USING VIRTUAL REALITY TO THE SAFETY WARNINGS DESIGN: THE EFFICIENCY THROUGH PRESENCE

USANDO A REALIDADE VIRTUAL PARA O PROJETO DOS AVISOS DE SEGURANÇA: A EFICIÊNCIA ATRAVÉS DA PRESENÇA

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Reginaldo Schiavini *reginaldoschiavini@gmail.com*
Doutor em Design pela Universidade de Lisboa (Lisboa/Portugal).
Consultor Ad hoc no Instituto Nacional de Estudos e Pesquisas Educacionais Anísio Teixeira (Brasília/Brasil).

Heli Meurer *heli.meurer@gmail.com*
Doutor em Informática pela Universidade Federal do Rio grande do Sul (Porto Alegre/Brasil). Conselheiro Administrativo e Lead UX designer na Companhia de Processamento de Dados do Estado do Rio Grande do Sul (Porto Alegre/Brasil).

ABSTRACT

The objective of this study was to use virtual reality as a validation method of a new multimodal warning for use in situations of risk and danger. This warning is intended to be more efficient than the static warnings as regards their ability to convey clear, objective information and securely. The virtual environment used was developed with immersive virtual reality simulating a risk and danger to the user. This virtual environment allows situations are simulated in real life would be impossible for putting at risk the lives of people. For the warning efficiency were evaluated, we used two warnings, static and multimodal, which consisted of harmonization between the ISO and ANSI standards. As innovation factor used was the explanation of the consequences of non-compliance. Multimodal elements used in the notice were a file with a recorded human voice and a flashing red light. These results demonstrated that the virtual environment used, and the multimodal warning were efficient in their goals. The results of the variables used were positive and the hypotheses was validated with the use of statistical tests.
Keywords: Design. