# A comparative study on two aspects that influence the sense of presence in virtual environments

Luiz Fernando Mattos Schlindwein[1]
Marcelo da Silva Hounsell[1]
Avanilde Kemczinski[1]

**Resumo:** Um dos objetivos e vantagens da Realidade Virtual é a promoção da sensação de "estar lá", de estar presente. As pesquisas existentes focaram em determinar "se" um fator contribui para o senso de presença. Este artigo compara dois sistemas de visualização, avaliando qual dos dois contribui mais para este senso. Dois sistemas de baixo custo e baixa tecnologia foram usados: estereoscopia anáglifa e campo de visão (FOV) largo (50º). O Questionário SUS foi aplicado a 63 participantes para avaliar o senso de presença. Os participantes foram divididos em dois grupos, num experimento intra-sujeitos seguido de um inter-sujeitos, assistiram a um passeio guiado em um campus universitário virtual. Ambos os sistemas contribuíram para aumentar o senso de presença. O aumento do FOV foi melhor para lembrar do lugar visitado enquanto a estereoscopia foi melhor em tornar o ambiente mais realista. Entretanto, percebeu-se que a estereoscopia anáglifa não pode ser usada sempre. Em termos gerais, os dados mostram que a estereoscopia anáglifa contribui mais que um FOV largo para o senso de presença. Concluímos sugerindo que o primeiro passo para aumentar a imersão de um Ambiente Virtual deva ser o uso de estereoscopia, nem que seja a anáglifa, se for apropriado.

***Palavras-chave:*** Campo de visão. Estereoscopia. Presença. Realidade virtual.

**Abstract*:*** *An objective and advantage of Virtual Reality is to promote the sense of "being there", to be present. Most existing research in this field is focused on determining "if" a given factor contributes to the sense of presence. This paper compares two visualization systems regarding their contribution to the sense of presence, assessing which one contributes the most. Two low-cost low-tech systems were considered: anaglyph-based stereoscopy and large Field-of-View (FOV) screens (50o). The SUS Questionnaire was applied to 63 participants to assess their sense of presence. Participants were divided in two groups on a within-subject followed by a between-subject experiment and watched a guided tour on a virtual University campus. It was confirmed that both systems contribute to increase the sense of presence. FOV enlargement was better to remember the place visited while adding stereoscopy bettered on rendering the environment more realistic. However, it could be seen that anaglyph-based stereoscopy cannot be used always. Overall, data analysis shows that anaglyph-based stereoscopy adds more than FOV enlargement towards the sense of presence. We conclude by suggesting that the very first step to raise the immersion of a Virtual Environment should be using stereoscopy, at least the anaglyph-based one, if suitable.*

***Keywords:*** Field-of-view. Presence. Stereoscopy. Virtual reality.

[1] LARVA – Laboratory for Research on Visual Applications. DCC – Departamento de Ciência da Computação. UDESC – Universidade do Estado de Santa Catarina. Rua Paulo Malschitzki, S/N - Campus Universitário Prof. Avelino Marcante - Bairro Zona Industrial Norte - Joinville-SC – Brasil. CEP 89219-710.
l.f.mattos.sch@gmail.com, {marcelo, avanilde}@joinville.udesc.br

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## 1 Instroduction

Virtual Reality (VR) is a technology composed by interactive computational simulations which stimuli users´ senses, giving them the impression of being present in that Virtual Environment (VE). When users sense to be in the VE they start to behave as in real life. Then, their reactions could be trained in a 3D, safe, controlled and flexible environment. Achieving the sense of being there is one of the purposes and advantages of VR. Among all feedbacks that a VR system may offer to the user there is the sense of sight which is the most complex of the five senses which promotes the notion of distance from the objects in the scene [1]. The most common way to present information in 3D interfaces is by using visualization systems [2]. The visualization systems and its parameters such as resolution, Field of View (FOV), stereoscopy, contrast, among others, have the purpose of better presenting the VE to the user [3].

Since the VE is an example of three-dimensional interface, what could be better for promoting the sense of presence than comparing two different ways of presenting the information against each other? Two factors of the visualization systems were analyzed by this research: the FOV enlargement and, the stereoscopy usage. Both factors have been already proved as having a positive influence on the sense of presence; but have not, in any related work, been compared against each other, to check which one promotes a greater "feeling of being there", in the VE. Therefore, the focus of this paper is comparing the impact on the users' sense of presence between low-tech low-cost anaglyph-based stereoscopy and FOV enlargement.

A VE that represents the campus of the Santa Catarina State University (UDESC) at Joinville was used for all experiments and no interaction was allowed during a guided tour where participants were assigned a simple task. The participants were all undergrad students that did have some knowledge of how a university campus might look like. A total of 63 participants enrolled in a within-subject followed by a between-subject study.

