BJRS

BRAZILIAN JOURNAL
OF
RADIATION SCIENCES
11-02 (2023) | 01-24 | e2276

The Use Virtual Reality to Assist In The Preparation Of An Ergonomic Analysis Of Nuclear Facilities

Machado[a], D.M.; Mol[a,b], A.C.A.; Santo[a,b], A.C.E.; Vidal[c], M.C., Lapa[a], C.M.F.

[a] *Instituto de Engenharia Nuclear (IEN/CNEN – RJ), Rua Hélio de Almeida, 75, 21941-906 – RJ -Brazil*

[b] *Centro Universitario Carioca (UniCarioca), Avenida Paulo de Frontin, 568, 20261-243 -- RJ – Brazil*

[c] *Instituto Alberto Luiz Coimbra de Pós-Graduaçãoe Pesquisa em Engenharia – COPPE -- UFRJ - Av. Horácio Macedo 2030, Cidade Universitária Rio de Janeiro, Brazil*

machado.mol@gmail.com

ABSTRACT

Ergonomic Analysis consists of making value judgments about the global performance of certain man-machine or man-task systems and may result from a demand related to conditions and/or safety at work. However, during the performance of the Ergonomic Analysis, the presence of ergonomists can interfere with the work progress, which limits the observation time. Organizations that have risk areas have already been using simulated exercises to train their professionals. With the use of simulation tools, it becomes increasingly necessary to develop methods and techniques that allow the performance of this training, as close as possible to real work activities. In this context, this article proposed to create and verify if the use of Virtual Reality can help the Ergonomic Analysis of Work, developing scenarios and virtual simulation environments, contextualized by the Ergonomics perspective. For this purpose, a case study was carried out at the Institute of Nuclear Engineering where the Ergonomic Work Analysis and the modeling of the virtual environment were carried out. Finally, from the results presented, it can be concluded that Virtual Reality serves as a complementary tool to assist the ergonomist in the Ergonomic Analysis process, allowing him to use the tool to reduce risks, saving time and improving his performance.

Keywords: **Ergonomic Analysis, Virtual Reality, Physical security.**

ISSN: 2319-0612
DOI: https://doi.org/10.15392/2319-0612.2023.2276
Submitted: 2023-03-27
Accepted: 2023-06-13

1. INTRODUCTION

Ergonomic Analysis consists of making value judgments about the global performance of certain man-machine or man-task systems and may result from a demand related to conditions and/or safety at work. An Ergonomic Analysis should be carried out by a "task force", composed of at least one experienced worker (knowing the work), a technician or engineer who knows the machine or the process well, a supervisor (knowing the operational reality of the area) and a specialist in Ergonomics. "The correct constitution of the task force must guarantee the principle of participative administration, but excessive numbers of people must be avoided, as it makes routing more complicated" [1,2]. However, during the performance of the Ergonomic Analysis, some difficulties faced by ergonomists may appear that can interfere with the progress of the work. As reported by Tinoco [3], some ergonomists have difficulty using equipment for filming and taking photographs in the field, as some companies prohibit this type of procedure within the facilities. It has also been reported that many workers do not get involved as they do not know if the recommendations made will be implemented.

Ergonomists need to interact, talk, dialogue with workers in the work situation. This interaction is important because they can get relevant details of the way of working, gather speeches about the work and give importance to the operative speeches of workers [4]. For this, it is essential to know how to approach the group of workers, however some companies restrict access to certain employees or limit this access to a specific time for this interaction to occur and this type of difficulty can hinder the progress of the analysis. Carrying out an ergonomic analysis during the transport of dangerous goods can put the integrity of the ergonomist at risk [5]. Ergonomic analysis in nuclear power plants can also be considered a great risk because it is a place where we find materials that are harmful to health [6].

Ergonomic analysis in the physical safety sector of nuclear power plants can also be considered of great risk because it is a place where we find materials that are harmful to health [6]. The CNEN STANDARD NN2.01 aims to establish general principles and minimum requirements necessary for the design, implementation, and maintenance of a Physical Protection System for nuclear materials and facilities. We call the Physical Protection System (SisPF) a set of elements, measures, rules, norms, procedures, equipment, devices, and human resources with the purpose of deterring, detecting, delaying and responding to any unauthorized act against a nuclear installation. The physical protection of a nuclear installation is defined by some objectives [7]:

I – protect nuclear material against theft, theft or any other form of unauthorized removal;

II – contribute to the recovery of nuclear material that may have been removed in an unauthorized manner or is missing;

III – protect nuclear facilities and material from unauthorized acts, especially sabotage;

IV – contribute to minimizing or mitigating the effects of an act of sabotage at the nuclear installation;

V – contribute to maintaining the physical integrity of personnel at the nuclear facility.

