

## **Non-verbal Aspects of Collaboration in Virtual Worlds: a CSCW Taxonomy-development Proposal Integrating the Presence Dimension**

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**Abstract:** Virtual worlds, particularly those able to provide a three-dimensional physical space, have features that make them suitable to support collaborative activities. These features distinguish virtual worlds from other collaboration tools, but current taxonomies of the field of Computer-Supported Cooperative Work do not account for several distinctive features of virtual worlds, namely those related with non-verbal communication. We intended to find out how the use of an avatar, gestures, spatial sounds, etc., influence collaboration in order to be able to include non-verbal communication in taxonomies of the field Computer-Supported Cooperative Work. Several cases of collaboration in virtual worlds are analysed, to find the impact of these non-verbal characteristics of virtual worlds. We proposed adding the concept of Presence to taxonomies of Computer-Supported Cooperative Work and contribute with guidance for future taxonomy development that includes it as a new dimension. This new dimension of Presence is subdivided into "avatar" and "physical space" subdimensions. In turn, these are divided into "physical appearance", "gestures, sounds and animations" and "focus, nimbus and aura"; "environment" and "objects / artefacts". This new taxonomy-development proposal may contribute to inform better design of virtual worlds in support of cooperative work.

**Keywords:** Presence, collaboration, taxonomy, 3D virtual worlds, CVEs, CSCW, development of CVEs.

**Categories:** H.4.3, H.5.2, I.6.3, I.6.7, L.5.0, L.5.1

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## 1 Introduction

Three-dimensional virtual worlds (3DVWs) are Collaborative Virtual Environments (CVEs) capable of supporting collaboration for work, social interaction or games [Benford et al., 2001][Yee, 2006] [Pinkwart& Oliver, 2009], and are pointed as having suitable features for collaboration between people. This may be due to them providing the simulation of a world that is familiar to us, because 3DVWs reproduce similar rules to the world in which we grew as individuals. They provide an immersive world, easily understandable by analogy to one's personal life experience, along with common collaboration tools (for example, text chat, instant messaging, etc.), hence raising the expectation of being usable with advantages for collaboration [Owens et al., 2009].

How can we know, with reasonable accuracy, the real capabilities of 3DVWs for collaboration? Collaboration has long been studied within the field of Computer Supported Cooperative Work (CSCW), which addresses the design of computer systems to support cooperative work [Bannon & Schmidt, 1989], and encompasses the activities of planning, coordination, communication, monitoring, and establishment of rules [Ferraris & Martel, 2000][Dommel, 2005].

In the CSCW field of study several taxonomies were created to classify and describe the tools used to support collaborative work. There is a high number of such CSCW taxonomies, due not only to the proliferation of new systems, but also due to their incapacity to combine the social and technical aspects of the tools [Cruz et al., 2012]. Since these reflect the core dimensions of study in CSCW, classifying tools according to their features that are most relevant to collaboration, a reasonable expectation was that using these taxonomies to classify 3DVWs would provide insights on their value to CSCW.

However, 3DVWs' characteristics are capable of supporting collaboration both for work and for social interaction or games [Benford et al., 2001][Yee, 2006] [Pinkwart& Oliver, 2009]. In these latter situations the social and technical aspects are paramount, and the suspicion aroused that these aspects might not be adequately covered by CSCW's taxonomies, which would make these taxonomies less appropriate for classification of 3DVW. These social interaction features in 3DVWs include all those that can be used more intuitively by users, by relating them to their personal life experience in the physical world, such as the use of embodied personas (avatars), the ability to interact with the spatial organization of the virtual world (to touch and reorganize objects, to move in space) and the thematic and contextual nature of the encompassing environment [Owens et al., 2009] [Hendaoui& Thompson, 2008]. In a previous work [Cruz et al., 2014], we demonstrated that these features are not adequately addressed by current CSCW taxonomies, by analysing them using a comprehensive taxonomy [Cruz et al., 2012]. Thus, CSCW taxonomies are inadequate to guide the design of virtual worlds for conducting computer-supported collaborative activities. Since the social interaction characteristics of 3DVWs are addressed by the theoretical field of Presence, the inspiration for this work was to bring the theoretical framework of Presence to CSCW taxonomies. The expectation was that such a combination, would make possible to classify more appropriately 3DVWs when used for collaboration, and thus contribute to better their design in support of cooperative work. Avatars, gestures and expressions, themed environment, as well as a three-dimensional space one can move within, are characteristics that have significant impact

in collaboration by enhancing communication, contributing to awareness, and promoting the sharing of artefacts, socialization, and team building. These characteristics, being that important for collaboration in 3DVW, should therefore, be considered relevant under the theoretical models of the CSCW community, and taken into account in future developments of these models. It is postulated that, without this improvement, these models will no longer be adequate to support the development of systems based on 3DVW for collaboration. By this, it will be lost, or at least postponed, the opportunity to have available tools that may be more intuitive, and probably easier to use in collaborative situations, increasing the productivity of the group.

## 2 CSCW

The concept of CSCW was coined to define the scope of cooperative work (CW), a social phenomenon characterizing the group work, when conducted with computer support (CS), i.e. computational technologies that support collaboration [Schmidt, & Bannon, 1992]. Currently, the CSCW field looks into activities and practices that range from planning, construction, and management, to negotiation, applied to intellectual tasks, games, mass production, or even mechanical assembly, as can be verified in the 3C model [Ellis et al., 1991]. A related concept, groupware, refers to the technology itself, used as a support for group work, and is usually referred to as computer-based system supporting the work of groups of people involved in common tasks or purpose, also providing an interface for shared environment [Ellis et al., 1991].

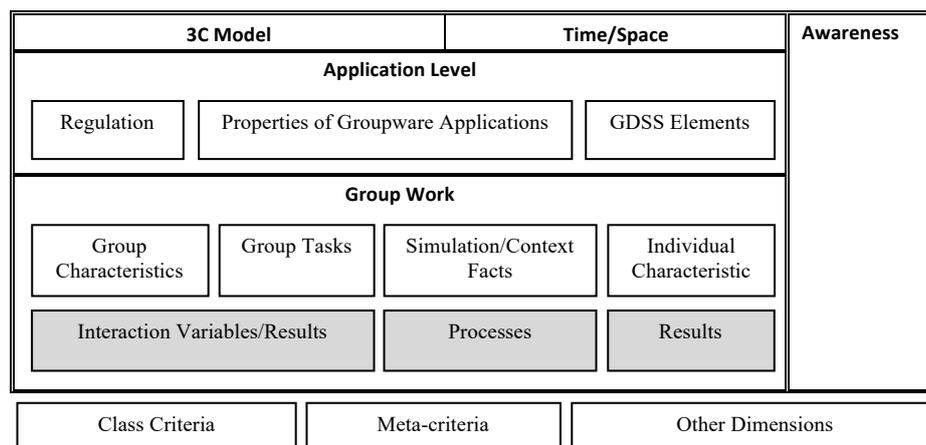


Figure 1 – Comprehensive model of CSCW [Cruz et al., 2012]

There are many taxonomies of CSCW with substantial differences between them. According to Johnson [2008], the creation and improvement of systems of classification and taxonomies are a crucial process in the development of theory. In this section we summarize a comprehensive classification model arising from those taxonomies, which categorizes the requirements of collaboration for the development of groupware, with attention to social aspects [Cruz et al., 2012]. This model brought continuity to the

dimensions of collaboration, creating terminological consensus for the categories proposed in literature (Figure 1). It shows the sociotechnical requirements for collaboration, basing its organization on the distinct categories of the field. This model addressed the lack of consensus on the conceptual framework of cooperative work and groupware by comprising technical requirements and social dimensions of work. The taxonomic elements were entirely based on CSCW and groupwork literature. Its blocks and meta-blocks establish a set of hierarchically structured domains.

### **3 Three-Dimensional Virtual Worlds, Presence, and Collaboration**

3DVWs are online graphical simulated realities, where multiple users interact via embodied personas within a common environment. These simulations began to appear in the early 1990 [Koster, 2002], and can be viewed as the combination of three-dimensional gaming environments with social interaction systems such as Multi-User Dungeons (MUD) [Castronova, 2001]. The embodied personas – avatars – as social interaction metaphors are the defining characteristic of these platforms [Morgado et al., 2012]. The avatars, as virtual representations of each user, become their means of interaction with the virtual world, affecting and being affected by it.

These immersive participation of avatars within virtual worlds is a case of what Minsky [1980] defined as Telepresence: the "feeling of being physically present in a remote environment mediated system's interface", and of what Sheridan [1992] defined as Presence: the "feeling of being physically present with virtual objects in place remote teleoperated". Steuer [1992] distinguished "presence" from "telepresence", with "presence" referring to the natural environment, and "telepresence" referring to the lack of a mediated environment. Lombard & Ditton [1997] argued that presence is achieved when the user does not acknowledge, or does not recognize the mediation and therefore, that the feeling of Presence cannot be achieved without a medium. Thus, there would be no need for the use of the term "telepresence" since both terms refer to the same thing. The term "presence" is the most used when referring to "the feel of the participant to be there" [Barfield et al., 1995], "the perceptive illusion of non mediation" [Lombard & Ditton, 1997], "a State of consciousness, the feeling of being in the (psychological) virtual environment" [Slater & Wilbur, 1997], or "the subjective experience of being in a place or environment, even when the person is physically located somewhere else" [Witmer & Singer, 1998]. From these definitions, it is clear that presence is independent of the technology used or medium, and there are in fact, authors who argue that the theory of Presence must be applied to all environments mediated, including television [ISPR, 2013] [Lombard & Ditton, 1997].

Some authors distinguish different types of Presence. Heeter [1992] defines three dimensions of Presence: personal presence, social presence, and environmental presence. Personal Presence refers to the feeling of being in a virtual world, and is based on the simulation of real-world perceptions, familiarity with the world, and experience in the use of the world; Social Presence refers to the existence of other beings in the world, and the interaction with them, whether they are other users or agents; Environmental Presence refers to the ability to interact with the virtual environment. Biocca [1997] also defined three types of presence: physical presence defined as the simulation of the virtual world in such a way that is perceived in a manner similar to

the real world; social presence as the feeling of the user being in interaction with another intelligence; and auto presence as the mental model the user has of himself/herself in the virtual world.

Romano et al. [1998] say that collaboration is related with a strong sense of shared presence. On the other hand, Kaltenbrunner & Huxor [2000] state that immersion and presence research developed using 3DVWswere created especially for simulation and games, and its conclusions do not relate 3DVW to CSCW. But these authors are the exception. The literature consensus is that immersion [Roman et al., 1998][Kaltenbrunner & Huxor, 2000][Romano & Brna, 2000][Sadagic et al., 2001][Jordan et al., 2002][Otto et al., 2005], non-verbal communication [Thie & Wijk, 1998][Bente, & Krämer, 2002][Bente et al., 2004][33-38][Gül, 2008] and interaction [Otto et al., 2005][Franceschi & Lee, 2008][Romano & Brna, 2002][Manninen, 2001][Swinth & Blascovich, 2002][Gyorfi et al., 2006] are important to create the feeling of presence.

However, exactly how presence relates to collaboration is not explained in the current literature. In fact, the relationship between the theory of collaboration within CSCW, and presence as found in 3DVW research, is not clear. However, some facts reported in the literature suggest a relationship between collaboration and presence. Non-verbal communication, including clues to social presence (proximity, direction, touch, focus, and physical appearance), as well as the use of avatar, provides a feeling of presence and is important for communication [Thie & Wijk, 1998][Bente et al., 2004][Rae et al., 2008][Swinth & Blascovich, 2002]. In addition to that, non-verbal communication can be used to provide group awareness [Bente et al., 2004], and support of collaborative tasks in general [Franceschi & Lee, 2008]. The field of vision, manipulation techniques, and navigation capabilities improve interaction, and the immersive environment created by 3DVW promotes cooperative tasks [Otto et al., 2005]. These facts clearly reveal a relationship between collaboration and presence, since communication, awareness, interaction, and cooperation are directly related to the collaboration.

On the one hand, Biocca and his colleagues [Biocca, 1997][Biocca et al., 2003] define physical presence as the simulation of the virtual world that is perceived in a similar way to the physical world. On the other hand, because we humans understand well the physical world, also 3DVW are easily understood in the same terms and can be effectively used for collaboration [Owens et al., 2009][Dreher et al., 2009]. And also, Romano & Brna [2002] found that low levels of collaboration are coincident with a low feeling of presence, or none, by the participants. It is possible that collaboration can exist without presence, but a strong sense of presence can improve collaboration, because perceiving the simulated world as if it was real, makes it easier to understand it.

Presence in the virtual world is strongly influenced by the themed environment (the contextual visual theme of the virtual space), the avatar, and features such as gestures and avatar customization [Lombard & Ditton, 1997][Stuer, 1995][Hendrix & Barfield, 1996]. By *virtual space* we mean the computer-generated space, including objects, colours, lighting, and sounds. The way the psychological process of presence happens, and the reasons for various types of presence, are not known [ISPR, 2013], and therefore, the way in which the environment, the avatar, and other 3DVW features, contribute to improving presence, are not explained yet.