This article is organized as follows: Section 1 presented the focus and purpose of the research; Section 2 explains the two visualization systems used on this experiment and gives the reason of the choice of those specific two; Section 3 discusses the meaning of presence; Section 4 presents related work; On Section 5 the experiment is presented including how measures were taken, participants, materials and procedures; Section 6 presents the results and analyses, and finally; Section 7 discloses the conclusions of this research.

## 2 Visualization Systems

Field of View (FOV) is the angle formed in a given moment by the user, as being the origin point, and the extents of the image, left to right for horizontal FOV and top to bottom bounds for the vertical FOV [1]. The closer the user is from the screen or the bigger the screen is, the bigger the FOV is going to be [2]. This is the physical FOV that could vary easily according to the visualization setup. There is also the graphical FOV which is related to similar geometry but regarding the virtual camera model, and then will not be considered because it is a fixed parameter of the rendering software.

Stereoscopy is the effect caused by seeing two distinct images (in contrast to one – monoscopic – view) from the same scene with a little difference imprinted in them. This difference between the images is known as parallax, and it causes the observer to perceive the effects of volume and distance; the brain is responsible for interpreting those two images and generating a 3D version of the scene [1] [3].

There are two types of stereoscopy: passive and active. In passive stereoscopy two different images are shown at the same time to the user that uses a passive filter to separate the right eye image from the left one. Among the passive stereoscopy there is one that uses colored lenses for filtering purposes - known as anaglyph. Anaglyphs are the simplest, cheapest and oldest method of getting the 3D effect. There is also the active filtering stereoscopy which uses glasses with transparent LCD lenses and a way to synchronize alternating images from the screen with the glasses. It works by commanding the glasses to shut off one of the lenses at a time, preventing one of the eyes from seeing the screen. It happens so fast that the brain perceives the images from both each eyes as being just one, and then reason about it in 3D [4].

The experiment presented in this paper has used the anaglyph-based stereoscopy. The lenses of the glasses were red/ blue. Red lenses make red color gamut of the light to be emphasized. Blue lenses emphasize the blue colors gamut and the green one somewhat. These are the most common and cheaper anaglyph lenses [5], but it is also possible to find glasses with red/ cyan, green/ magenta lenses or even blue/ yellow, an option to users that present color-blindness [6].

## 3 Presence

"Presence" is commonly confused with "immersion", but actually these are two different aspects [1] [7]: Immersion is the artificial stimulus on the body senses. It means that the user will be immersed if it responds to artificial stimuli coming from the environment; Presence is the sense of being deeply engaged in the environment, the belief that the user is in there.

So, does presence exist without immersion? Dreams can cause the sense of presence, since hallucinations are able to involve all the senses with no sensorial stimuli [8]. To avoid misunderstandings, presence have been defined as a psychological sense of "being there", in the environment [13]; it is a state of mind, a suspension of disbelieve on what is reality; it is the feeling of being inside the environment and that the environment is the reality. This definition is the most widespread and accepted notion of presence [9] [10] [11] [7].

The sense of presence may be influenced by many factors [10]: Immersion is the main aspect that influences the sense of presence as well as the accuracy of the sensorial information (realism); In second place, there is the latency, the time elapsed between user's movements and its repercussion on the virtual scene; How the user interact with objects, actors, events inside the environment, and; at last, users´ perceptive, cognitive and motor abilities, their prior experiences and their willingness to suspend disbelieve.

The higher the sense of presence the better will be the users' impression that all that happened in the VE was real. As mentioned in [12], in the case of a VE being used on training of firefighters or surgeons, presence is crucial because users are expected to act like they do in real life and transfer the knowledge learned in the environment to reality.

## 4 Related Work

Ijsselsteijn et al. [14] made two experiments to check (a) FOV and image motion and, (b) stereoscopy and image motion. It was applied to twenty-four students ranging from 18 to 30 years of age. The experiment was to watch two different video sequences of a rally. The image motion was filmed by a camera positioned on a car hood, and the still sequence was a view from a spectator, where the participants could see the car passing by. They used a curved stereoscopic projection screen measuring 1.9m x1.45m, providing a horizontal FOV of 50°. Two projectors were used with polarized filters and users needed to wear polarized glasses to see the 3D effect. The study for the stereoscopy and image motion was a within-subjects: users tested all four combinations (stereo or mono; still or moving image), with the only constraint that no participant could see two moving or two stills consecutively, to avoid motion sickness. For the FOV they designed a between-subjects study to reproduce the experiment of [15], but with a horizontal FOV changing from 28° to 50°. Participants were required to watch short videos and their responses were monitored. After each of the four video sequences the participants were asked to fill in a presence rating scale. A positive effect of stereoscopy and image motion on the sense of presence was found. About the FOV, when comparing the results with the values from [15], an increase on the sense of presence was found on the moving images but not on the still ones.

Shim and Kim [16] validated the positive effect of the FOV on the sense of presence. They tested the level of detail of the scene, being it high or low, and FOV varying between 180°, 150° and 120° with the help of three displays. No other sensorial device had been used and there was no form of interaction with the VE also. The task was to observe a virtual aquarium for 90 seconds containing 30 fishes, each fish with a different behavior. Six visual combinations from the 3 different FOVs with high or low quality details were experienced. Twenty-three undergraduate students have participated in the experiment. Their age varied between 19 and 27 years old. Eight questions from a Presence Questionnaire [17] were used to evaluate the sense of presence. It was concluded that a highly detailed scene and a larger FOV have higher effect on the sense of presence. Indeed, there seems to be no doubt if FOV enlargement promotes higher sense of presence from existing and usual screens but it has already been realized [18] that there must be a point at which further enlargement is redundant.

Freeman et al. [15] proved positive the relation between stereoscopy and the sense of presence. Their experiment consisted in three distinct motion controlled films (observer motion, scene motion and minimal motion) presented in mono and stereo but all through a stereoscopic display. Twelve college students participated on the experiment, being six male and six female. They had to read the definition of presence and the directions of what to do. After confirming that they understood everything, they could begin the experiment. This approach had been used in our experiment as well. It was a within-subject study, where every participant watched both stereo and mono version of all three 30 sec. films. They found that, no matter the difference in what moves, "presence ratings were enhanced by stereoscopic presentation".

These work ([16][15][14]), among others ( [18] [19]), proved that stereoscopy and FOV have a positive effect on the sense of presence, but no comparison against each other on their impact on the sense of presence was found. Further, the sense of presence achieved by anaglyph-based stereoscopy seems not to be affected by users´ computer literacy [24]. All these work used a non-interactive way to present the task to participants and the population was mainly university students - features that will also be applied to our experiment.

The use of immersive devices can also be investigated but are costly and not always available whilst there are other cheaper visualization systems that can be used but, for some reasons, have been neglected. This is the case for anaglyph stereoscopy. The investigation in this paper is concerned with low-cost low-tech stereoscopy; the kind of stereoscopy that almost any VR setup can use. Thus, the focus of this paper is not to argue if stereoscopy has positive influence on the sense of presence, but we are concerned with comparing low-cost low-tech visualization systems against each other.

A dozen participants seem to be a reasonable sample but a bigger sample was used to raise confidence on the results. It should also be noticed that previous experiments minimized user interaction in order to emphasize the importance of observing (seeing) the scene (through the stereoscopic device) so, the same strategy was adopted in our experiments.

# 5 Method

### 5.1. Measuring Presence

The sense of presence can be measured in two different ways. The objective way evaluates the user's physiological reactions. This kind of measuring does not require the user's knowledge of the meaning of presence. It is not widespread and usually there is an associated subjective measure altogether [10] [18]. The subjective way depends on the conviction users have about presence because they will respond in different ways to how they thinks about themselves being present. Nevertheless this subjective way is believed to be the most reasonable way of measuring presence, because presence is also a subjective feeling [18].

Youngblut [18] also asserts that questionnaires are the most usual method to measure presence. She surveyed 156 researches that used questionnaires as a way to measure presence. There are all kinds of questionnaires: Some contain subjective questions about how the user felt during the experiment; some can contain questions requiring users to describe they own behavioral and physiological observations [19] [17]; some contain only one question; while others are made of up to 150 questions. The most used one is the SUS Questionnaire [18].

The SUS Questionnaire has been used in the present work. It has been chosen because it evaluates presence in a manner closer to the definition of presence. It is based on 6 questions related to 3 themes: the sensation of "being there", inside the VE; the importance that the VE has become dominant over the real world; and the experience being remembered as a place visited by the user. Users have to answer the questions in a scale from 1 to 7, where 1 means no sense of presence at all and 7 means a strong feeling of being present. The level of the sense of presence is accounted by the number of questions which the answers were higher than or equal to 6 [20].

### 5.2. Participants

Participants were acquainted to the real environment which the experiment was trying to reproduce. They were supposed to know the maximum value of presence of being really there, and use this to compare with the sense of presence on the virtual campus [20]. A total of sixty-three (n=63) participants have engaged in the experiment. From those, thirty (n=30) used the FOV enlargement and thirty-three (n=33) used the monoscopic to stereoscopic change. The groups were of different sizes because they all volunteered to participate and we accepted as many as possible over a specific period of time. Most of them were students (undergraduate and graduate) and, some were professors from a computer science department but all with little/no use of related technologies, as can be seen from Table 1.

Table 1: Knowledge profile of the participants.

| Age (Average) | Computing Students | Little/No use of RV | Little/No use of CAD | Little/No use of 3D Games |
|---|---|---|---|---|
| 23 years and 10 months | 89% | 92% | 95% | 67% |

### 5.3. Materials

The 3D VE used in this experiment was a X3D [21] model of the Santa Catarina State University (UDESC) campus, located in Joinville-Brazil. For the stereoscopic visualization of the virtual campus, BS Contact plug-in version 7.2.1.2 has been used which enables the anaglyph-based stereoscopy visualization of 3D models.

All VEs are supposed to have a purpose [22] and thus, participants were asked to count garbage cans along the navigation path. Garbage cans were modeled and positioned along the chosen path at similar location as the 24 real garbage cans are in the real campus. Garbage cans have been modeled in Blender and exported to X3D. They can have several colors and shapes as shown on Figure 1. The navigation through the environment has been implemented by camera movements. It is necessary to set right both position and direction of the camera for each instant of the navigation. This is done by a PositionInterpolator and an OrientationInterpolator nodes of X3D. The navigation lasts for 2.5 minutes.

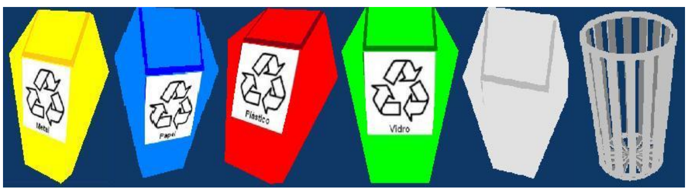

Figure 1: Garbage cans

It was found in pilot tests that users who knew the X3D visualization software knows a way to navigate by using the keyboard and felt tempted to use it. So, to avoid that, all the interaction between the user and the environment was removed and even the keyboard was taken away from the participants. The experiment guide, the person who watched over the experiment to verify if everything went alright, was responsible for clicking on the mouse to start the navigation.

Participants start the navigation at the entrance of the Computer Science building, next to four garbage cans (see Figure 2, left) so, they are readily acquainted to the garbage cans and to their task on the VE. Then, they pass by a photocopy service and go through the corridor all the way to the hall (Figure 2, right). Then, they go to the second floor using a ramp. When getting there, they go to the balcony to look all over the campus (Figure 3, left). Then, back to the ramp to climb to the third floor to look to both sides of the corridor. Next, they go back to the second floor (Figure 3, right) and take the way to the Civil Engineering building (see Figure 4, left). Arriving there, they stop at the entrance (Figure 4, right) and the navigation finishes. Figure 5 presents some pictures of the real campus.

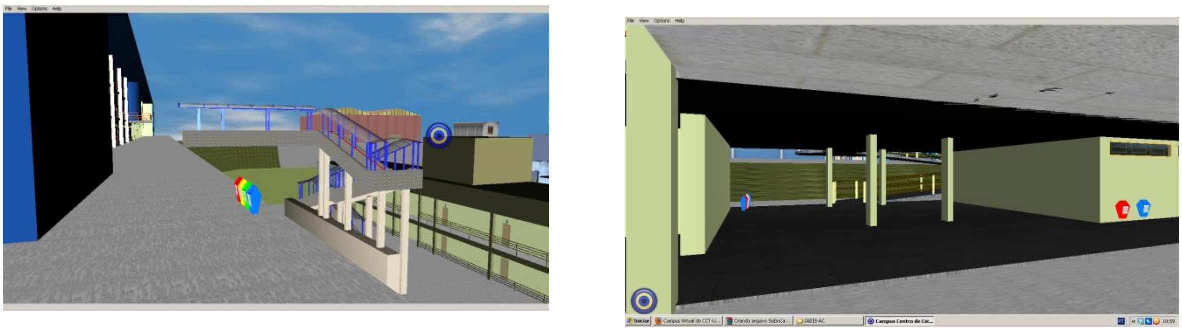

Figure 2: The starting point (left) and the entrance to the computer building (right)

Figure 3: A view from the balcony (left) and from the stairs of the computer building (right).

Figure 4: A view of the corridor (left) and the entrance (right) to the civil engineering building.

Figure 5: Photos of the real campus.