It is worth mentioning that many organizations, such as the military, those in the nuclear areas, disaster responses, logistical air traffic planning, space mission control, among others, have been increasingly using exercise simulation to train their professionals [8]. This is reflected in the search for new technologies to simulate, explore and test new forms of operations that seek to solve adverse situations or prevent future emergencies. With simulation, it becomes increasingly necessary to use methods and techniques that allow training for adverse events, to prevent them. To meet such needs, the use of a simulator has been shown to be important in the construction of interfaces in three-dimensional virtual environments. The use of Virtual Reality has become a constant in recent years, several projects are dedicated to the use of techniques and tools already developed for the regular virtual reality market. The Game Cores can be used to build these virtual environments for simulation. Game Centers, also known as Game Engines, are programs intended to produce electronic games. Seeking to provide the developer with a complete and agile environment, the most used game engines are accompanied by integrated content creation and editing tools, such as scenario editors and script interpreters for programming functions necessary for games and applications. In addition to these, to be characterized as a game core, the tool must provide some fundamental features such as audio playback, animation support, video playback, ability to communicate with other instances of the application to perform network communication (multiplayer applications), artificial intelligence functions, file access and interpretation, memory management, etc [9].

NR 17 – ERGONOMICS (Regulatory Norm) aims to establish the guidelines and requirements to adapt working conditions to the psychophysiological characteristics of workers, with the aim of providing comfort, safety, health and consequently improving performance at work.

Working conditions may include aspects related to lifting, transporting and unloading materials, furnishing workstations, working with machines, equipment and hand tools, comfort conditions in the work environment and work organization itself. It is important to point out that in activities that require static or dynamic muscular overload of the trunk, neck, head, upper and lower limbs, measures must be adopted, whether organizational or administrative, with the main objective of reducing overloads. of workers, based on a preliminary ergonomic assessment or an Ergonomic Work Analysis. Based on this assessment or analysis, preventive measures must be taken to prevent workers from being forced to perform continuously and repetitively when carrying out their activities [10]:

1- extreme or harmful postures of the trunk, neck, head, upper limbs and/or lower limbs;

2- sudden impact movements of the upper limbs;

3- excessive use of muscle strength;

4- frequency of movements of the upper or lower limbs that could compromise the safety and health of the worker;

5- exposure to vibrations;

6- cognitive requirement that may compromise the safety and health of the worker.

For the design of work stations, organizational and environmental factors, the nature of the task and activities, and facilitating the alternation of postures must be taken into account. It is also important to verify that the dimensions of the work and circulation spaces, inherent to the execution of the task, must be sufficient for the worker to move freely, facilitating the work, reducing the effort of the worker and not requiring the adoption of extreme postures or harmful [10].

That said, one of the possible solutions to help Ergonomic Analysis would be through simulation using virtual reality. Virtual environments bring some advantages, among them: they are attractive to the public, as it allows them to feel immersed in their respective environments, without being exposed to any risk; allows simulations of hypothetical situations, provided for in protocols and difficult to train, to be carried out; it has a lower cost than a real simulation; it can be carried out at your place of work, without the need to be away for a long period; can be used in the design of a project, predicting the disposition of buildings, among others.

In this context, the objective of this article is to propose and verify if the use of Virtual Reality can help in Ergonomic Analysis, developing scenarios and virtual simulation environments, contextualized by the perspective of Ergonomics.

Thus, the following items were verified during the ergonomic analysis: lighting, workstation, furniture, climate (rain, sun), perception in the virtual environment of the variation of what is day and night (morning, afternoon and night), use of headset for communication between guards.

This article is organized as follows:

- in section 2, the general format of the study: the development of the virtual environment using Unity 3D is described, describing who were the project participants, how the data were collected (questionnaire and interview), the PILOT TEST, and the way to analyze the data.
- in section 3, we have the results of the data analysis.
- in section 4, the conclusions.

2. MATERIALS AND METHODS

This research had as its initial objective to carry out an ergonomic analysis in loco in the physical security sector of a nuclear installation.After this evaluation, a virtual environment was modeled and created to best reproduce the real environment of the nuclear installation.After creating the virtual environment, it was presented to specialists in ergonomics and security agents in order to validate the virtual environment by comparing it with the real one, through sessions.At the end, a simulation was performed, with security agents from the nuclear facility, in the virtual environment, where they operated physical security procedures in the virtual environment (the same as they do in the real environment).The simulation was concurrently performed by ergonomics professionals who, at the end of the simulation, were presented with a questionnaire to verify the use of virtual environments to assist in an ergonomic analysis.