## 4 Methodology

To clarify how the non-verbal communication characteristics of 3DVWs can influence collaboration, we observed and analysed collaborative situations in which these characteristics are used. There have been efforts on these situations, hence they are situations in which there are no variables defined, and also it was not intended to prove any theory with the studies performed, but to deepen the knowledge of those situations. This, as well as the subjectivity of non-verbal communication intrinsic to each situation, and the expected complexity of the analysis, led to the conclusion that quantitative methodologies were not suitable for this work, therefore the choice was to use qualitative methodologies.

In 3DVWs, features like gestures and emotions are used to produce behaviours that reflect social symbolisms, as culture, ethnicity and religion [Olds et al., 2005][Yin, 2009][Case & Light, 2011]. The themed environment is also used to influence the state of mind and mood of users, helping them socialize [Olds et al., 2005][Yin, 2009][Case & Light, 2011]. These behaviours are complex, subjective in nature, and are difficult to separate from context. These are good reasons to choose a qualitative methodology, due to the subjectivity of the situations, the lack of known variables, and the scarcity of studies of these situations in 3DVWs.

It was not intended to improve any process or develop any theory; thus, action research and grounded theory were excluded. We considered the possibility of conducting ethnographic studies, which include observation of situations in their real context, but in ethnographic studies the aim of the observations is stronger on social and cultural relations. Such studies could also be an interesting way to study the use of features such as gestures and emotions, to better understand how they are used in social symbolisms as culture, ethnicity, or religion in 3DVW, but our objectives relate to more specific relationships, already foreseen in current CSCW taxonomies, such as communication and awareness. So, for this work we used the case study methodology, by focusing it on how non-verbal communication affects 3DVW collaboration.

Probably the most common and natural method of research, observation, allows the researchers to collect data for their studies directly, that is, without the use of any other instrument and in the first person. This method will be used for data collection in the cases reported further in this work, because it is simple, and because it allows for autonomous data collection. This method can be easily applied through instant messaging, or even voice conversations, therefore we preferred it to questionnaires, which would not guarantee full participation and recording of all collaboration events.

In this work, the focus of the research questions is on how non-verbal communication affects collaboration in 3DVW. This general concern can be specified as two questions:

RQ1-how does the use of an avatar influences collaboration in 3DVW?

RQ2-how does the virtual space influences collaboration in 3DVW?

To answer these questions, we started by establishing several propositions related to the subjects of the research questions. Afterwards, the truthfulness of these propositions was tested by searching for supporting evidence. Thus, we propose a set of propositions related to non-verbal communication and the impact it can have on the

collaboration, based on expectations of the research on 3DVWs and Presence, referred to in previous sections. These propositions are based on relationships between the various distinctive features of 3DVWs for collaboration. Therefore, the propositions were defined for the characteristics related to the avatar and physical space.

Units of Analysis	Research Question 1				Research Question 2		
	Propositions						
	1	2	3	4	5	6	7
Appearance	X						
Gestures made		X					
Sounds emitted		X					
Eye gaze			X				
Facial demeanor			X				
Facial orientation			X				
Direction of movement			X				
Body position		X					
Avatar placement			X				
Visual artifacts used for interaction	X			X	X	X	
Animated visual artifacts or artifacts for interaction					X	X	
Non-animated visual artifacts					X	X	
Non-visual artifacts					X		
Visual environment							X

Table 1 – Distribution of the propositions throughout the unit of analysis

The characteristics related to the avatar (propositions 1 to 3) are the physical appearance, gestures, sounds, and eye gaze. The characteristics of the physical space are related to objects/artefacts, their usefulness, layout, and theme of the environment (propositions 4 to 7). Note that the proposition 4 relates the avatar with the physical space, however, the emphasis is on objects used for interaction. The propositions are the following:

P1 - the appearance of the avatar influences the perception by other users, of the role of the user of the avatar and/or his or hers attitude.

P2 - the avatar uses gestures and sounds to influence the perception by other users, about how the user in question wants to cooperate, or how he or she wants others to collaborate.

P3 - Eye gaze or direction, direction of movement (such as motion of the avatar), and position of the avatar, provides clues about what the user is paying attention to, or about what the user would like others turn their attention in to.

P4 - The interaction of the avatar with specific objects provides clues about which objects are intended to be used by other people in the process of collaboration.

P5 - The disposition of objects (for example, collocation or alignment) provides clues to their purpose for collaboration.

P6 - The transfer of visual artefacts (i.e., „objects“, „clothes“, „tools“) between avatars, with specific and explicit visual resources, helps to define the team, contributing to the perception of the roles for collaboration in a group.

P7 - The characteristics of the virtual space, such as light, sound or music, visual effects, aesthetics, among other, influence the attitude of the users collaborating.

We have also defined units of analysis both for avatars and for the virtual spatial environment. Referring to the research questions, the units of analysis for avatars used are: “Appearance”, “Gestures made”, “Sounds emitted”, “Eye gaze”, “Facial demeanour”, “Facial orientation”, “Direction of movement”, “Body position”, “Avatar placement”, and “Visual artefacts used for interaction”. And the units of analysis for the physical space are: “Animated visual artefacts (animated objects) or artefacts for interaction” (i.e. pose balls), “Non-animated visual artefacts”, “Non-visual artefacts” (e.g., scripts), and “Visual environment” (e.g., what kind of place the action is taking place in). Table 1 shows the distribution of the propositions throughout the units of analysis mapped under the research questions.

## 5 Case Studies

In this section we presented the cases from which we extracted chains of evidence related to the case study protocol, which are examined in the next section.

### 5.1 First Case – Apella Meeting

This case it is about a meeting held in Second Life by users belonging to the same RPG (Role Playing Game), The Spartan Empire, which belongs to a category known as Ancient Worlds that recreates ancient empires. The main activities of these RPGs include battles and tournaments between the empires.

The meeting is open to all members, and is scheduled weekly for every Tuesday at 12 hours (Second Life Time, a virtual time zone matching Pacific Standard Time in the USA) on the calendar (Figure 2a). In these meetings they discuss matters related to the game. Minutes before it starts, the event is recalled to all members by Instant Messaging (IM). All the discussion takes place in local text chat. These meetings are also used to announce the allocation of new ranks or distinctions. So, two examples will be presented: a discussion of several issues related to the game (situation A); and a promotion of a member (situation B).

#### 5.1.1 Scenery

The location, for both situations, is a dedicated building called the Apella (Figure 2b), in a land whose architecture and decoration recreate the ancient city-state of Sparta. This recreation is not entirely historically accurate. The predominant architecture is similar to that used at the time in Greece, and there is a dress code that requires players to wear clothes of that era, although no historical accuracy is required. Clothing, note cards with several information, rules, objects, animations, among others, are part of a package available to members, near to the entrance of a building named the Arena (Figure 3a), belonging to the same land.

As in many other cases in Second Life, avatars of this RPG bear text boxes over their heads announcing the role or hierarchical position that each one occupies. By these

text boxes it is possible for example, to check that the King chairs the meeting. It can be seen by the same text boxes that the top spots are occupied by avatars with positions of higher hierarchy, and in the audience sit the other participants (Figure 2c). In the roles of the group, it can be seen that the King in fact, owns the land. This avatar bears a crown on the head, and there is a red carpet that extends from the entrance to the chair of the King. This and the remaining chairs are arranged in an arc around a pedestal. To sit, users must select the intended location and click on right-side mouse button. A menu appears and by selecting "sit", the avatar takes the sitting position. The King and the Queen Mother are found sitting, while other avatars near them are standing despite the rule of everybody having to be sitting during the meeting, except with the authorization of the King. Also, no one is allowed to enter after the beginning of the meeting or to leave before its end. The remaining participants sit on benches flanking the enclosure and apart from the chairs. These participants are spread with several vacant seats between them.

Some of the avatars that are standing bearing Greek culture-related titles. They are around the King, except for one who is at the door, and another near the centre of the enclosure, which speaks via chat after authorization of the King. Some of them wear martial attire, such as a helmet and a cape, and two of them, identified as guards, have swords and shields. The avatar next to the door is identified with the title as a guard too, with swords in sheath. The three guards are the only ones with weapons. Some avatars appear after the start of the meeting, and they sit on chairs without leaving vacant seats between them (Figure 2d). In the bench area nobody came in late.

While most avatars employ sitting poses with straight backs, parallel legs and hands on the thighs, both the King and a Princess have their legs crossed. The arms of the King are laid over the armrests of the chair, and the Princess has arms crossed. Probably both are using an Animation Override (AO). The AOs allow an avatar to assume a pose selected by the user, for a given position of the avatar, instead of the one provided by an object, in this case the chair. Another case of the use of AOs is the avatar that is standing to the left of the King. This avatar leans to one side and then to the other, crossing the hands in different ways (Figures 2c to e) standing out from others who are in fixed positions.

### 5.1.2 Case Summary

In the first situation, situation A, the King and his entourage enter along the red carpet onto the chairs, where King and Queen Mother sit. The King gives order to close the door by chat. The King begins to speak for a few minutes and the words of the King appear in chat, ending by assigning the word to a given avatar. The avatar whom the King has given the word, stands up and the chat shows what that person is writing. Some avatars perform a war yell at the same time they make an animation of fist raised (Figure 2e). Later, the King says in the chat that gives the word to another avatar. It is seen on chat what that user is writing. War yells are heard, and some avatars are seen performing the animation of a raised fist, including the King. This is repeated several times. In some cases, just after they started to speak, battle cries are performed by those who the speakers had yelled cries at before. In the end, the King announced his decision about the subject in hand. Then, a new theme began, in all aspects similar to the one we described. This was repeated over several different themes. Finally, the King

announced by chat the end of the meeting, and all the avatars abandoned the place after the King and his entourage (Figure 2f).

In situation B, the King stood up and called for an avatar using the chat. The avatar that was called up stood up and walked to be positioned in front of the King. Then the avatar knelt before the King. The King announced a new rank for the avatar, and the avatar rose and returned to its original place. There were several battle cries performed by other participants, as well as its associated animation.

## 5.2 Second Case – Tournament

This case it is about a tournament held in Second Life by users belonging to the same RPG, again, The Spartan Empire. The tournaments are scheduled in advance in the existing calendar on the land (Figure 2a). Usually, an event reminder is also sent through IM to all members.



Figure 2 – Left to right and top to bottom, figures a to f

### 5.2.1 Scenery

The location of the tournament is the same as the previous case but now, in a building called the Arena (Figure 3a). This building has a large and wide rectangular space in

the centre. It also has two porches, one in front and another on the left. The architecture is also similar to that used at the time in Greece. In those porches, there are a few benches, but most of the avatars are standing. The avatars are wearing clothing which includes elements such as helmets, armour, weapons, and other combat-related items. At the top left corner of the porch there are four chairs, one of which stands out for its armrests and pose balls with floating text reading "sit" (Figure 3b). Only one of these chairs is occupied by an avatar who is sitting in the far-left chair. By the title of that avatar, it is someone of high hierarchy.

### 5.2.2 Case Summary

The avatars positioned themselves around the porch facing the arena (Figure 3a). One of the avatars was identified as Commander in a text box over its head (Figure 3c). This avatar said in the chat that those interested in participating in the tournament had to touch a panel. By touching that panel, it displayed the name of the avatar that touched it. This Panel also displayed the results of the tournament as it played out.

The avatar identified as Commander said in chat the names of two avatars. After that, these avatars moved to the middle of the arena positioning themselves face to face. The two opponents adopted bodily positions of fighters (Figure 3d), as well as facial expressions, such as open mouths and frowned eyebrows. The avatars had separate meters which measured the levels of "life" of the fighters.

The Commander started the fight by announcing it in chat (Figure 3d). The fighting movements of two opponents were visible, as well as their levels of "life" diminishing. Finally, one of the opponents fell on the floor without "life". His meter sent a message in chat telling who won and who was defeated, being the defeated the one who fell. In the panel with the names of the participants, the name of the winner was shown, meaning he/she should advance in the tournament (Figure 3c). In this manner, the fighting went on until the final match. At the end of the tournament, the three names on the top positions of the Panel were called by the avatar identified as Commander, again in chat. After being called, those avatars were seen occupying the places in a podium located in front of the Commander. Those occupied places matched the results of the fighting. Then, in chat appeared messages congratulating the winners, sounds of applause were heard, and trophies appeared in the hands of the avatars on the podium (Figure 3e).

## 5.3 Third Case – English Class I

This case it is about an English language class held in Second Life. The school is called English as Second Language and provides separate classes for a fee. The schedule of classes is on a panel at the arrival area of the land (Figure 4a) or can be found on the Web. The participation in these lessons requires the use of voice. In this description, the voice is used exclusively thus, even if it is not referred to this fact, should be considered that all dialogs use the voice medium. In Second Life, avatars with enabled voice chat have a white ball that hangs over their heads. When one speaks, around that white ball green arcs appear resembling a volume indicator, which changes according to the variation of intensity of the voice heard. With this there is a means to figure out who can speak and who is talking.