For the VE presentation, the following devices were used: The 20° FOV display was a 18.5" monitor, 1360x768 pixels of resolution, 250 cd/m² of brightness, 50000:1 of dynamic contrast ratio, 16:9 of aspect ratio, 5ms response time and price tag around US$ 150.00; The anaglyph effect was obtained thanks to red and blue glasses and the BS Contact software set to generate anaglyph images; The 50° FOV display was achieved via a DLP projector with 1024x768 resolution, 20000:1 dynamic contrast ratio, 1.700 ANSI Lumens, 16:9 aspect ratio, price tag around US$ 750.00 and a flat screen.

### 5.4. Procedure

The experiment protocol was set as follows:

- Participants were randomly sorted to engage in one of the experiment, FOV enlargement or monoscopic to stereoscopic change and, thereafter dealt with individually; They were asked to read and sign a consent form expressing their free will and understanding of the experiment;
- Participant were questioned if they knew the campus and, specifically, the Computer Science building and the path to the Civil engineering building;
- Participants were positioned 1.10m from the display and seated 43cm from the floor, in all experiments. The computer display measured 41cm of width and 23cm of height, and was located 89cm from the floor;
- Before starting the experiment, the experiment guide asked them all to fill in a demographic questionnaire;
- An explanation about the sense of presence was given;
- Participants were told their objective during the experiment (to count garbage cans). It was explained to them that they would not need to do anything besides watching and counting. Thus, it was assumed that every participant had the same knowledge about presence and what to do in the environment;
- The experiment guide asked if the participant understood everything and if s/he was comfortably seated and ready to start. The guide waited for an affirmative answer to begin the animation/navigation;
- After the navigation, the participant was required to fill in the SUS Questionnaire;

The experiment has been divided into three phases (see Figure 6); first, all participants used the monoscopic vision with a 20° FOV display (called Phase 1) next; about half of them used the anaglyph-based stereoscopic vision on the same display (called Phase 2) while the other half used the enlargement of the FOV to 50° but maintained the monoscopic vision (Phase 3). The order of experiments started off from the simplest version of the visualization system and it was made so to prove the sense of presence increment, similar to others' work [23].

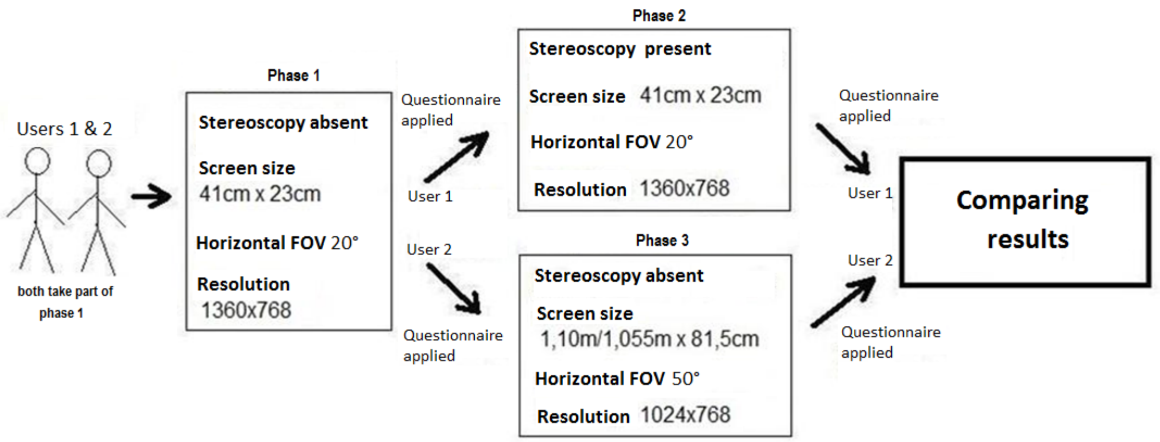


Figure 6: Experiment desgin.

The experiment scheme is shown in Figure 6, where it is possible to check that the SUS questionnaires were applied after each experiment individually. Regarding the SUS Questionnaire, a question asking if the user felt any kind of discomfort during the experiment and, a space to write down any contribution or comment participants want to share have been added.

As shown in Figure 6, a within-subjects design study was applied first to compare the results of the participants against the specific visualization setup; from monoscopic view (Phase 1) changing to stereoscopic view (Phase 2) or FOV sizes (Phase 3). Subsequently a between-subjects design study was applied to compare the performance of participants against the two visualization setups.

## 6 Results and Analyses

A demographic analysis shows that FOV and stereoscopic experiments had participants alike regarding their knowledge on 3D applications. They stated no use of VR (Virtual Reality) or 3D games or 3D CAD (Computer-Aided 3D Design) systems. From all participants, seven (7) had complained about some kind of discomfort. None of them from the FOV experiment (Phase 3). To avoid disturbing results, these seven participants were taken off further analysis because they confirmed in their written comments that stereoscopy interfered on their capacity to distinguish objects in the VE. Some of them had achieved a really high score in the sense of presence, but were taken off the statistics nevertheless. Most of these excluded participants, considered themselves with an outstanding knowledge in computing, and the age of most of them was much higher than the total average of 24 years old.

It is plausible to affirm that the age and the level of knowledge of the complainers might represent a long time in front of the computer display, what might have resulted in a visual tiredness that somehow interfered in the perception of the three-dimensional effect. Besides, these participants could had a visual disease, anything from amblyopic, squint or color blindness (that affects up to 8% of males), that echoed somehow on the anaglyph filtering (these pathologies were not tested nor confirmed).

### 6.1 Percentage of Participants at Various Presence Levels

The percentage of participants that achieved certain value of the sense of presence is shown in Figures 7 and 8. Lines regarding Questionnaire 1 indicate the results of the SUS Questionnaire just after Phase 1. Lines regarding Questionnaire 2 indicate the results of the SUS Questionnaire after the corresponding improvement (say Phase 3 for FOV enlargement, and so on).

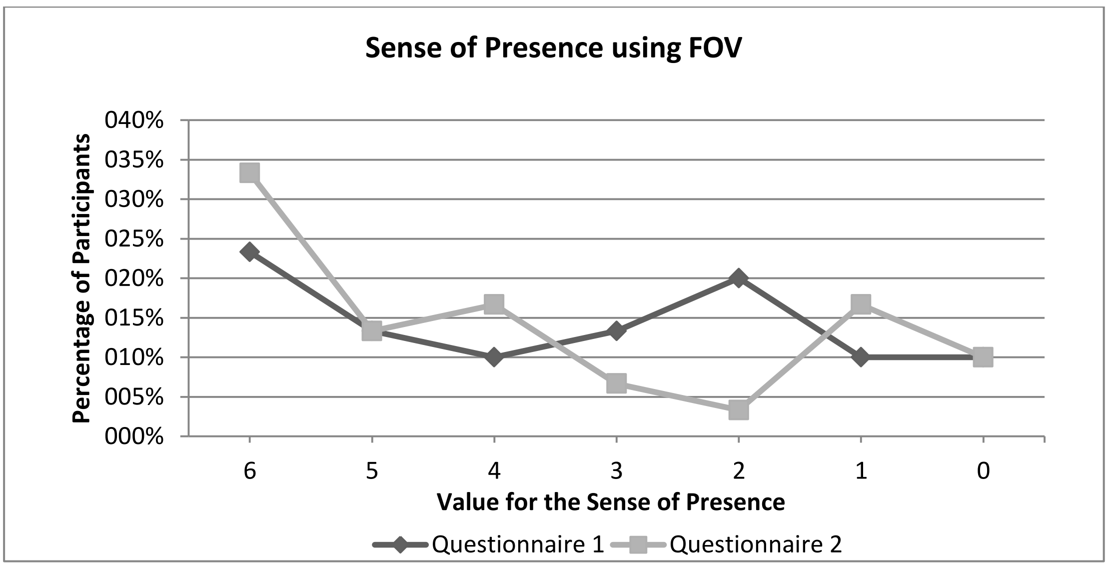


Figure 7: Sense of presence due to FOV

In the FOV experiment Phase 3 (see Figure 7), 7 out of 30 participants felt completely present (scored 6) at first (with the simplest setup of a monoscopic and small FOV); on a second experiment (Phase 2) they were 10, an increase of 42%. In the stereoscopic case (Figure 8), 5 participants felt completely present at first but after changing to stereoscopy (Phase 3), 9 out of 26 participants felt completely present in the VE, an increase of 80%.

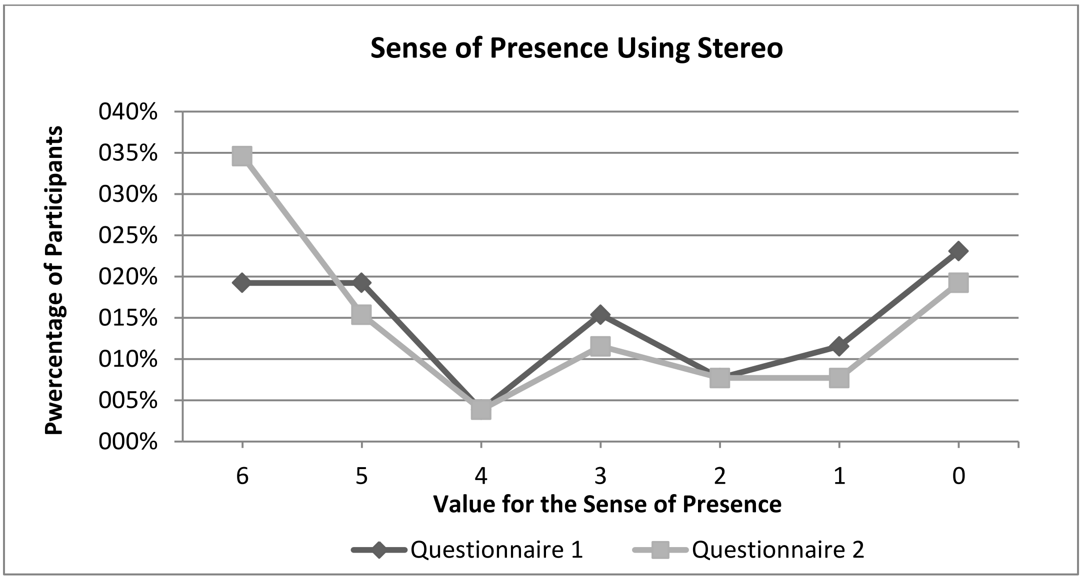


Figure 8: Sense of presence due to stereoscopy

### 6.2 Analysis

The shape of Figures 7 and 8 shows that the majority of participants reported a higher score on the sense of presence. It also suggests that most participants increased at least one level on the sense of presence regardless of the visualization setup change.

Table 2 shows statistical values for the FOV experiment for each of the questionnaires. The second column represents the values of the SUS Questionnaire for Phase 1, the third column represents the values of the questionnaire from the Phase 3, larger FOV, and the fourth column represents the increase in the sense of presence (difference of the values from third and second columns). Table 3 shows the same data but for the stereoscopy group of participants that participated in Phase 2.

Table 2: Values of presence of the FOV experiment in Joinville.

| | FOV | Quest. 1 | Quest. 2 | Difference |
|---|---|---|---|---|
| **Joinville** | **Average** | 3.37 | 3.77 | 0.40 |
| | **Standard Deviation** | 2.06 | 2.21 | 0.15 |
| | **Median** | 3.00 | 4.00 | 1.00 |

Table 3: Values of presence of the stereoscopic experiment in Joinville.

| | Stereoscopy | Quest. 1 | Quest.2 | Difference |
|---|---|---|---|---|
| **Joinville** | **Average** | 3.00 | 3.58 | 0.58 |
| | **Standard Deviation** | 2.27 | 2.35 | 0.08 |
| | **Median** | 3.00 | 4.50 | 1.50 |

Comparing Table 2 and 3 it can be seen that participants from the FOV experiment felt a higher level on the sense of presence at first (Phase 1) than stereoscopic ones but their median values were both 3.0. On the second part of the experiment, the median is higher in the stereoscopic experiment (Phase 2) than in the FOV one (Phase 3). The differences in the averages and medians show a higher increase on sense of presence and a decrease in standard deviation utilizing stereoscopy as a visual system enhancement than FOV.

Table 4 contains the statistics for each question of the SUS Questionnaires before and after changing the visual setup. It considers all values from 1 to 7. The Average Increment column shows the difference between the average values from Questionnaire 2 and Questionnaire 1 for each group. The Total Average line shows the averages of all values from each column.

Considering the results from Table 4, it can be said that question 6, which evaluates how much the participant had really believed being in the campus, got the highest standard deviations for the majority of cases, showing that participants' beliefs varied a lot. Question 6 values also show the smallest averages and medians in all cases which suggest that something prevented participants to believe in their visual stimulus, because most of them had believed of being actually in the campus but not so often. On the other hand, question 4, which questions the sensation of being in the campus stronger than being anywhere else, obtained the highest medians and averages in all cases which suggests that participants had engaged in the campus environment (regardless if it was real or virtual).

Table 4: Detailed scores for each question of the SUS questionnaire.

| | | | **Quest. 1** | **FOV** |
|---|---|---|---|---|
| | **Average** | **Standard Deviation** | **Median** | **Mode** |
| **Question1** | 5.70 | 1.34 | 6 | 6 |
| **Question2** | 5.53 | 1.11 | 5.5 | 5 |
| **Question3** | 5.43 | 1.45 | 6 | 6 |
| **Question4** | **6.00** | 1.17 | 6 | **7** |
| **Question5** | 5.47 | 0.94 | 6 | 6 |
| **Question6** | 4.77 | 1.61 | 5 | 5 |
| **Total aver.** | 5.48 | 1.34 | 5.75 | 6.00 |