To achieve the main objective of this article, which is to evaluate the capacity of a Virtual Environment to assist in an ergonomic analysis, the study participants were initially chosen, who are IEN workers, in addition to professionals specializing in ergonomics. During the 10-day period, a total of 7 specialists were responsible for observing the simulations carried out by the guards. After choosing the professionals, a real work situation was selected, modeled and implemented in a Virtual Environment. Initially, the place where the tests and the study of this work would be carried out was chosen.

With the choice of location, a specialist performed an Ergonomic Analysis in loco, after which the construction of a virtual environment based on the real environment began. This modeling aims to give realism to the virtual environment. After the construction of the virtual environment, it was presented to the same specialist (ergonomist) who had already performed the ergonomic analysis in the real environment, in order to see the expert's perception comparing the real analysis with the one made virtually, drawing his conclusions, what we call a pilot test. Such conclusions were obtained through a questionnaire answered by the specialist. During the work, the following items were analyzed: workplace lighting; furniture; weather (rain, sun); perception in the virtual environment of the variation of what is day and night (morning, afternoon and night); use of headset for communication between guards; location where the workstation is located (angle of vision in relation to the terrain); travel time between jobs.

The virtual environment was presented to the workers (which in this case are the guards). This presentation was made so that they could perform a computer simulation (perform simulations with the workers in the created environment) where they should perform in the virtual environment all the activities they perform in the real environment, to test the tool (virtual environment). All the simulation performed by the workers was monitored (observed) by ergonomists, who aimed to verify if, through this simulation, they could perform an ergonomic analysis, only observing the interaction of users (surveillancers) with the machines.

At the end of the tests, the Ergonomists were submitted to a questionnaire containing 11 items to assess their perception of the use of virtual environments to aid in ergonomic analysis.

2.1. Case Study

The case study analyzed in this article was carried out at the Institute of Nuclear Engineering (IEN) (Figures 1 and 2), which served as a basis for Ergonomic Analysis and for virtual modeling.

Figure 1: IEN

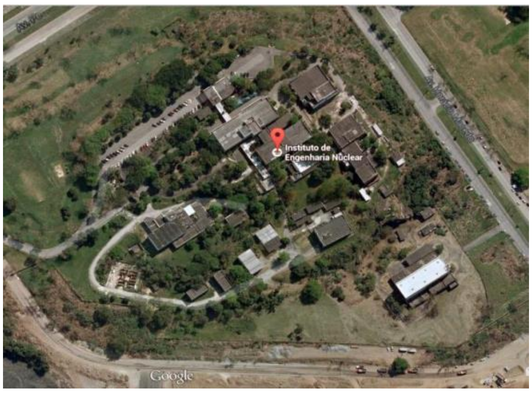
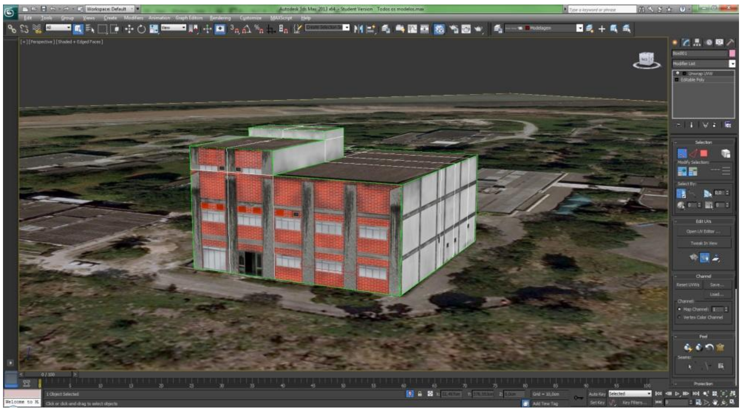


Figure 2: Installations IEN

2.2. Creation of the Virtual Environment

The modeling of the buildings was performed using Autodesk 3Ds Max software (Figure 3). A topographic image was added and served as a reference for the modeled area. Only the facades of the buildings were modeled. A technique called Poly Modeling was used to build the model. The second stage consisted of the texturing process. Still in 3Ds Max, the object had its mesh flattened and later transformed into a figure. Texture layers were applied, which were based on photos taken on site. In the textures, aspects of the state of conservation and natural effects caused by humidity, dust and etc.