### 5.3.1 Scenery

The class takes place in a room with simple furnishings and plain décor (Figure 4b), similar to a physical classroom. It has boxes arranged as an amphitheatre which, in this case, were used as seats. On the opposite side of the boxes, there is a small stage near the wall, and in the wall, there is a panel with the symbol of the school.

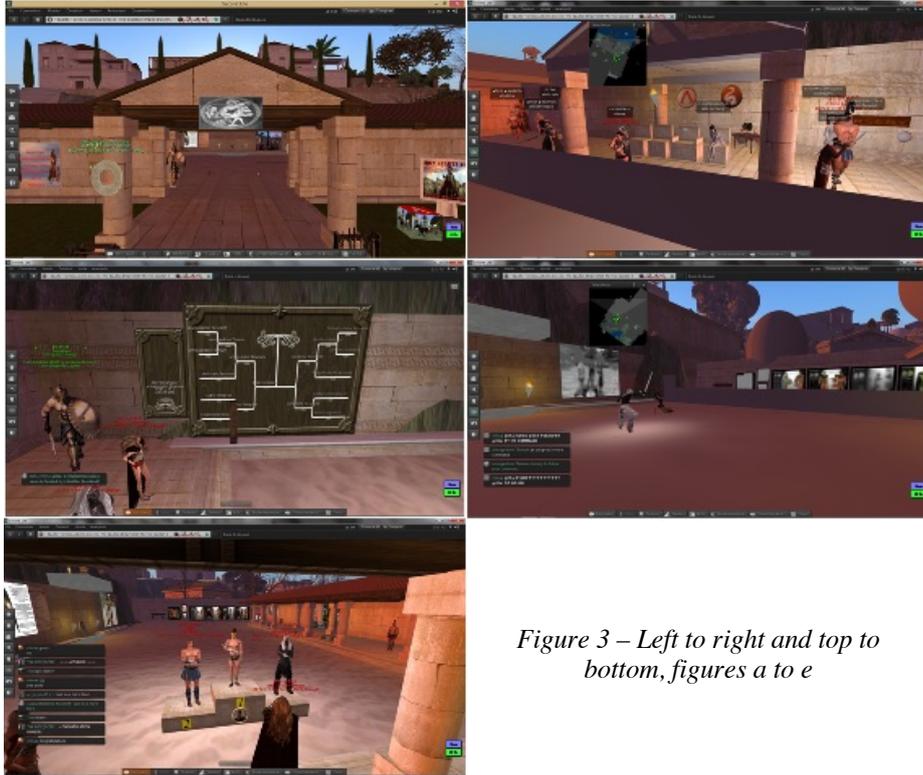


Figure 3 – Left to right and top to bottom, figures a to e

### 5.3.2 Case Summary

Minutes before the class starts, the observational researcher received an IM from his contact at the school. This contact was noted on the calendar as being responsible for this class. The IM informed that a lesson was going to take place and included a link. Following that link, one arrived in the school. There was there the avatar that contacted the researcher, as well as two other avatars. Several voices could be heard, accompanied by the graphics of the voice chat over their heads. The avatar leading the class (henceforth, “teacher”) said that one of the avatars was being heard very well. Then, he greeted the researched and ask him if the researcher could use voice chat. The researcher answered “yes” and greeted all the people present. The teacher questioned the researcher if he could hear him well, to what the researcher answered “yes”. He answered back, saying that he also listened well. The teacher said that was time to go to the classroom. He asked us to follow him, and he walked to a grey circle on the floor.

He positioned himself facing the circle and next to it. Then, he told the group to touch the circle and, after taking the position of sitting on the circle, his avatar disappeared. By touching the circle, the researcher's avatar took the position of sitting over the circle, too, and then was transported to another similar circle in a room.

This type of objects is known in Second Life as "teleporters". Looking around by turning the avatar to one side and the other, the researcher observed the room, saw the teacher, as well as other avatars who had been with him before the teleportation, and emerged on the grey circle (Figure 4c).

The teacher asked the group to sit down. The other avatars entered the room and sat on the front row of boxes, facing an image across the room (Figure 4d). The researcher sat his avatar on one of the available boxes, by positioning the mouse on it, opening the right-click menu, and selecting „sit“. The researcher's avatar assumed the position of sitting towards the image. The teacher disappeared. After a few minutes, he came back. The image on the wall had been replaced by the poster of the school. The teacher stood, positioned next to the stage, with his back to the poster, facing the other avatars (Figure 4e). Meanwhile, another avatar appeared on the gray circle amidst the floor. The teacher welcomed him by voice, and the avatar welcomed back by voice. The teacher asked him to sit, and he sat in the front row, on an available box.

The teacher said the class had started. Then, the researcher received from him a notecard with some text written in English. He explained that he was going to read the text. And after that, he would ask each of the students to read a paragraph. He read the text, and then asked each of the students to read a paragraph. The voice graph appeared over the head of the avatar the teacher had asked to read, and the text request is heard being read. The teacher interrupted the reading a few times, repeating a word or phrase in the text. The readers repeated the word or phrase to the teacher in a similar manner.

At the end of each reading, the teacher asked if anyone had any questions. Some students said that they had not understood the meaning of a few words or phrases, with their voice graphs clearly visible above their heads as they did that. The teacher answered them. After that, he asked if they had cleared up their doubts. After reading all the paragraphs of the text, the process was repeated with a second text in a second notecard that the teacher sent to the researcher, once again by IM. After reading all paragraphs of the second text, in a similar manner to the one already described, the teacher said that the class had ended.

## **5.4 Fourth Case–English Class II**

This case is also about an English language class held in Second Life, and the school is the same as in the previous case. However, the activity carried out in this class was a class excursion or field trip, i.e., not held in the virtual school space but in a different location, albeit still within Second Life. As in the previous case, the use of voice was required. Again, in case of omission, all described dialog used that medium.

### **5.4.1 Scenery**

This kind of classes (excursion/field trip) is usually held in different locations in Second Life. The goal is to practice the vocabulary by asking the students to describe what they see on the site, using the English language. This time, it was at a place called Art Box. This location has two levels: the top one with multiple images, mostly referring to

paintings, but others related to movies, music, and other forms of art (Figure 5a); the lower level is completely empty, with a white background. By clicking with the right mouse button on each of the images of the upper floor, a menu appears. Selecting "sit" on that menu causes the rendering of a three-dimensional representation of the selected image on the lower level. These representations have pose balls in front of them, allowing avatars to assume poses in the scene.

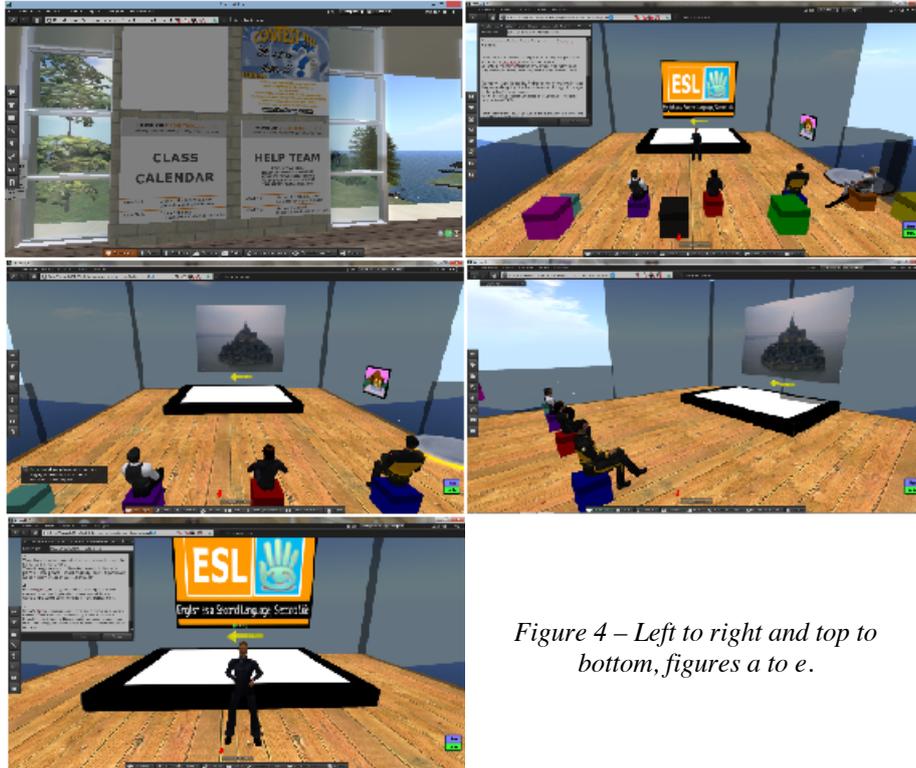


Figure 4 – Left to right and top to bottom, figures a to e.

#### 5.4.2 Case Summary

The observational researcher received an IM with the announcement of class and a link. Following the link his avatar emerged at the location described in the IM, where other three avatars (one male and two female) were already present. They greeted the researcher, who greeted them back. This also enabled him to notice that their voice tones coincided with the genders of the avatars. One of them, with a text box over the head identifying her as a teacher, asked the group to pose on the image that was in the background (Figure 5b) about the pop music band "The Beatles". Her avatar emerged in the scene by replacing one of the characters (Figure 5c). The other present avatars did the same. After selecting "sit" on the last of the pose balls, the researcher's avatar also replaced one of the scene characters (Figure 5d). The teacher then asked questions to the avatars in the scene. Those questions dealt with the original characters in that scene, and the voice graph on her avatar's head was clearly visible. Later, she left the

pose and went to a black circle on the floor, positioning herself near a blue arrow hovering over the ground, pointing to the circle. The teacher said to the other male avatar to follow her in order to choose another artistic piece. To do so, she said it would be necessary to "sit" on the blue arrow. Her avatar was then seen turning to face the arrow (Figure 5e). Then, after some light balls appeared flying around the arrow, the avatar of the teacher presented a circle entry animation (Figure 5f).

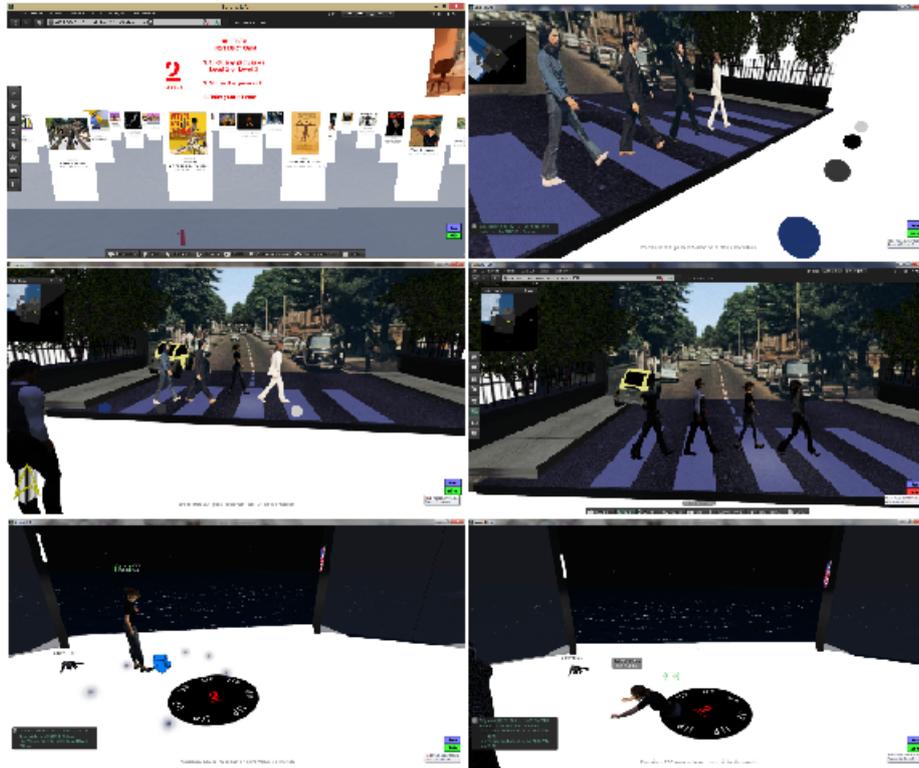


Figure 5 – From left to right and top to bottom, figures a to f

The other male avatar followed the teacher, displaying the same animation. After a few seconds, a new three-dimensional scene appeared in the background (Figure 6a), and the teacher and the other avatar returned. The teacher asked him to describe the scene, and while he did that, the bars of his voice graph could be seen changing over his head. This scene had two pose balls, one of which the teacher used, and appeared in the scene. After the description of this scene, the teacher asked the researcher to follow her through the circle as described before. The researcher followed her, and his avatar emerged at the top floor. Then, she asked the researcher to select an image, which he did by selecting "sit" in one of them (Figure 6b). On the lower level the three-dimensional scene corresponding to the image that the researcher selected appeared (Figure 6c).

