the instructor's. Sometimes, some students issued messages in text chat, or made their avatars start animations/sounds such as waving and whistling. Upon occurrence of those animations or sounds, the instructor and assistant would address the source avatars, communicating by voice. It was observable that sometimes from the hands of the avatars of the instructor team, beams of light balls would come out again towards the objects in front of the students, changing them. After everyone finished the exercise, with varying degrees of success, the class was declared ended by the instructor.

4.4. Evidence collection in the pilot case

The evidences were drawn directly from the description of the above case. Thus, each reference to the use of a feature or behavior was accounted as evidence, relating it to one or more units of analysis, according to the impact of the evidence described in the unit. Not all of the units of analysis have evidences in this case. Table 1 summarizes the evidences of the units of analysis for the avatar, with a brief description of the reference of the case description. Similarly, Table 2 summarizes the evidence of units of analysis for the physical space.

4.5. Evidence analysis in the pilot case

To analyze the collected data, several evidences were related in order to create a chain of evidences to support each of the propositions mentioned above. Table 3 summarizes the propositions and the chains of evidences supporting them. Each proposition has one or more chains of evidences, each beginning with an evidence of a unit of analysis directly related to the proposition, as shown in Table 3. The other elements of the chain may or may not be from the same unit. In some cases, evidences taken directly from the case were added to help clarify the relationship.

The first proposition related the appearance of the avatar, is supported by the fact that all participants' avatars wear uniforms. The meaning of the different uniforms is available either textually or verbally. Referring to gestures and sounds, the second proposition is sustained by the reaction the instruction team had in assisting the students, when some of them used gestures and sounds, sometimes accompanied by messages in chat. The proposition on the direction of movement, eye gaze/head direction or avatar placement is supported by two chains of evidence. The first is related to the movement of other avatars who do not participate in class, but their physical attitudes, gestures, and interaction on objects, reveal their activities. The second chain starts at the reunion of students around the instruction team, which triggered the beginning of the instructor's exposition. The following proposition, related to interaction with objects, is also

supported by two chains of evidence. The first is based on the object used by the instructor to reflect the intentions expressed by him, leading students to imitate his actions. The second, it is based on the exercise proposed by the instructor, which urged the students to build a similar chair to the one presented.

Table 1. Evidences of the units of analysis related to the avatar

Units of analysis	Evidences
Appearance	All participants' avatars were dressed with uniforms.
Gestures made	Beams of light balls could be seen coming out of the hands of some of the avatars.
	A beam of light balls was emitted from the hand of the instructor towards the object of exemplification.
	Students emitted similar beams towards objects that came up before each of them.
	During execution of the chair-building exercise, light beams where emitted from the hands of several avatars towards objects that changed shape, position and texture.
	Beams of light balls would be emitted from the hands of the instruction team towards objects of students, changing them.
Sounds emitted	Some students made calling gestures and/or sounds such as waving and whistling.
Direction of movement	Instructor and assistant walked towards the students.
Avatar placement	The sandbox had several participants moving around, positioning themselves near some of the objects and often facing them.
	Participants gathered around the instruction team, forming roughly a circle.
Visual artifacts used for interaction	Visible changes of the physical objects near avatars were observed.
	The instructor's object reflected the changes mentioned by him.
	Objects near students changed in a similar manner to the instructor's.
	The instructor rendered a chair.
	Objects appeared in apparent groupings in front of each student.
	Students' objects changed shape, position and texture.
	Light balls were emitted by the hands of the instruction team towards objects of students, changing them.
	Objects in front of each student assumed a spatial positioning resembling a chair.

Table 2. Evidences of the units of analysis related to the physical space.

Units of analysis	Evidences
Non-animated visual artifacts	The instructor used an object for demonstration.
	The instructor rendered a chair.
	Objects appeared in apparent groupings in front of each student.
	All avatars had text titles visible over their heads.
Non-visual artifacts	The scheduling of the class was provided by a group notice with date and time.
	Text notes with rules, schedules and activities, are available to group members, as well as uniforms, titles and other objects.
	The instructor distributed a texture using IM.
Visual environment	The class was held on a large empty space ("sandbox").

TABLE 3. Propositions and evidences/units of analysis related.

Proposition	Evidences	Related Evidences	Additional evidence
The appearance of the avatar influences the perception by others, of the role of the avatar's user and/or his attitude.	All participants had uniforms.	Text files, with rules, schedules and activities, are made available to group members, as well as uniforms, titles and other objects.	The interpretation of titles and uniforms is available in text files. This and other texts (with rules, schedules and activities, etc.), as well as uniforms, titles and other resources, can be obtained in a warehouse. The instructor transmits some rules, including the roles of each of the instruction team member.
The gestures and sounds that the avatar does influences the perception by others about how the user in question wants to collaborate or how he or she wants others to collaborate.	Some students made gestures and/or sounds such as waving and whistling.	Instructor and assistant moved towards the students. The instruction team emitted light balls beams towards objects of students, changing them.	Some students used messages in chat, or made animations and/or sounds, after which the instructor and assistant addressed those students, communicating by voice.
The focus, walk direction, or position of avatar provides clues about what the user is paying attention, or what the user would like the attention be paid to.	The sandbox had several participants moving around, positioning themselves near some of the objects and often turned at them. The participants gathered around the instruction team, forming roughly a circle.	Beams of light balls came out of the hands of some of the avatars within the sandbox. Visual changes in the physical objects near avatars were observed. The instructor used the voice channel to introduce himself, welcome everyone, and transmit rules.	
Interaction with certain objects by the avatar also provides clues about which ones are intended to be used in the collaboration.	The instructor used an object for demonstration.	A beam of light balls was emitted from the hand of the instructor towards the object of exemplification The object reflected the changes mentioned by the instructor. Students emitted similar beams towards objects that came up before each.	
	The instructor rendered a chair.	Objects near the students changed in a similar manner to the instructor's. During the chair exercise, light beams where emitted from the hands of several avatars towards objects that changed in shape, position and texture.	The instructor mentioned that he would render a chair, and a chair appeared in front of his avatar, after which he urged the cadets for each one to make a similar chair.

The arrangement of objects and how they are grouped reveals clues of its usefulness for collaboration.	Visually grouped objects came up in front of each student.	The objects changed shape, position and texture. Objects in front of each student were assembled in a visual placement resembling chairs. The instruction team emitted light balls beams towards some objects of students, changing them.	
The exchange of artifacts or objects, their features, and their usefulness, helps to define the team, contributing to the group consciousness and correct perception of collaboration, that is, awareness.	The scheduling of the class was provided by a group notice with date and time. They all had titles visible over their heads.	The participants gathered around the instruction team, forming roughly a circle. Text notes with rules, schedules and activities are available to group members, as well as uniforms, titles and other objects.	
	The instructor distributed a texture using IM.	During the execution of the chair exercise, light beams where emitted from the hands of several avatars towards objects that changed in shape, position and texture.	The instructor distributed a texture to be used in the making of the chair.
The environment, including lighting, sound or music, and visuals, influences the attitude of collaborators.	The class was held on a large empty space.	Beams of light balls were seen coming out of the hands of some of the avatars within the empty space. Visual changes in the physical objects near avatars within the space were observed. The participants gathered around the instruction team, forming roughly a circle.	There is a cultural term in Second Life for designating such empty spaces for building: "sandbox", regardless of having actual sand or whether it is within a box or not.

The next proposition, about the arrangement and grouping of objects, is based on the fact of the objects that students have in groups near them, having their properties changed to form chairs. This fact is so revealing of completion that the instruction team, when addressing some participants to assist them, used some of these groups of objects for assistance of others.

The proposition related to the exchange and use of objects and artifacts is sustained by three chains of evidence. The first is related to the fact that the participants have gathered at the date and time scheduled by a group notice. In the second chain, the titles clarify each participant's role in the group. And in the third chain the texture's function confirms the intentions of the instructor. Finally, the proposition concerning the environment is supported by the fact that the class has taken place on a site whose purpose is to render and build objects. This purpose is supported by its visual properties:

being large and empty, perhaps with a few scattered disorganized artifacts resulting from previous building exercises, which for users of Second Life are all cues enabling the identification of the space as a "sandbox".

5. Conclusion

In this paper we presented the first steps for creation of a protocol for case study research of Presence and Cooperation in virtual worlds, according to Yin's methodology. The propositions were defined and validated with a pilot case. Thus, these propositions and units of analysis can be used in future research for evidence collection on 3DVW when used for collaboration.

The pilot case was held on Second Life, in a usual scenario, and with a well known and easy to recreate subject: a class to teach how to build objects. After the description of the case itself, we analyzed it by extracting from the description examples of behaviors related to each unit of analysis. Then, chain of evidences were created by relating evidences based on the fact that each time a behavior of a avatar or group of avatars, had as consequence, behaviors on other avatars. These cause/consequence relations where used to support the propositions. It was possible to find at least one chain of evidences for each proposition. This process can be replicated with more case studies to provide multiple sources of chains to support the propositions in order to have enough confidence on them, and only then, share them.

Acknowledgements

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