| | | | **Quest. 2** | **FOV** | |
|---|---|---|---|---|---|
| | **Average** | **Standard Deviation** | **Median** | **Mode** | **Average Increment** |
| **Question1** | 5.73 | 1.26 | 6 | 6 | 0.03 |
| **Question2** | 5.47 | 1.20 | 6 | 6 | -0.07 |
| **Question3** | 5.83 | 1.05 | 6 | **7** | **0.40** |
| **Question4** | **6.07** | 1.11 | 6 | **7** | 0.07 |
| **Question5** | 5.63 | 1.07 | 6 | 6 | 0.17 |
| **Question6** | 5.13 | 1.50 | 5.5 | 6 | 0.37 |
| **Total aver.** | 5.64 | 1.20 | 5.92 | 6.00 | 0.16 |

| | | | **Quest. 1** | **Stereoscopy** |
|---|---|---|---|---|
| | **Average** | **Standard Deviation** | **Median** | **Mode** |
| **Question1** | 5.42 | 1.33 | 5 | 5 |
| **Question2** | 4.88 | 1.58 | 5 | 4 |
| **Question3** | 4.96 | 1.75 | 5 | 6 |
| **Question4** | **5.88** | 1.45 | 6 | **7** |
| **Question5** | 5.15 | 1.73 | 6 | 6 |
| **Question6** | 4.57 | 2.06 | 5 | **7** |
| **Total aver.** | 5.15 | 1.65 | 5.33 | 5.83 |

| | | | **Quest. 2** | **Stereoscopy** | |
|---|---|---|---|---|---|
| | **Average** | **Standard Deviation** | **Median** | **Mode** | **Average Increment** |
| **Question1** | 5.80 | 1.16 | 6 | 7 | 0.38 |
| **Question2** | 5.57 | 1.47 | 6 | 7 | **0.69** |
| **Question3** | 5.61 | 1.52 | 6 | 7 | 0.65 |
| **Question4** | **5.88** | 1.47 | **6.5** | 7 | 0 |
| **Question5** | 5.57 | 1.47 | 6 | 7 | 0.42 |
| **Question6** | 5.11 | 1.73 | 5 | 7 | 0.54 |
| **Total aver.** | 5.60 | 1.47 | 5.92 | 7.00 | 0.45 |

Because of the anaglyph glasses, a few of the participants complained about discomfort. The over saturated colors of the garbage cans may have been the cause of this feeling. Anaglyph glasses filter the images by using colors; the problem is that a large spectrum of colors is to be filtered by only two filters/colors, one for each eye. Anaglyphs work better with low saturated images. However, most of the users had been able to see the 3D effect caused by anaglyph stereoscopy: one participant mentioned that he had felt the stereoscopic effect for the very first time and he really had enjoyed the experience.

For Phase 1 to Phase 3 experiment with participants (n=26), the Shapiro-Wilk test at 1% confidence resulted p=0.000608 and the Wilcoxon test resulted p=0.1203 which says that there were basically no gain (or, at least, a very small one) in the sense of presence to participants due to FOV enlargement.

The Shapiro-Wilk test comparing the results from Phase 1 to Phase 2 for participants (n=30) resulted p=0.0303 and the Wilcoxon test resulted p=0.03895 which proves that there was an increment in the sense of presence for the participants due to stereoscopy. All tests were performed using the "R" software, version 2.13.0.

## 7 Conclusions

The sense of presence is regarded as one of the main purposes and advantages of Virtual Reality (VR) which is a technology that has captured a significant attention from the scientific community [25]. We have put to the test, two visualization features that are said to contribute positively to the sense of presence: FOV (Field of View) enlargement against stereoscopy usage. Both features can be easily and cheaply achieved by image projectors or anaglyph-based eye glasses, respectively. Using the same VE, participants watched a navigation in a University campus on either a standard display and then on a FOV-enlarged or stereoscopy-enabled setup.

It was found that simple low-cost low-tech anaglyph-based stereoscopy produced a larger increase in the sense of presence than FOV enlargement. However, an increase in the value for the sense of presence was sought in both setups but in a distinct way: Larger FOV makes users better remember the VE as a place visited, because a large FOV covers a great deal of users FOV, making them see the environment closer to what they see in the real world. Stereoscopy gives volume and distance to the scene and this three-dimensional effect seems to help render the environment more realistic, believable.

In conclusion, just using a low-tech anaglyph-based visualization and wearing cheap eyeglasses participants do sense to be more present than FOV enlargement but it is not to everyone. Its usage is limited to those scenes that are not so color-saturated and, for some reason, anaglyph-based stereoscopy is uncomfortable to some people (of certain age and of outstanding computer literacy) that needs to be further investigated. Therefore, stereoscopy seems to be the very first step to be taken to become really close to VR purposes and advantages.

The interactive version of the virtual campus is available to be experienced over the internet at the following URL: http://www2.joinville.udesc.br/~larva/cctvirtual (in Portuguese).

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