The teacher used the only pose ball of the scene (Figure 6b). Then, she asked the researcher to describe the scene. He did it by voice. Then, she asked the female avatar to follow her, and she did. After a few seconds another new scene appeared (Figure 6d). They returned to the lower floor. This scene had several pose balls that the participants used. The teacher asked the female avatar to describe the scene, which she did. Then, the teacher walked towards some conical objects in the scene and asked what those could be. Her avatar turned to face one of the objects (Figure 6e). The other female avatar positioned herself next to the teacher. Her avatar also faced the object. A beam of light balls came out of one hand of the teacher towards one of the objects. Afterwards, the teacher went to the upper floor, and another scene emerged. The teacher said that the site was very interesting, and she would be back there in another excursion class, but the time for this class had ended. The participants said goodbye by voice. The teacher greeted in chat too (Figure 6f).



Figure 6 – From left to right and top to bottom, figures a to f

### 5.5 Fifth Case – Meditation

This case was a meditation guidance meeting held in Second Life by users belonging to the same group, the Citta Bhavana Ashram. This group is dedicated to activities of meditation, yoga, philosophy, and oriental arts. Its main activities include meditation sessions, discussions, singing, and similar ones. The sessions are pre-scheduled through

note card delivered to the members of the group. However, members are also reminded through IM some minutes before session start. These sessions have a responsible person assigned, identified both in the note card and in the IM (henceforth, “coach”).

### **5.5.1 Scenery**

The location of the session is an open space, with bucolic landscape, and melodious, slow tempo, calm background music, reminding oriental melodies. The space is paved with several carpets arranged in a circle (Figure 4a). These carpets have animations that allow the avatars to assume several poses while sitting, according to user choice on a menu.

### **5.5.2 Case Summary**

After arriving the observational researcher looked around, to see a large enclosure with carpets on the floor arranged a circle (Figure 4b). He saw the coach’s avatar, sitting on a carpet in a position usually used for meditation, facing the centre of the circle formed by the carpets. There were other avatars there, sitting on other carpets, facing the centre, some in the pose commonly associated with meditation, others in other poses. Some were stretched and crossed legs, others had their legs folded. The researcher heard different voices greeting him, as well as chat messages. He replied by chat, greeting everyone. Other avatars appeared and sat on the free carpets, also facing the centre, and again, several greetings were made, either by voice or by chat. By placing the mouse over a free carpet, and with the right mouse button, the researcher selected "sit". A menu opened allowing the choice of several poses. The researcher chose a meditation pose and his avatar appeared on the carpet in that pose, facing the centre.

A voice was heard saying to assume a relaxed position at home too. In the chat the same message could be read, identifying its author as the event coach. The voice graph was also visible over the head of the coach, while the message was being heard (Figure 4b). The coach continued, giving instructions of breathing exercises (Figure 4c), once again by voice and repeated in the chat, until the end of the session. The same voice also said that a quiet period was about to start, and that it would end with the sound of a bell. The background music stopped. Everybody remained in silence. Two bell rings were heard, and the same voice announced that the session was complete. Then, several thanks to the coach were pronounced by voice and chat (Figure 4d).



Figure 7 – From left to right and top to bottom, figures a to d

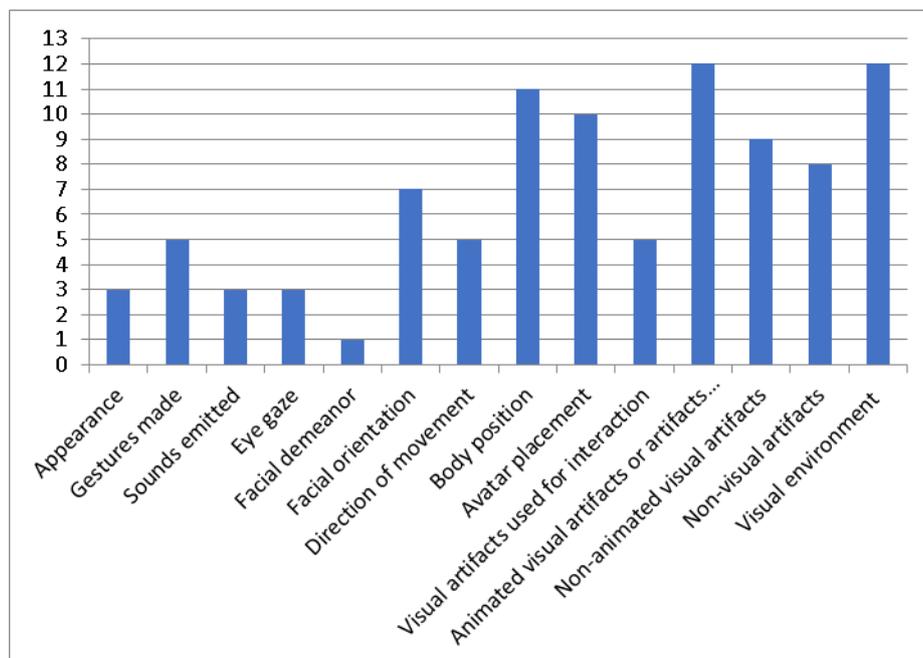


Figure 8 – Distribution of evidence throughout the units of analysis

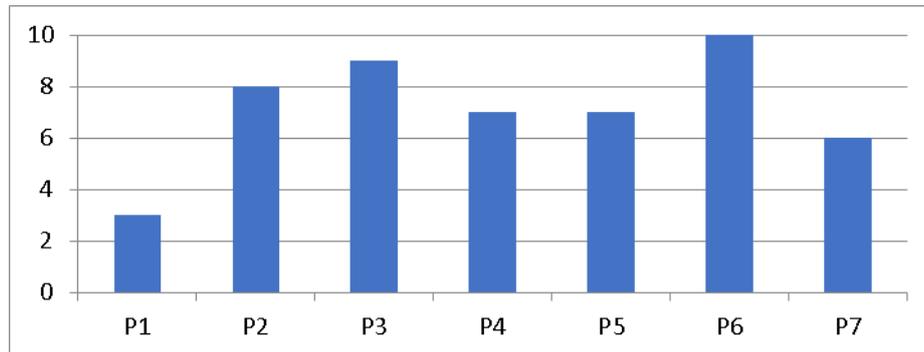


Figure 9 – Number of chains of evidence throughout the propositions

### 5.5.3 Summary of data collected from the cases

In total, we gathered 94 chains of evidence, with 53 being related to the avatar, and 41 being related to the physical space (Figure 5). There are also more units of analysis relating to the avatar (10) than to the physical space (4). In fact, distributing the evidence by the number of units a 5.3 evidence ratio per unit of analysis on the avatar is obtained, and 10.25 evidence ratio on the physical space, roughly the double.

Figure 6 presents the number of chains of evidence for each proposition. Although there are units of analysis with few evidence, including *Appearance*, *Sounds emitted*, and *Eye gaze*, with 3 elements each, and *Facial demeanour* with just one chain of evidence, it does not question the validity of the propositions, because it was possible to find other chains of evidence based on other units, supporting the same propositions. Therefore, it was possible to find chains of evidence related to all the propositions, with the first proposition having fewer chains, but still having them nonetheless (three chains of evidence). In total, 50 chains of evidence were found. Figure 6 shows that proposition 6, with 10 chains, has the largest number of chains of evidence. The next with more chains is proposition 3 with nine chains, then proposition 2 with eight, then 4 and 5 with seven each, and proposition 1 with the smallest number, only three. This small number is because, in the third case, propositions 1 and 2 do not have any chains and, in the fourth and fifth cases, the same happens with proposition 1. In these cases, as can be seen in the figures that complement their descriptions, the avatars wore different clothes and had the most diverse appearances, and so, it is not apparent any relationship of these with the first proposition (i.e., no indication of role, status, or rank from their appearance). In the case of English Class I, no sounds or animations were used in relation with the second proposition (i.e., no sounds or animations to express cooperation intent or perception by other users). Table 2 presents the number of evidence of each unit of analysis throughout the cases. The distribution of evidence is fairly even by the cases, with only a few units lacking evidence for some cases.

Units of analysis	Cases				
	Appela Meeting	Tournament	English Class I	English Class II	Meditation
Appearance	1	2			
Gestures made	1	2		2	
Sounds emitted	1	1			1
Eye gaze				3	
Facial demeanor		1			
Facial orientation		3	2		2
Direction of movement	1	1	1	2	
Body Position	5	1	2		3
Avatar placement	2	2	2	3	1
Visual Artifacts used for interaction	1	1	1	2	1
Animated visual artifacts or for interaction	3	2	2	4	1
Non-animated visual artifacts	3	4	2		
Non-visual artifacts	2	2	1		2
Visual environment	3	4	1	1	3

Table 2 – Number of evidence of each unit of Analysis by case

## 6 Data Analysis

The techniques of data analysis recommended by Yin [2009], are those of Miles & Huberman [1994], and among them the creation of flow charts, which will be used in order to illustrate the relationships between the units of analysis and each chain of evidence. For each proposition, the chains related to it were gathered, each one beginning on a unit of analysis directly related to the proposition, and then the chains were analysed in order to verify whether they are in accordance with the respective proposition. If they agree, the respective proposition can be considered as true. By the propositions being true, it was possible to assign to each unit of analysis a meaning for collaboration, and thus, answer the research questions, which is done at the end of this section. Tables 3 to 9 illustrate the analysis.

## 6.1 First Proposition

*P1-the appearance of the avatar influences the perception by other users, of the role of the user of the avatar and/or his or her attitude.*

The first proposition is supported by a total of three chains of evidence (Table 2). The chain about clothing is repeated in the first two cases, which reveals the consistency of this chain. The chain about the use of AOs was not repeated in any other case. In these cases, the outfit can distinguish, for example, the avatars which are on guard duty in case of the Apella Meeting, or those who are ready for confrontation, in the case of the Tournament.

The AOs also distinguished the King, the Queen Mother, and another avatar. And although it may be uncertain the exact meaning of the attitude they show, a core fact is that it is an attitude different from that used by the others of lesser status. This in itself allows for their differentiation from other avatars. Therefore, both the appearance and the attitude of avatars are revealed in these chains. So, it is possible to say that the appearance of the avatar influences collaboration by influencing the perception by other users of the role and/or attitude of the avatar.

## 6.2 Second Proposition

*P2-the avatar uses gestures and sounds to influence the perception by other users, about how the user in question wants to cooperate, or how he or she wants others to collaborate.*

The second proposition is supported by eight chains of evidence, none of them repeated in the five cases presented. Six of the chains of evidence are related with gestures or animations performed by the avatars, and two with sounds emitted by them. A good example is the animation of raising a fist simultaneously with a battle cry, done while some of the participants were speaking. As in the previous proposition, the exact meaning of these animations is uncertain. However, by being performed at the moment they were, combined with the fact that other participants also performed the battle cries, suggests support for this proposition. This proposition is also supported by the chain of evidence in which an avatar rises when he/she is told by the King to speak, and this is accompanied by the communication made by that avatar being visible in the chat. It is also supported by the chain of evidence in which the King stands up and calls a specific avatar. This avatar then moves next to the King. These two chains clearly reveal the use of gestures to transmit intent: the intent to speak in the first chain of evidence, and the intent to receive the new position or distinction in the second.

In the case of the tournament, this proposition is supported, firstly, by the chain that begins with the body positions revealed by the fighters. By using these positions, the fighters reveal to others that they want to fight. This proposition is also supported by another chain that begins with sounds of applause heard when the avatars that won the first places, occupy the podium. They are congratulated by several people, and trophies appear in their arms. By positioning themselves on the podium, they hear applause and receive trophies, which confirm their understanding of how others expected them to collaborate in the event.