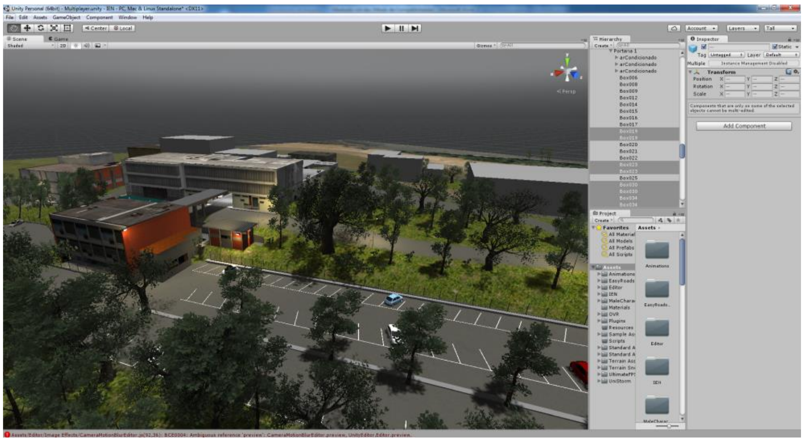
Figure 3: Modeling 3Ds Max



2.3. Terrain Modeling

The tool chosen to perform the terrain modeling was Unity 3D adjusting the terrain. Using the measurements and proportions derived from the topographic image of the nuclear installation, regarding the extensions and scales of the scenario, the standard terrain of Unity 3D was dimensioned (Figure 4). Thus, the shapes, magnitudes of width and length of the land under development were adequate to the real ones found at the nuclear site. From the modeled virtual terrain (in its shapes and dimensions of width and length) and already textured, the relevant changes were made to the relief of this area and aiming to provide greater realism to the virtual scenario, the vegetation characteristics found in the installation, such as grasses, shrubs and trees. Finally, to enable interaction with the developed scenario, avatars, virtual characters, controlled by the application user, were inserted.

Figure 4: Model Unity 3D



3. RESULTS AND DISCUSSION

The virtual environment developed in this work aimed to maintain a similarity with the facilities of the Institute of Nuclear Engineering, basing its measurements and proportions on maps, plans, photos and manual measurements of the real buildings of the IEN, from there a virtual scenario was developed for carrying out simulations with security guards and for evaluating the system by specialists in Ergonomics. The results were obtained through virtual simulation and questionnaires.

Initially, a pilot test was carried out where we contacted an ergonomics consultant who carried out an ergonomic analysis in the real work environment of the guards (in the IEN). This analysis was used as a basis for the construction of the virtual environment. The ergonomist explored (walked through) the environment in a virtual way in the same way that he explored the real environment. His participation was important because, in addition to carrying out the original analysis in the work environment, he also wrote his master's thesis debating issues relevant to what was addressed in this article.

A questionnaire was prepared and presented to the ergonomics consultant who mainly used his memory of the issues he identified at the time (from the analysis in the real environment), and how well these issues were represented in the virtual environment. The potential of simulations made through a Virtual Environment (VE) was also addressed to analyze the work, discuss and design proposals for improving the workspace.

In order to carry out the questionnaire, simulations were carried out in 2 (two) stages, where outsourced security agents (called agent A and agent B), responsible for the safety of the nuclear installation and ergonomics specialists (called PE), who accompanied and observed the activities that the agents performed. The first step was called Validation of the Virtual Environment and the second step was the Proposition of Activities within the Virtual Environment. The entire simulation was accompanied by experts in ergonomics who used their knowledge to evaluate the usefulness of the system to support an Ergonomic Analysis.

After the simulation, the participants were submitted to a questionnaire with objective questions. The objective was to extract the perception of the agents regarding the similarity of the created environment with the real environment and the performance of activities within it and extract from the ergonomics specialists their opinions regarding the use of the system to assist in an Ergonomic Analysis.

Altogether it took approximately one year and six months of work. Among which most of it was carried out within the IEN. The help of a multidisciplinary team (ergonomists, engineers, design, IT professionals, programmers) was needed to build the entire project. Everything was thought out and carried out in the best way and with great commitment and exchange of information between professionals. From field analysis to the final construction of the virtual model and virtual simulation.

3.1. Validation of the Virtual Environment

Objectives: to go through the simulated virtual environment with the objective of validating the degree of fidelity Virtual x Real; Extract the perception of the agents regarding the degree of realism of the virtual environment compared to the real one.

Agents A and B were submitted to an interview where the answers ranged from (1) I totally disagree to (5) I totally agree, where they answered according to their perception. Below are the questions asked in the questionnaires and the agents' responses, including photos taken during the simulation.

P1. When walking through the virtual environment, were you able to easily identify the installations?

Agent A: I totally agree

Agent B: I totally agree

P2 The buildings and terrain of the virtual environment resemble the real environment?

Agent A: I totally agree

Agent B: I totally agree

P3 The workplace is adequately reproduced in the virtual environment?

Agent A: I totally agree

Agent B: I totally agree

The figure 5 represents the real work environment (station 3) and figure 6 show the agents walking through the virtual environment with the avatar. It is possible to see the similarity between post 3 of the real surveillance and the one created virtually.

Figure 5: Post 3 of the real Surveillance

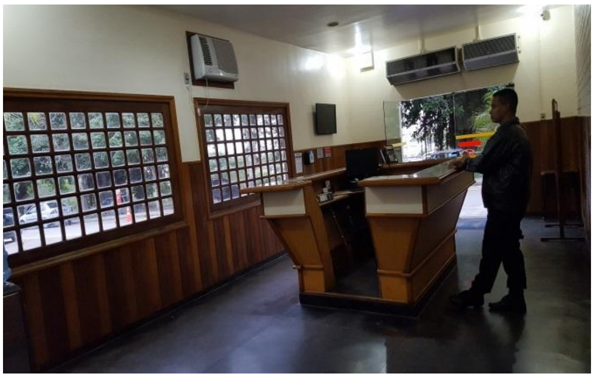


Figure 6: Virtual Surveillance post 3

In this same context, figure 7 shows the surveillance post 4, which is responsible for accessing the internal area of the IEN. In figure 8 we can see the representation of the virtual environment of post 4.

Figure 7: Surveillance post 4

Figure 8: Surveillance post 4

Post 4, also known as lobby two, is intended for the entry of employees and collaborators. Figures 9 and 10 show respectively a photo of station 4 and this one developed in the virtual scenery.

Figure 9: Photo of the 2nd ordinance - IEN

Figure 10: 2nd ordinance in virtual reality

The parking surveillance post was also reproduced in a virtual way, as it is a strategic point where the guards patrol. In figure 11 and 12 we can see the real surveillance post and its virtual representation, respectively.

Figure 11: Parking – IEN

Figure 12: Virtual Parking - IEN

3.2. Proposition of Activities within the Virtual Environment

In this step, activities were carried out within the virtual environment where the agents would have to perform specific procedures and the ergonomist monitored these procedures. At the end of the activities, carried out in the virtual environment, the security agents and the ergonomics professional were submitted to a questionnaire to evaluate the built virtual environment.

3.2.1 Activity 1 - Exchange of Positions

Objective 1: to verify if the communication that is made between them in the real environment can be simulated in the virtual one, figures 13 and 14 (through headset);

Objective 2: verify the displacement time of the avatar (character) between one job and another and compare with the real.

Next, we can observe the questions asked to agents A and B, through a questionnaire and the answers obtained. The questions related to activity 1 were represented from P4 (question 4) to P6 (question 6) and were represented below.

P4. The communication made between the guards in the real environment was able to be reproduced in the virtual environment through a microphone and headset.?

Agent A: I totally agree

Agent B: I totally agree

P5. Was this communication easy to carry out?

Agent A: I totally agree

Agent B: I totally agree

Figure 13: Headset Communication

Figure 14: Headset Communication

P6. Do you consider that the avatar (virtual puppet) has moved in a similar way to its movement in the real environment during the changes of positions?

Agent A: I totally agree
Agent B: I totally agree

The displacement simulations between stations 3 and 4 were made to compare the virtual environment and the real environment. Figure 15 shows the representation of stations 3 and 4.

Figure 15: Station 3 and Station 4 (virtual)

Table 1 represents the times during the route from path 3 to 4 walking, where simulation 1 means the guard leaving station 3 and going towards 4 and simulation 2 the guard going from station 4 to 3.

Table 1: Actions, Real Time, Simulation Time, Average Simulation Time

Action		simulation1 (seconds)	Simulação 2 (seconds)	Average Simulation Time (seconds)
Walking	Real	110,8	107,6	109,2
	Virtual	105,6	103,1	104,35
Running	Real	48,7	45,9	47,3
	Virtual	35,5	34,6	35,05

3.2.2 Activity 2 – Round

The second activity was called "Round", it consists of carrying out a simulation with multi-users where the guard will use the virtual environment to perform the same procedure of 'surveillance' that is done in the real environment.

The evaluation of this activity was done through the questionnaire and were represented by questions P7 (question 7) to P9 (question 9). The questions and answers obtained by the security agents (agent A and B) and by an ergonomist professional (EP) were described below, who performed the Ergonomics Analysis in loco in the real environment.

P7. Can the patrol procedure that is carried out in the work environment be done and reproduced in the virtual environment?

Agent A: I totally agree

Agent B: I totally agree

EP: I totally agree

P8. During the patrol procedure in the virtual field, was it possible to identify situations that should be reported to the superior?

Agent A: I totally agree

Agent B: I totally agree

EP: I totally agree

P9. Was the procedure done in the virtual environment very similar to what is done in the real environment?

Agent A: I totally agree

Agent B: I totally agree

EP: I totally agree

Below, figures 16 and 17 were made during the simulation of agents A and B and represented the round carried out in the virtual environment.

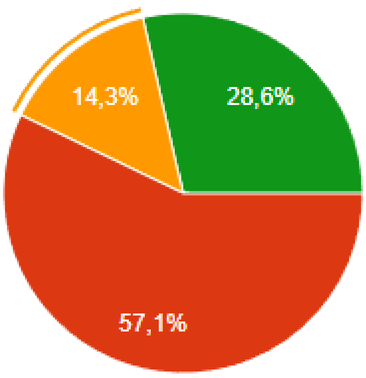
Figure 16: Guard during parking rounds

Figure 16: Round carried out in the Central Building

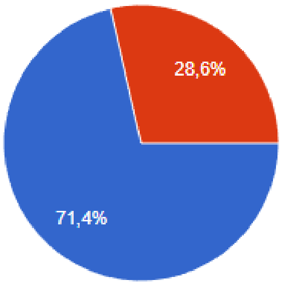
3.2.3 Questionnaire.

For the evaluation 11 questions were asked to ergonomics specialists (7 interviewees) who observed the activities developed during the simulation. The results obtained through the questionnaire will be seen below.

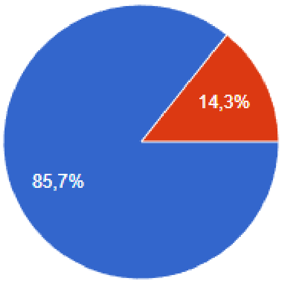
1 – Education Level: 57,1% of respondents have a master's degree, 14,3% have a doctorate and 28,6% have other courses. More than 70% of respondents are masters or doctors, which demonstrates a high degree of knowledge on the subject.



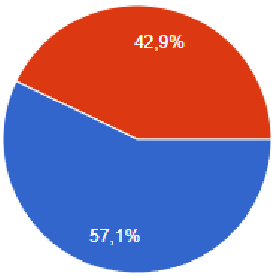
2 – I have experience with the Ergonomics discipline: 77,4% fully agree with the statement and 28,6% only agree. All interviewees have knowledge about ergonomics, so they are qualified to validate the answers.



3 – I have already performed an Ergonomic Analysis: 85,7% fully agree with the statement and 14,3% only agree. All interviewees have experience and have already performed an ergonomic analysis.

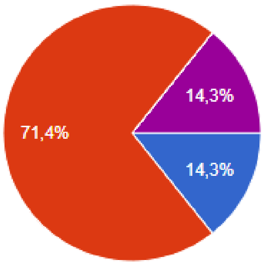


4 – I've seen some activity performed in a real environment simulated through a computer program: 57,1% have already seen and 42,9% have never seen this type of simulation. Almost 60% of respondents have had previous experience with virtual environments.

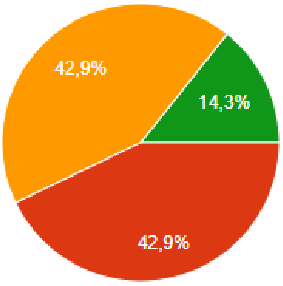


5 – What is your opinion about this type of simulation? Answer 1: Simulation is a tool that can complement the analysis of work in a real environment; Answer 2: I didn't find it practical; Answer 3: Abstain; Answer 4: Very useful for training; Answer 5: This simulation can greatly help the ergonomist in situations of difficult access or restricted access; Answer 6: Within the context, from my point of view, it serves the purpose for which it is proposed. Most of the interviewees evaluated that the simulation can help in an analysis.

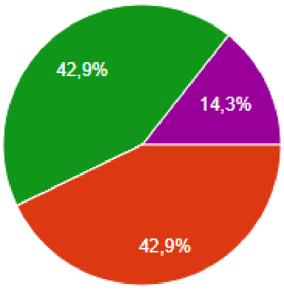
6 – The Virtual Environment can help an Ergonomic Analysis: 71,4% agree with this statement, 14,3% fully agree and 14,3% said it was not possible to evaluate. More than 80% of respondents realized that this type of simulation can help in an ergonomic analysis.



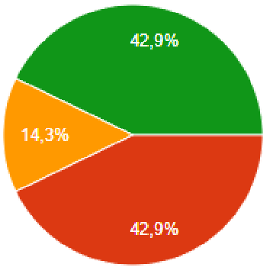
7 – After an Ergonomic Analysis, using the Virtual Environment, it is possible to observe enough elements to suggest improvements: 42,9% of respondents agree with the statement, 42,9% disagree with the statement and 14,3% strongly disagree. More than 85% of respondents understood that through simulation it is possible to suggest some improvements in the environment.