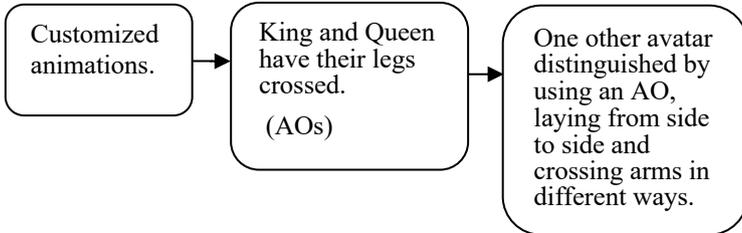
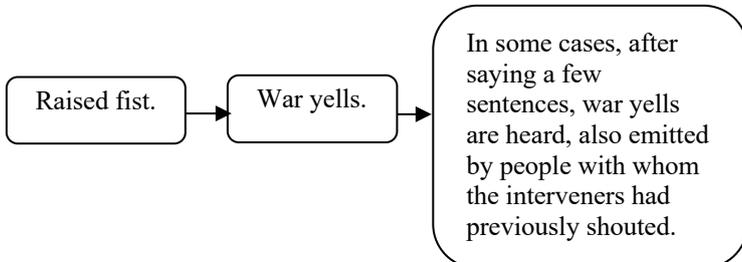
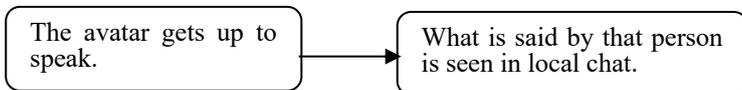
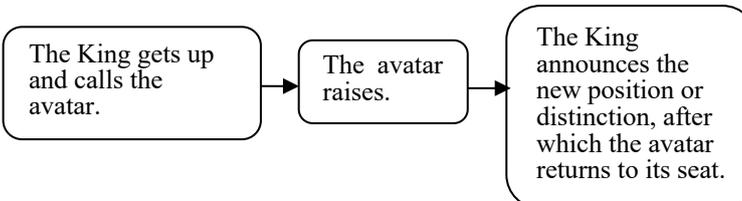
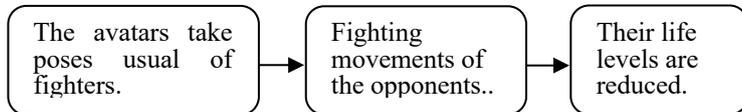
Cases	Chains of Evidence of the First Proposition
Apella Meeting & Tournament	 <pre> graph LR     A[Clothing from the era.] --&gt; B[There is a code of dressing.]             </pre>
Apella Meeting	 <pre> graph LR     A[Customized animations.] --&gt; B[King and Queen have their legs crossed. (AOs)]     B --&gt; C[One other avatar distinguished by using an AO, laying from side to side and crossing arms in different ways.]             </pre>

Table 2 – Chains of evidence of the first proposition

Cases	Chains of Evidence of the Second Proposition
Apella Meeting	 <pre> graph LR     A[Raised fist.] --&gt; B[War yells.]     B --&gt; C[In some cases, after saying a few sentences, war yells are heard, also emitted by people with whom the interveners had previously shouted.]             </pre>
Apella Meeting	 <pre> graph LR     A[The avatar gets up to speak.] --&gt; B[What is said by that person is seen in local chat.]             </pre>
Apella Meeting	 <pre> graph LR     A[The King gets up and calls the avatar.] --&gt; B[The avatar raises.]     B --&gt; C[The King announces the new position or distinction, after which the avatar returns to its seat.]             </pre>
Tournament	 <pre> graph LR     A[The avatars take poses usual of fighters.] --&gt; B[Fighting movements of the opponents..]     B --&gt; C[Their life levels are reduced.]             </pre>

Tournament	<p>Sounds of applauses. → The avatars position themselves in the podium according to the results of the fights. → In chat are messages congratulating the winners, sounds of applauses are heard, and trophies emerge at the hands of the awarded.</p>
English Class II	<p>The teacher's avatar performed an animation entering the circle. → The student's avatar followed her, showing the same animation. → The teacher told the male avatar to follow her so he could choose another art object.</p>
English Class II	<p>The teacher's avatar emerged in the scene, replacing one of the characters in it. → The other avatars did the same. → The teacher asked us to pose in the image.</p>
Meditation	<p>The session ends with two bell rings. → A voice graph over the head of the coach. → The same voice ends the session. → Thanks to the coach are heard.</p>

Table 3 – Chains of evidence of the second proposition

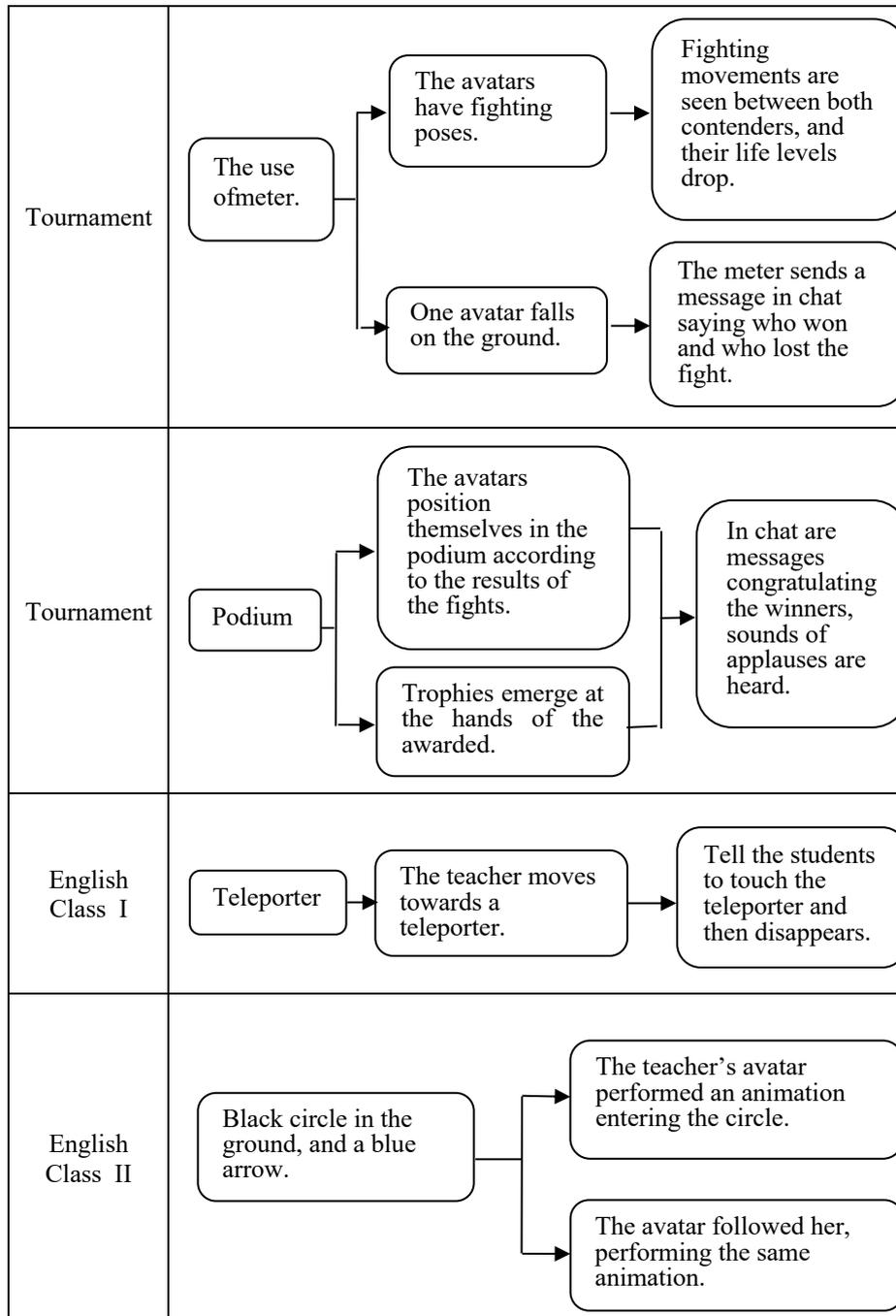
Cases	Chains of Evidence of the Third Proposition
Apella Meeting	<p>The avatar stops in front of the King. → The avatar takes a knee. → The King announces the new position or distinction, after which the avatar returns to its seat.</p>

<p>Tournament</p>	<p>The avatars called move to the center of the arena.</p> <p>The avatars called are face-to-face.</p> <p>The avatars in the porch turn in to the arena.</p>
<p>Tournament</p>	<p>The winners position themselves facing the commander</p> <p>The avatars position themselves in the podium according to the results of the fights.</p> <p>In chat are messages congratulating the winners, sounds of applauses are heard, and trophies emerge at the hands of the awarded.</p>
<p>English Class I</p>	<p>The students are sited in the front row.</p> <p>The teacher stood by the stage.</p> <p>The teacher started the class by voice.</p>
<p>English Class II</p>	<p>The teacher's avatar moves to a black circle in the floor, stopping near a hovering blue arrow.</p> <p>The teacher's avatar turned its face to the arrow.</p> <p>The student's avatar followed her, showing the same animation.</p>
<p>English Class II</p>	<p>The teacher moved to some conical objects and asked what that could be.</p> <p>The teacher's avatar turned its face to one conical object.</p> <p>A beam of light balls could be seen projected from the teacher's hand towards a conical object.</p>

English Class II	The other female avatar positioned herself next to the teacher.	→	The other female avatar also turned the face to one conical object.
Meditation	The coach sits turned the center of the circle.	→	The avatars sit turned to the centre.
Meditation	The coach is sited in a carpet, in a meditation pose.	→	Some avatars assume a pose of meditation.

Table 4 – Chains of evidence of the third proposition

Cases	Chains of Evidence of the Forth Proposition				
Apella Meeting	In the chairs are sited the avatars with higher rank, and the others sit in the benches.	→	Benches and red carpet.	→	The rest of the avatars sit in the benches around the place, apart from the chairs.
Tournament	Panel.	→	The avatars position themselves in the podium according to the results of the fights.	→	In the panel the name of the winners can be seen moving on to the next fight.



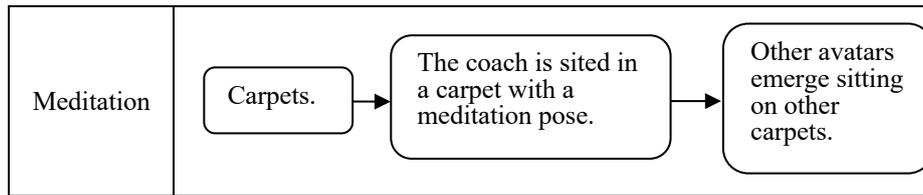


Table 5 – Chains of evidence of the fourth proposition

Cases	Chains of Evidence of the Fifth Proposition
Apella Meeting	<pre> graph LR     A[Chairs arranged in a semi-circle over a stage.] --&gt; B[Text boxes over avatar's heads showing their ranks.]     B --&gt; C[Everybody keeps sited with exception of those authorized by the King.]             </pre>
Tournament	<pre> graph LR     A[The building has a wide rectangular space in the centre, and two porches in the sides.] --&gt; B[The tournament is held in a place called Arena.]     A --&gt; C[The avatars position themselves in the porches facing the centre.]     A --&gt; D[The avatars called move to the centre of the Arena.]             </pre>
English Class I	<pre> graph LR     A[Boxes arranged in amphitheatre.] --&gt; B[The students sit in the front row.]     B --&gt; C[The teacher asks them to sit.]             </pre>
English Class I	<pre> graph LR     A[Panels.] --&gt; B[The students stood facing the panel.]             </pre>
English Class I	<pre> graph LR     A[Stage.] --&gt; B[The teacher stood next to the stage.]             </pre>

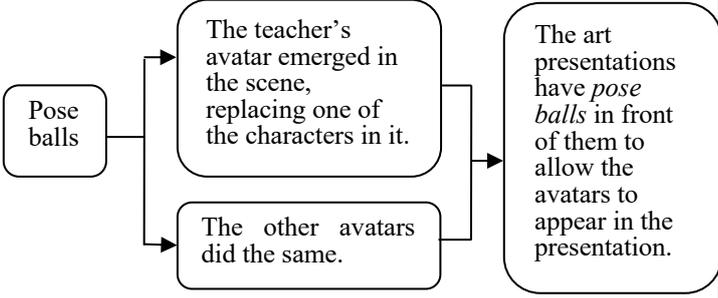
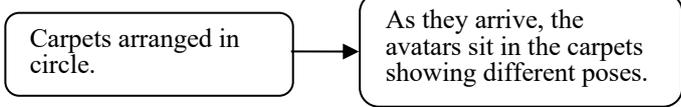
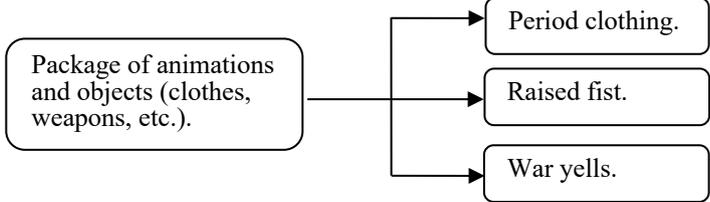
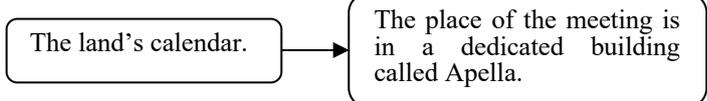
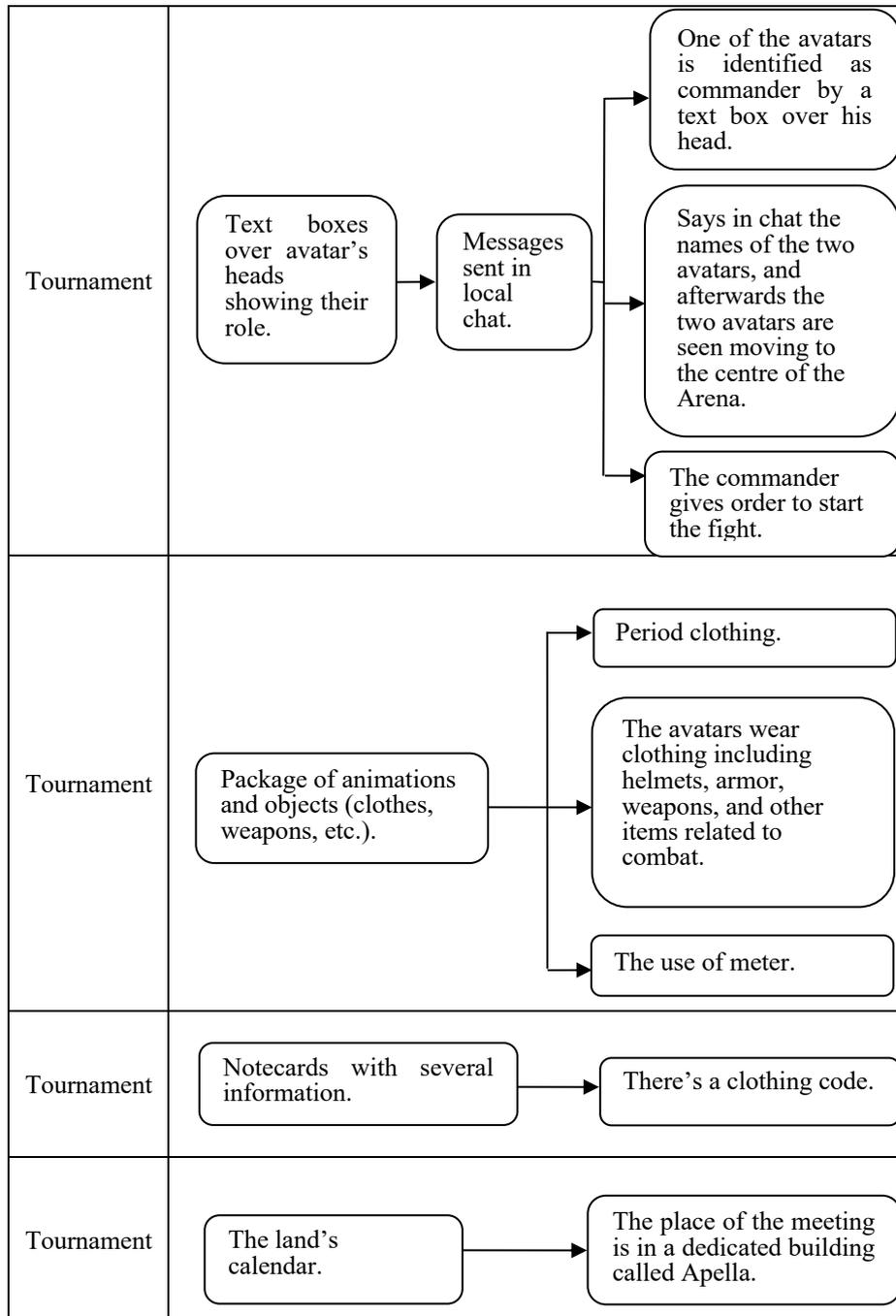
<p>English Class II</p>	 <pre> graph LR     A[Pose balls] --&gt; B[The teacher's avatar emerged in the scene, replacing one of the characters in it.]     A --&gt; C[The other avatars did the same.]     B --&gt; D[The art presentations have pose balls in front of them to allow the avatars to appear in the presentation.]     C --&gt; D         </pre>
<p>Meditation</p>	 <pre> graph LR     A[Carpets arranged in circle.] --&gt; B[As they arrive, the avatars sit in the carpets showing different poses.]         </pre>

Table 6 – Chains of evidence of the fifth proposition

Cases	Chains of Evidence of the Sixth Proposition
<p>Apella Meeting</p>	 <pre> graph LR     A[Package of animations and objects (clothes, weapons, etc.)] --&gt; B[Period clothing.]     A --&gt; C[Raised fist.]     A --&gt; D[War yells.]         </pre>
<p>Apella Meeting</p>	 <pre> graph LR     A[Notecards with several information.] --&gt; B[There's a clothing code.]         </pre>
<p>Apella Meeting</p>	 <pre> graph LR     A[The land's calendar.] --&gt; B[The place of the meeting is in a dedicated building called Apella.]         </pre>



English Class I	<pre> graph LR     A[Note cards.] --&gt; B[Voice graph over the heads of the avatars.]     B --&gt; C[The teacher asked each one to read one paragraph.]     B --&gt; D[It could be seen the voice's graph over the head of the avatar who was reading.]             </pre>
English Class II	<pre> graph LR     A[Text box showing the teacher's role.] --&gt; B[The teacher's avatar appeared in the scene replacing one of the characters in the scene.]     A --&gt; C[The other avatars did the same.]     B --&gt; D[The teacher asked us to pose in the scene.]     C --&gt; D             </pre>
Meditation	<pre> graph LR     A[The sessions are scheduled by note card.] --&gt; B[The coach is identified by instant messaging.]     A --&gt; C[The voice's graph over the head of the coach.]             </pre>

Table 7 – Chains of evidence of the sixth proposition

Cases	Chains of Evidence of the Seventh Proposition
Apella Meeting and Tournament	<pre> graph LR     A[Architecture similar to the time period.] --&gt; B[Re-creation of the ancient city-state of Sparta.]     B --&gt; C[Their main activities include battles and tournaments.]             </pre>

English Class I	<pre> graph LR     A[Classroom.] --&gt; B[The students sit in the front row.]     B --&gt; C[The teacher told us to go to the classroom.]           </pre>
English Class II	<pre> graph LR     A[Empty space] --&gt; B[Art images.]     B --&gt; C[The teacher asked us to describe the scenes.]           </pre>
Meditation	<pre> graph LR     A[The session takes place in an open bucolic space.] --&gt; B[It can be heard a melodious, slow, orient like music.]     A --&gt; C[Some avatars are in a meditation pose.]           </pre>
Meditation	<pre> graph LR     A[Silent pause.] --&gt; B[It can be heard a melodious, slow, orient like music.]     B --&gt; C[The music stops.]     B --&gt; D[Everybody is silent.]           </pre>

Table 8 – Chains of evidence of the seventh proposition

In the case of English Class II, the second proposition is supported by two chains of evidence. In the first one, the teacher explains how to go to the next floor, and then she is followed by the avatar that she had called upon. The second chain also begins with the example of the teacher posing in the same way as she wants others to. In both cases the teacher made it clear, by example, how she wanted the avatars to participate. And in the case of Meditation, there is also a chain of evidence to support the proposition in question. The coach's avatar, informed participants by voice of the meaning of the upcoming signal, the sound of a bell. She also announced the end of the session by voice, and then began issuing thanks and farewells. The clarification by the coach made clear the meaning of the sound: the end of the session. It is clear in this chain that the sounds are in fact used to tell others how it is intended that they cooperate.

The intention of using gestures might be to show how someone wants to participate in the collaboration. It may also be to show how others are expected to collaborate. This intent is also revealed through the use of sounds. The use of sound occurs in three of

the eight chains, and besides being used to show how others are supposed to collaborate. It is also used to confirm the form of collaboration. Thus, it is demonstrated that the avatar uses gestures and sounds both to show to others how to collaborate and to show to others how he or she wants them to collaborate.

### 6.3 Third Proposition

*P3- Eye gaze or direction, direction of movement (such as motion of the avatar), and position of the avatar, provides clues about what the user is paying attention to, or about what the user would like others turn their attention in to.*

The third proposition has nine chains of evidence. Seven of them refer to the placement of the avatar, and two to the direction of movement and/or eye gaze. Referring to the positioning, in the case of the Apella Meeting, the avatar called by the king kneels in front of him, which causes the king to proceed with the announcement that he intended to make about that avatar. And also, in the case of the Tournament, the avatars that are supposed to fight are called, and then position themselves near the centre of the arena face to face, in clear distinction from the others that remain below the porches around the arena. In this case, still another chain starts with the positioning of the winners on the podium facing the commander and occupying the places matching the results of the tournament, after which they receive their prizes. These chains reveal that avatars want attention drawn to them for some reason.

Still regarding the positioning, in the case of English Class I, there is a chain that begins when the students sit in the front row, while the teacher stands on the stage, and begins the lesson. In this way, students and teacher stand face to face. This positioning can indicate that the students want to attend the class, and it can also indicate that the teacher wants to start it. And in fact the class begins. Also, in the case of Meditation, there are two chains of support to the third proposition. The coach assumes a position and direction that are imitated by other avatars. In fact, when they sit on the carpets, they signal that they want to pay attention to that person, the person in charge – the coach. The second chain reinforces this idea, since the avatar of the coach is in a pose that is commonly related to one who is meditating or intends to meditate. In both cases the avatars behave very much like what is commonly seen in the physical world. It is therefore reasonable to assume that the behaviour of the participants, in these cases, was not by chance, but rather because they behaved in a similar way to how they would in their physical lives, making known through their own positioning, that they intended to pay attention or to receive it.

In the case of the English Class II, the third proposition has three chains of evidence. The first one refers to the circle used for teleportation, where the teacher's avatar moves the head orienting the face towards the blue arrow. This movement follows the movement that the user makes with the mouse, revealing where the user is looking at or what she is paying attention to. In this way, it reinforces the intention to direct the attention of others to the arrow. The second chain, similarly, refers to the same movement of the head that the teacher presents, but this time, oriented towards one of the conical objects. The other avatar reveals the same movement of the head towards the same object, after positioning itself by the teacher and the conical object, revealing the interpretation she made of the positioning of the teacher and her gaze.

The placement of the avatar is used to lead others to collaborate in some way, as well as the direction of the movement, or the direction of the avatar's head that ends up narrowing down the range of possibilities to where its user may be looking, thus, helping others realize what they should pay attention to. Based on this analysis, it can be concluded that the positioning or direction of the movement of the avatar, and the direction of look or gaze, reveals what the user is paying attention to, or towards what the user wants others to pay attention.

#### **6.4 Fourth Proposition**

*P4- The interaction of the avatar with specific objects provides clues about which objects are intended to be used by other people in the process of collaboration.*

The fourth proposition has seven chains of evidence. In the Apella Meeting a chain of evidence was found that begins in the seats where the upper hierarchy sits, which seems to have implied that the benches would be for other participants. In the case of the Tournament, three chains of evidence were found. The first one starts on the panel that allows monitoring the results of the fight, including the final results. These results allowed people to know who would fight who. The second chain is related to the use of a meter, which allows the opponents to control the state of "life" of both competitors. Only the competitors had meters, distinguishing them from the spectators, and letting everyone know what they intended to do. The third chain refers to the podium to distinguish and honour the winners.

In English Class I, there is a chain of evidence that begins in the teleport that was used to transport all participants into the room after exemplification of the teacher. Similarly, in English Class II, there is a chain that also begins in the teleport. In this case, the teacher made it very clear, either by saying it or by demonstrating it, that students are supposed to use the teleport.

Finally, in the case of Meditation, there is a chain of evidence that begins with the carpets and the coach sitting in on one of them, which seems to have led the others to sit on the free carpets as well. In fact, the coach did not give any indication besides the example, and probably the cultural background expectation associated with carpets in the context of meditation, all led the students to understand that they were supposed to sit on them.

These chains of evidence reveal important data about objects for collaboration. The cues about the usefulness of objects for collaboration may be implicit, as in the carpets in the case of Meditation. Or they can be explicit, as in the case of the Tournament panel. And they can be exclusive, as when it is intended that those who do not have proper hierarchy sit on the benches. Either way it is demonstrated that the interaction of the avatar with specific objects reveals their importance to the collaboration.

#### **6.5 Fifth Proposition**

*P5- The disposition of objects (for example, collocation or alignment) provides clues to their purpose for collaboration.*

The fifth proposition also has seven chains of evidence that refer to objects such as chairs and carpets, panels, pose balls, and even the architecture of buildings. In the first

case, Appela Meeting, there was a chain of evidence that began in the arrangement of the chairs. It turns out that the avatars sit according to the hierarchy they display in the text changing over their heads. This leads one to believe that the disposition of the chairs is interpreted as a cue for people to sit according to their hierarchy.

In the case of the Tournament, proposition five is supported by a chain of evidence based on the architecture of the building intended for this type of events. The competitors occupy the arena only when called upon, and all others remain below the porches, which leads to the conclusion that participants deduce the use of space intuitively, so the building itself provides cues to its purpose.

In English Class I there are three chains of evidence supporting proposition five. The first is about the cubes that function as chairs, the second is about the panels that serve as a reference, because they are in opposite position in the room to the chairs, affirming the purpose of these. And the third chain also reinforces this idea, because there is a stage on the opposite side of the chairs, next to which the teacher has positioned himself.

In English Class II there is a chain of evidence related to the pose balls positioned in the scenes which, coupled with the context of the scenes, seems to allow users to realize the utility of pose balls. In this case, the example of the teacher left no doubt about the purpose for the class.

Also, in the case of Meditation there is a chain of evidence, this time related to the carpets, arranged in a circle, a layout that is often assumed by people who come together for something in common. This seems to have been the interpretation they all took, as they all sat on the carpets, although there had been no instructions for such.

In all the cases studied, the cues suggested by the arrangement of the objects for the collaboration are implicit. The participants were able to interpret not only the generic use, as in the case of carpets used simply to sit, but also a more specific use of objects, denounced by their relative position. With all these examples, it can be concluded that physical space influences collaboration through the arrangement of objects that reveals cues of its purpose for collaboration.