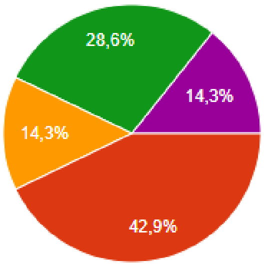
8 – Analyzing the Virtual Environment, it was possible to perceive the "real" (daylight or absence of light) and "artificial" lighting (light from): 42,9% of respondents agree with the statement, 42,9% strongly disagree and 14,3% said it was not possible to assess. More than 85% of respondents realized that the lighting of the virtual environment was able to satisfactorily represent the lighting of the real environment.



9 – The variation between day and night, in the virtual environment, resembles the real environment: 42,9% of respondents agree with the statement, 42,9% totally disagree and 14,3% said they just disagree. During the simulation, more than 57% of the interviewees were unable to perceive the variation between day and night in the virtual environment.



10 – It was possible to observe the climatic variation within the virtual environment (rain, wind, sun): 42,9% of respondents agreed with the statement, 14,3% disagreed, 28,6% strongly disagreed and 14,3% said it was not possible to assess. During the simulation, more than 85% of the interviewees were unable to perceive the climate variation in the virtual environment.



11 – In the space below, describe positive or negative aspects of using a Virtual Environment to assist the Ergonomist in an Ergonomic Analysis.

1 - Positive aspects: assessment of the work environment, assessment of the environmental conditions of the workplace; Negative aspects: difficulty in analyzing decision-making process; 2 - The virtual environment will never correspond to the real one. The analysis would be very limited. 3 - The best evaluation is in loco; 4 - This type of method can be useful, but in my opinion, it could not be used alone; 5 - Positive point would be the possibility of carrying out an analysis even not being in the real place. But this could also harm the analysis if workers are unable to represent their activities in this type of environment. 6 - I think that somehow it is a tool applicable to ergonomics, however, it lacks humanity, within the context of an Ergonomic Analysis of Work. Congratulations on the search.

3.2.4 Analysis of Results.

Based on the results obtained through the simulations, we can say that the virtual environment developed was reproduced with fidelity, compared to the real environment. The security agents and the ergonomist, who participated in the simulation, were able to easily identify all the facilities and buildings represented in the virtual environment, in addition to the terrain and relief.

During the simulations, it was possible to observe that the built virtual environment made the security guards excited, as the resemblance to the real one impressed them, giving them the feeling of being in the real environment and at the same time they knew that they did not run any type of risk when performing their activities in the virtual environment. For the ergonomist it was important to see that the agents were able to perform their activities within the virtual environment, because in this way he could assess how the agents worked.

The lighting made in the virtual environment managed to faithfully represent the lighting of the real environment. It was also possible to represent the lack of lighting, one of the major complaints of the guards, because when the simulation took place in “night mode” (night mode was the simulation carried out at night, within the virtual environment) where security agents walked around the premises and they had difficulty seeing all the virtual terrain, which also happened in the real environment, so the similarity was great. The ergonomist was able to have the same impression he had in the real environment, as he was able to see the difficulty that security agents had during night work. During the simulations, the agents were able to communicate perfectly through the Headset, reproducing in an analogous way the communication through radio communicators used in the real environment. For the guards, the surveillance and patrol procedures performed during their work routine managed to be represented in a similar way in the virtual environment, both in terms of procedure and time. During the simulations they were able to perform the entire procedure perfectly, using headset communication to simulate the radio communicator, they were able to communicate perfectly. They carried out the exchange of positions in the same way as they do in the real environment, the resemblance to the real one was impressive.

Ergonomics Experts felt that the system has the potential to assist during an Ergonomics Review. They were able to monitor the activities carried out by security agents in the virtual environment and verified that the procedures performed were similar to what had been done in the real environment.

4. CONCLUSIONS

This article proposed to create and verify if the use of Virtual Reality can help the Ergonomic Analysis of Work, developing scenarios and virtual simulation environments, contextualized by the Ergonomics perspective. Therefore, the first objective was to go through the virtual environment with the objective of validating the degree of Virtual x Real fidelity and extracting the perception of security agents and the ergonomics professional regarding the degree of realism of the virtual environment compared to the real one.

Finally, activities were carried out within the virtual environment where the agents would have to carry out specific procedures and would be accompanied by the ergonomist. At the end of the activities, carried out in the virtual environment, the security agents and the ergonomist were submitted to a questionnaire to evaluate the built virtual environment. For this purpose, the degree of realism of the built environment was measured through comparisons of proportions and analysis of displacement times.

At first, the guard walked (through an avatar) through the built virtual environment to compare the installation and its virtual buildings with the real environment (photos). It was observed that the proportions of the real environment and the objects inserted in it in relation to human beings were equivalent to the proportions of the avatars inserted in the environment. This measurement was based on the comparison of images and real scenes reproduced virtually, which preserved the equivalence in their dimensions. Displacement time measurements were used as a parameter in paths performed in the IEN and the speeds imprinted by avatars when moving in the virtual environment were evaluated. For this purpose, the same path was carried out in the virtual and real environment and, when comparing them, it was observed that the real and virtual times were very close.