## 6.6 Sixth Proposition

*P6- The transfer of visual artefacts (i.e., "objects", "clothes", "tools") between avatars, with specific and explicit visual resources, helps to define the team, contributing to the perception of the roles for collaboration in a group.*

Proposition six is the one with the most chains of evidence, ten. In the case of the English Class I, three chains of evidence were found. The first one refers to the animation package available on the land that includes clothing, animations, rules, etc. The second refers precisely to the note cards with the rules and explaining the hierarchy, helping to define the roles. The third chain of evidence, which refers to the timetable to inform the place and time of the meeting, allows everyone to meet at the same time, thus having an important coordination role by providing to the group a temporal perspective. These chains of evidence are repeated in the case of the Tournament without significant changes. Another chain of evidence that this second case provides, is the identification through a text hovering above the head of the avatar, of the hierarchy of the speaking avatar (the commander). It is noticeable that others obey to this avatar, evidencing the importance of the overhead text in the perception of the roles

of users. This perception is also clear in the case of the English Class II, in which the teacher also has overhead text identifying him as such. This leads participants to follow the example and to participate in the activities issued by the teacher without arguing about his legitimacy, since he is clearly identified.

In the case of the English Class I, a note card with the texts to be studied in class is distributed. The teacher names the reader, and the other students can follow the reading on their own note card while listening the reading. The note card helps them realize the role in the collaboration. And in the case of Meditation, a note card is also used to schedule the event. In this case the note card ends up having a function similar to a calendar, with more information such as who is responsible for the session. It also has a time-aggregating function as well as one of role definition.

Of the ten chains, four are repeated without significant changes in the first two cases. They are related to animations, clothing, and information that are distributed to participants. Note cards are present in all cases as a form of distribution of some type of information. They are also used to inform the roles of at least some participants, as in the case of Meditation. Another way of stating the roles is through the text that hovers over the head of the avatars. Similar clothing, as well as similar animations, bring something in common to those who have them, helping to define teams, and differentiating them from others. Thus, these chains of evidence show that the transfer of objects helps define the team and the roles, contributing to the perception of the group roles for collaboration.

### **6.7 Seventh Proposition**

*P7- The characteristics of the virtual space, such as light, sound or music, visual effects, aesthetics, among other, influence the attitude of the users collaborating.*

Finally, the seventh proposition has six chains of evidence to support it. In the first two cases a chain of evidence related to the architecture of the used space is repeated. The architecture of the terrain, similar to that of the epoch serves as a theme, helping the participants blend in the spirit of the game. In the case of the English Class I, the seventh proposition is supported by a chain of evidence that refers to the classroom, previously referred by the teacher, so that the students became aware of the supposed use of space. In the case of the English Class II, there is a chain of evidence, relating to the empty space where the class takes place. In this case, it was filled by the art works chosen by the participants.

In the case of Meditation, the seventh proposition is supported by two chains of evidence. The first one has to do with the visual aspect of the place and the ambient music. It is common expectation to associate meditation with contemplation, with serenity, with natural beauty. All these characteristics of the surrounding environment are verified in this case. There is also a second chain in which a period of silence is performed after the breathing exercises. The ambient music stops, and in fact everyone remained silent until the ringing of a bell.

Chains of evidence refer to the architecture that visually recreates the aesthetics of an era, a time that is the reference for clothing, activities (combats, the type of weaponry used, etc.) and even a hierarchy. In the case of the English Class I, the room that was mentioned by the teacher ends up visually recreating a traditional classroom. In the classroom of English Class II, there is an empty space where the three-dimensional

recreations appear. And in the case of meditation, again the sense of sight is used along with music, to create an environment suitable to meditation. By this we can conclude that the thematic environment adopted in the physical space influences the attitude of the collaborators.

## 6.8 Analysis Summary

In this section, the chains of evidence were analysed in order to verify the propositions. It was found that all propositions have examples of chains of evidence supporting them. Thus, at least in the cases studied, it can be concluded that the propositions are true. It is also possible to conclude that non-verbal communication, based on avatars and the physical space recreated by 3DVWs, is used for collaboration. In the literature, such statements are common without supporting evidence. With this study, it is possible to understand how non-verbal communication is actually used for 3D VW collaboration. This "how" is the answer to the research questions, which we can now answer based on the propositions. In response to question one, the avatar influences collaboration through:

- Appearance - revealing roles or attitudes (by proposition 1);
- Gestures and sounds - showing how one wants to collaborate, or how the other elements of the group should collaborate (by proposition 2);
- Look, direction of movement, and positioning - revealing what one is paying attention to, or what one wants others to pay attention to (by proposition 3);
- Interaction with specific objects - revealing those most important for collaboration (by proposition 4).

In response to question two, physical space influences collaboration through:

- Arrangement of objects - revealing their purpose for collaboration (by proposition 5);
- Transfer of objects - helping to define the team and roles (by proposition 6);
- Thematic environment (architecture, decoration, ambient music, etc.) adopted in the physical space - influencing the attitude of the participants (proposition 7).

## 7 Conclusions

An important conclusion drawn from the classification of 3DVWs under the CSCW taxonomies was that these did not address several features of 3DVWs. Specifically, characteristics which enable non-verbal communication, including cues such as proximity, orientation, eye contact, eye gaze and physical appearance. The fact that CSCW taxonomies do not contemplate these characteristics as initially suspected constituted the starting problem of this work. A decisive argument for this problem was the realization that the characteristics of 3DVWs, such as the avatar and the physical space, are strongly related to the theoretical frameworks of Presence. As expressed earlier, these characteristics provide the sensation of virtual presence and are recognized as important for communication and bear importance to provide group awareness and collaborative tasks in general. Other characteristics common in 3DVWs,

which are relevant in the theoretical framework of Presence, are: field of vision, manipulation techniques and navigation capabilities (important for interaction), and the immersive environment provided by 3DVW (cooperation facilitator). These distinctive features suggested the possibility of a theoretical treatment related to the theoretical frameworks of the CSCW and Presence, through the characteristics of communication, awareness, interaction, and cooperation. Because these distinctive features of 3DVWs coincided with those considered more important for the creation of the sensation of presence, it was proposed in previous work [Cruz et al., 2012] that this theoretical treatment should be done by adding the Presence to the CSCW taxonomies, thus creating a more comprehensive taxonomy.

There is no explicit relationship between Presence and collaboration but, in order to progress towards a new taxonomy that acknowledge this, it was important to know precisely how these characteristics affect the collaboration in 3DVWs. We did this validation by answering the two research questions presented. For that, real situations of collaboration in 3DVWs were analysed, in which the mentioned characteristics were used. Chains of evidence capable of affirming the veracity of propositions were extracted from the cases. These cases reflect different situations of collaboration and enabled us to collect several chains of evidence. Despite the small number of cases, they sufficed to provide chains of evidence related to all propositions. By analysis of the chains of evidence it was found that the chains assigned to each of the propositions agreed with what the propositions affirmed. Thus, the validity of the propositions was verified, and the research questions answered. Consequently, it was found that non-verbal communication in 3DVWs is in fact used for collaboration and the specific role of the distinctive features of 3DVWs (and common to Presence) for this purpose was understood.

Using avatars with possibility of customization, gestures and sounds, contributes to communication, coordination, cooperation, interaction and awareness, and virtual physical space, including the thematic environment, contributes to communication, artefact sharing, interaction and awareness. That is, both the avatar and the physical space are important for several categories that impact the first level of the comprehensive taxonomy used. These categories are the model 3C (communication, coordination, and cooperation), time/space (sharing and interaction), and Awareness. It was seen earlier that features of 3DVWs such as immersion and non-verbal communication are important to create a sense of Presence. It was also seen that the scientific community that studies Presence agrees that the use of avatar is important for the communication. That non-verbal communication is important for collaboration and awareness, and that the virtual environment created by 3DVWs enhances cooperation. It is concluded that communication, awareness, interaction, and cooperation relate collaboration with Presence. Presence this crosses over all dimensions of the 3C model (which includes communication and cooperation), time / space (which includes interaction), and awareness. The existing CSCW taxonomies do not include these features. The importance of these features (virtual physical space, environment and avatars) is transversal to all cases of collaboration. However, these features are not covered by the CSCW or, at least, are not explicitly covered. This gap places the 3DVW in a situation of little attention in the collaborative research community in the light of the CSCW, a situation that is not in accordance with the usefulness that the 3DVW have been showing to have for collaboration, recognized by many authors such as [Benford et al., 2001] [Yee, 2006] [Pinkwart & Oliver, 2009][Prasolova-Førland & Divitini,

2003]. Thus, it is proposed, for new CSCW taxonomies, that Presence, as a new theoretical perspective, be positioned crossing these three dimensions. And it is also proposed that the avatar and the physical space be positioned at a lower level of granularity (the other avatar and physical space characteristics would be at an even lower level). It is also proposed that future CSCW taxonomies maintain the position of the avatar in the groupware application properties sub-level and the physical space in the GDSS elements sub-level. Figure 10 illustrates this proposal.

With this proposal, we believe that future CSCW taxonomies can emerge that adequately enable theoretical treatment of 3DVWs in a light that does not obscure their affordances towards collaboration, thus contributing to better design of 3DVWs to leverage this ability. The COVID-19 pandemic has heightened the need for better CSCW tools and knowledge in many areas, and particularly so in Education and in Conferencing, activities that changed overnight from physical cooperation into virtual cooperation. Virtual worlds such as Virbela were suddenly critical for hosting high-profile events worldwide or providing spatial context solutions. This framing of CSCW taxonomies including Presence may thus play a central role in developing a more comprehensive understanding of this new panorama.

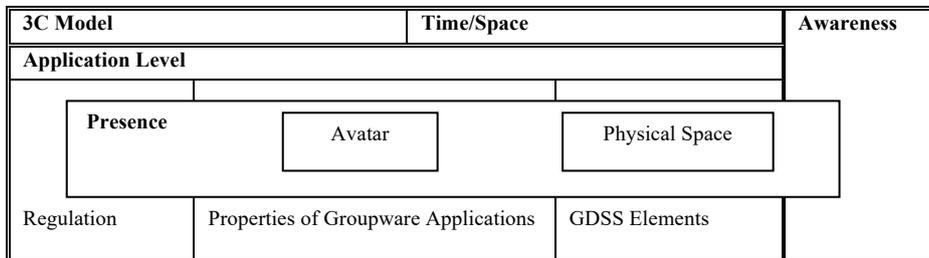


Figure 10 – Comprehensive framing for CSCW taxonomies including Presence

## 8 Future Work

As for future work, more cases should be studied to contemplate group tasks, for example. This would simplify the organization of cases and would enable the study of features in a more detailed level. At a finer level, it may also be interesting to use other methodologies, namely ethnographic studies. With these methodologies, factors of added complexity will probably arise in the relationships within the group, such as culture, norms, hierarchy, etc., providing opportunities of new findings.

Two-dimensional virtual worlds, as well as text-based virtual worlds were excluded from our theoretical analysis. The case studies were carried out only in Second Life. This 3DVW is the one with the most users in its category (free content creation), has a very rich diversity of cases, and is very versatile, allowing to quickly study different situations and with richness of interaction. By allowing users to develop their own content, 3DVW like Second Life probably provide good opportunities of collaboration for users, due to the freedom that this feature provides. The high number of Second Life users provides many collaborative situations, which makes it easier for

researchers to choose suitable case studies. However, it is still a single technological platform, so case studies of other platforms may reveal complementary or unexpected facts, which could require a revision of the conclusions obtained here.

Finally, since we initiated this work, the theory on the phenomenon of immersion has been gaining prominence in close relationship with Presence theory. Cooperation is an aspect of the three dimensions of Immersion [Beck et al., 2020], hence there is an as-of-yet unclarified connection between CSCW and Immersion. The inclusion of Presence in CSCW taxonomies may hold the potential to bring about this clarification, and we hope to pursue this avenue of inquiry in the future.