Thus, the results achieved in the evaluation regarding the quality of reproduction allowed us to conclude that the Virtual Reality tool used to model the virtual scenario and interact with it was able to reproduce the real environment, indicating good similarity between the virtual model and an environment real.

In the procedure for changing posts and patrols, the guards performed the same procedure for changing posts and patrols that they carry out in their day-to-day activities. These procedures were performed in the virtual environment, in which communication and interaction between them, even not being in physical proximity, were enormous.

The guards themselves found the tool quite useful for training. To enable this evaluation of strategies in different scenarios, in the system developed here, different controls were inserted to adjust the configuration of the virtual environment, such as variation of weather conditions, alteration of real and artificial lighting and different angles of observation of the system, using cameras of surveillance. In this way, as in real training and simulations, it is possible to assess the reaction of security agents in the face of adverse situations and conditions.

For most of the ergonomics specialists who followed the simulations, the tool has the ability to help in an Ergonomic Analysis, as it is easy to handle, it can be used in a controlled environment, allowing a greater analysis of the activities of security agents and above all through this tool it is possible to insert variations in the system into the virtual environment, making the worker's reaction to a given situation different. Therefore, the results achieved in the evaluation regarding the relevance of reproduction allowed us to conclude that the situations reproduced through the virtual reality tool have the potential to be used to assist the Ergonomic Analysis of Work, developing scenarios and virtual simulation environments, contextualized by the perspective of Ergonomics.

Finally, by the results presented, the present work reached its purpose, which was to verify that Virtual Reality can serve as a complementary tool to assist the ergonomist during an Ergonomic Analysis, allowing him to use the tool to reduce risks, saving time and improving his performance.

5. ACKNOWLEDGMENT

The authors would like to acknowledge the support of Alberto Luiz Coimbra Institute for Graduate Studies and Research in Engineering - COPPE, Federal University of Rio de Janeiro – UFRJ, and National Research Council - CNPq. Our thanks also to the National Nuclear Energy Commission - CNEN, that, through the Institute of Nuclear Engineering - IEN, has provided all necessary resources to the development of this work.

6. REFERENCES

[1] COUTO, H. A. Ergonomia aplicada ao trabalho; o manual técnico da máquina humana. 2v. Belo Horizonte. Ergo, 1995.

[2] COUTO, H. A., Como implantar Ergonomia na empresa; a prática dos comitês de Ergonomia. Belo Horizonte: Ergo, 2002..

[3] TINOCO, F. P.; AS Dificuldades Encontradas na Atividade Consultiva de Ergonomia no Brasil, Dissertação de M.Sc.,COPPE/UFRJ, Rio de Janeiro, RJ, Brasil, 2010.

[4] BONFATTI, R. J. Bases Conceituais para o Encaminhamento das Interações Necessárias à Análise Ergonômica do Trabalho. Tese de D.Sc.,COPPE/UFRJ, Rio de Janeiro, RJ, Brasil, 2004.

[5] SCHENINI, P. C.; NEUENFELD, D. R.; ROSA, A. L. M. .. O gerenciamento de riscos no transporte de produtos perigosos. In: SIMPEP, 13., 2006, Bauru: Anais, 2006. p. 1 -12..

[6] GATTO, L. B. S. Realidade virtual aplicada na avaliação ergonômica de salas de controle de plantas nucleares. 121 f. Dissertação (mestrado em Ciência em Engenharia Nuclear), Instituto de Engenharia Nuclear, Rio de Janeiro, 2012.

[7] NORMA CNEN NN 2.01. Proteção física de materiais e instalações nucleares, Available at : http://appasp.cnen.gov.br/seguranca/normas/pdf/Nrm-NN201.pdf , Last accessed: 19 Jan. 2023

[8] VOSHELL, M. G. Planning Support for Running Large Scale Exercises as Learning Laboratories. The Ohio State University, 2009.

[9] AUGUSTO, S. C.; MÓL, A. C. A.; JORGE, C. A. F., et al. Use of virtual reality to estimate radiantion dose rates in nuclear plants. International Atlantic Conference – INAC 2007, Santos, São Paulo, Brasil, Outubro 2007.

[10] BRASIL NR17 – ERGONOMIA . Available at: https://www.gov.br/trabalho-e-previdencia/pt-br/acesso-a-informacao/participacao-social/conselhos-e-orgaos-colegiados/ctpp/normas-regulamentadora/normas-regulamentadoras-vigentes/norma-regulamentadora-no-17-nr-17 . Last accessed: 10 Jan. 2023.