## References

- [Bannon& Shmidt, 1989] Bannon, L., & Shmidt, K. (1989). CSCW: Four Characters in Search of a Context. Proceedings of the 1st European Conference on Computer Supported Cooperative Work (pp. 358-372). Gatwick, United Kindgom: ACM Press.
- [Barfield et al.,1995] Barfield, W., Zeltzer, D., Sheridan, T., & Slater, M. (1995). Presence and performance within virtual environments. In W. Barfield, & T. Furness III, *Virtual environments and advance interface design* (pp. 473-513). NewYork: Oxford University Press.
- [Beck et al., 2020] Beck, D., O’Shea, P., Morgado, L. (2020). Finding the gaps about uses of immersive learning environments: a survey of surveys. *Journal of Universal Computer Science*, 26, 1043-1073.
- [Benford et al., 2001] Benford, S., Greenhalgh, C., Rodden, T., & Pycock, J. (2001). Collaborative Virtual Environments. *Communications of the ACM*, 44(7), 79-85.
- [Bente et al., 2004] Bente, G., Rüggenberg, S., Nicole, & Krämer, C. (2004). Social Presence and Interpersonal Trust in Avatar-Based, Collaborative Net-Communications. *Presence 2004-7th Annual International Workshop on Presence*. Valencia, Spain: ISPR. From: <http://astro.temple.edu/~lombard/ISPR/Proceedings/2004/Bente,%20Ruggenberg,%20Kramer.pdf>.
- [Bente, & Krämer, 2002] Bente, G., & Krämer, N. (2002). Virtual gestures: Analyzing social presence effects of computer-mediated and computer-generated nonverbal behaviour. *Presence 2002: 5th Annual International Workshop on Presence*. Porto, Portugal: ISPR. From: <http://astro.temple.edu/~lombard/ISPR/Proceedings/2002/Bente%20and%20Kramer.pdf>.
- [Biocca et al., 2003] Biocca, F., Harms, C., & Burgoon, J. (2003). Toward a More Robust Theory. *Presence: Teleoperators & Virtual Environments*, 12(5), 456- 481.
- [Biocca, 1997] Biocca, F. (1997). The cyborg's dilemma: progressive embodiment in virtual environments. *Journal of Computer Mediated Communication*, 3(2).
- [Case & Light, 2011] Case, M. J., & Light, G. (2011). Emerging Methodologies in Engineering Education Research. *Journal of Engineering Education*, 186-201.
- [Castronova, 2001] Castronova, E. (2001). *Virtual Worlds: A First-Hand Account of Market and Society on the Cyberian Frontier*. The Gruter Institute Working Papers on Law, Economics, and Evolutionary Biology.
- [Cruz et al., 2012] Cruz, A., Correia, A., Paredes, H., Fonseca, B., Morgado, L., & Martins, P. (2012). Towards an overarching classification model of CSCW and groupware: a socio-technical perspective. *CRIWIG* (pp. 1-17). Berlin Heidelberg: Springer-Verlag.

- [Cruz et al., 2014] A Cruz, H Paredes, B Fonseca, L Morgado, P Martins (2014); Can presence improve collaboration in 3D virtual worlds?; *Procedia Technology*, 2014.
- [Dommel, 2005] Dommel, H. (2005). *The Challenges of Ambient Collaboration*. Proceedings of the 2005 Conference on Diversity in Computing (pp. 10-13). Albuquerque, Novo Mexico, EUA: ACM.
- [Dreher et al., 2009] Dreher, C., Reiners, T., Dreher, N., & Dreher, H. (2009). 3D Virtual Worlds Enriching Innovation and Collaboration in Information Systems Research, Development, and Commercialisation. 3rd IEEE International Conference on Digital Ecosystems and Technologies (pp. 168-173). Istanbul, Turkey: IEEE.
- [Ellis et al., 1991] Ellis, C., Gibbs, S., & Rein, G. (1991). Groupware: Some issues and experiences. *Communications of the ACM*, 34(1), 38-58.
- [Ferraris & Martel, 2000] Ferraris, C., & Martel, C. (2000). Regulation in groupware: the example of a collaborative drawing tool for young children. Proceedings of 6th International Workshop on Groupware (CRIWG '00) (pp. 119-127). Madeira, Portugal: IEEE.
- [Franceschi & Lee, 2008] Franceschi, K., & Lee, R. (2008). Virtual Social Presence for Effective Collaborative E-Learning. Presence 2008 - Proceedings of the 11th Annual International Workshop on Presence (pp. 254-257). Padova, Italy: ISPR. From: <http://astro.temple.edu/~lombard/ISPR/Proceedings/2008/Franceschi.pdf>.
- [Gül, 2008] Gül, L. (2008). Affording Embodiment in Collaborative Virtual Environments: What is the Role of Presence in Collaborative Design? Presence 2008 - Proceedings of the 11th Annual International Workshop on Presence (pp. 297-304). Padova, Italy: ISPR. From: <http://astro.temple.edu/~lombard/ISPR/Proceedings/2008/Figen%20Gul.pdf>.
- [Gyorfi et al., 2006] Gyorfi, J., Buhrke, E., Tarlton, M., Lopez, J., & Valliath, G. (2006). VICC: Virtual Incident Command Center. Presence 2005 - 8th Annual International Workshop on Presence. Cleveland, Ohio, USA: ISPR. From: <http://astro.temple.edu/~lombard/ISPR/Proceedings/2006/Gyorfi,%20Buhrke,%20Tarlton,%20Lopez,%20Valliath.pdf>.
- [Heeter, 1992] Heeter, C. (1992). Being There: The subjective experience of presence. Presence: Teleoperators and Virtual Environments, MIT Press, 1(2), 262-271.
- [Hendaoui & Thompson, 2008] Hendaoui, A., & Thompson, M. (Jan/Feb2008). 3D Social Virtual Worlds - Research Issues and Challenges. *Architectural Perspectives*, 88-92.
- [Hendrix & Barfield, 1996] Hendrix, C., & Barfield, W. (1996). The Sense of Presence within Auditory Virtual Environments. Presence: Teleoperators and Virtual Environments, 5(3), 290-301.
- [ISPR, 2013] International Society for Presence Research. (n.d.). Retrieved in March 2013, from <http://ispr.info/>
- [Johnson , 2008] Johnson, D. P. (2008). *Contemporary sociological theory: an integrated multi-level approach* . NewYork: Springer.
- [Jordan et al., 2002] Jordan, J., Mortensen, J., Oliveira, M., & Slater, M. (2002). Collaboration in a Mediated Haptic Environment. Presence 2002: 5th Annual International Workshop on Presence. Porto, Portugal: ISPR. From: <http://astro.temple.edu/~lombard/ISPR/Proceedings/2002/Jordan%20et%20al.pdf>.
- [Kaltenbrunner & Huxor, 2000] Kaltenbrunner, M., & Huxor, A. (2000). Multiple Presence through Auditory Bots in Virtual Environments. Presence 2000: The Third International Workshop on Presence. Delft, Netherlands.

- [Koch & Gross, 2006] Koch, M., & Gross, T. (2006). Computer-Supported Cooperative Work - Concepts and Trends, Lecture Notes in Informatics (LNI). Conf. of the Association Information And Management (AIM) (p. 92). Bonn, Germany: Koellen Verlag.
- [Koster, 2002] Koster, R. (2002). Online World Timeline. Retrieved in 2011 from Raph Koster's Website: <http://www.raphkoster.com/gaming/multimeline.shtml>.
- [Lombard & Ditton , 1997] Lombard, M., & Ditton, T. (1997). At the heart of it all: The concept of presence. *Journal of Computer-Mediated Communication*, 3(2).
- [Manninen, 2001] Manninen, T. (2001). Virtual Team Interactions in Networked Multimedia Games. *Presence 2001: The 4th Annual International Workshop on Presence*. Philadelphia, Pennsylvania, USA: ISPR. From: <http://astro.temple.edu/~lombard/ISPR/Proceedings/2001/Manninen.pdf>.
- [Miles, & Huberman, 1994] Miles, M., & Huberman, A. (1994). *Qualitative Data Analysis*. Thousand Oaks, California, USA: Sage Publications.
- [Minsky , 1980] Minsky, M. (1980). Telepresence. *Omni Magazine*, 45-51.
- [Morgado et al., 2012] Morgado, L., Varajão, J., Coelho, D., Rodrigues, C., Sancin, C., & Castello, V. (2010). The Attributes and Advantages of Virtual Worlds for Real World Training. *The Journal of Virtual Worlds and Education*, 15-35.
- [Olds et al., 2005] Olds, B. M., Moskal, B. M., & Miller, R. L. (2005). Assessment in Engineering Education: Evolution, Approaches and Future Collaboration. *Journal of Engineering Education*, 13-25.
- [Otto et al., 2005] Otto, O., Roberts, D., & Wolff, R. (2005). A Study of Influential Factors on Effective Closely-Coupled Collaboration based on Single User Perceptions. *Presence 2005 - 8th Annual International Workshop on Presence* (pp. 181-188). London, UK: ISPR. From: <http://astro.temple.edu/~lombard/ISPR/Proceedings/2005/Otta,%20Roberts,%20Wolff.pdf>.
- [Owens et al., 2009] Owens, D., Davies, A., Murphy, J., Khazanchi, D., & Zigurs, I. (2009). Real-World. *IT Pro* (pp. 34-41). IEEE.
- [Pinkwart & Oliver, 2009] Pinkwart, N., & Oliver, H. (2009). Cooperative virtual worlds – A viable ecollaboration pathway or merely a gaming trend? *Electronic Markets*, 19(4), 233-236.
- [Prasolova-Førland & Divitini, 2003] Prasolova-Førland, E., & Divitini, M. (2003). Collaborative Virtual Environments for Supporting Learning Communities: an Experience of Use. *GROUP '03 Proceedings of the 2003 international ACM SIGGROUP conference on Supporting group work* (pp. 58-67). Sanibel Island, Florida, USA: ACM.
- [Rae et al., 2008] Rae, J., Guimaraes, E., & Steptoe, W. (2008). Simulation versus Reproduction for Avatar Eye-Gaze in Immersive Collaborative Virtual Environments. *Presence 2008 - Proceedings of the 11th Annual International Workshop on Presence*. Padova, Italy: ISPR. From: <http://astro.temple.edu/~lombard/ISPR/Proceedings/2008/Rae.pdf>.
- [Romanet et al., 1998] Romano, D., Brna, P., & Self, J. (1998). Collaborative Decision-Making and Presence in Shared Dynamic Virtual Environments. *Presence in Shared Virtual Environments Workshop*. BT Labs, Martlesham Heath: ISPR. From: <http://astro.temple.edu/~lombard/ISPR/Proceedings/1998/Romano,%20Brna,%20Self.pdf>.
- [Romano & Brna , 2000] Romano, D., & Brna, P. (2000). ACTIVE World: Manipulating Time and Point of View to Promote a Sense of Presence in a Collaborative Virtual Environment for Training in Emergency Situations. *Presence 2000: The Third International Workshop on Presence*. Delft University of Technology, Netherlands.

- [Romano & Brna, 2002] Romano, D., & Brna, P. (2002). Collaboration, Presence and Performance in Virtual Learning Environments: Can Collaboration be Used to Measure Shared Presence? Presence 2002: 5th Annual International Workshop on Presence. Porto, Portugal: ISPR. From: <http://astro.temple.edu/~lombard/ISPR/Proceedings/2002/Romano%20and%20Brna.pdf>.
- [Sadagic et al., 2001] Sadagic, A., Towles, H., Holden, L., Daniilidis, K., & Zeleznik, B. (2001). Tele-immersion Portal: Towards an Ultimate Synthesis of Computer Graphics and Computer Vision Systems. Presence 2001: The 4th Annual International Workshop on Presence. Philadelphia, Pennsylvania, EUA: ISPR. From: <http://astro.temple.edu/~lombard/ISPR/Proceedings/2001/Sadagic.pdf>.
- [Schmidt, & Bannon, 1992] Schmidt, K., & Bannon, L. (1992). Taking CSCW Seriously - Supporting Articulation Work. In Computer Supported Cooperative Work (pp. 7-40). Kluwer Academic Publishers.
- [Sheridan, 1992] Sheridan, T. (1992). Musings on telepresence and virtual presence. Presence: Teleoperators and Virtual Environments, 1, 120-125.
- [Slater & Wilbur, 1997] Slater, M., & Wilbur, S. (1997). A framework for Immersive Virtual Environments (FIVE): Speculations on the Role of Presence in Virtual environments. Presence: Teleoperators and Virtual Environments, 6(6), 603 - 616.
- [Steuer, 1992] Steuer, J. (1992). Defining virtual reality: Dimensions determining telepresence. Journal of Communication, 42(4), 73-93.
- [Stuer, 1995] Stuer, T. (1995). Defining virtual reality: Dimensions determining telepresence. In F. Biocca, & M. Levy, Communication in the age of virtual reality (pp. 33-56). Hilldale: Nova Jersey: Lawrence Erlbaum Associates.
- [Swinth & Blascovich, 2002] Swinth, K., & Blascovich, J. (2002). Perceiving and Responding to Others: Human-Human and Human-Computer Social Interaction in Collaborative Virtual Environments. Presence 2002: 5th Annual International Workshop on Presence. Porto, Portugal: ISPR. From: <http://astro.temple.edu/~lombard/ISPR/Proceedings/2002/Swinth%20&%20Blascovich.pdf>.
- [Thie & Wijk, 1998] Thie, S., & Wijk, J. (1998). Experimental Evaluation of Social Virtual Presence in a Decision Making Task. Presence in Shared Virtual Environments Workshop. BT Labs, Martlesham Heath.
- [Witmer & Singer, 1998] Witmer, M., & Singer, M. (1998). Measuring immersion in virtual environments: A Presence Questionnaire. Presence: Teleoperators and Virtual Environments, 7(3), 225-240.
- [Yee, 2006] Yee, N. (2006). The Demographics, Motivations and Derived Experiences of Users of Massively-Multiuser Online Graphical Environments. Presence: Teleoperators and Virtual, 15, 309-329.
- [Yin, 2009] Yin, R. K. (2009). Case study research: Design and methods. In Applied Social Research Series, Vol. 5., 4<sup>th</sup> Ed.. London: Sage.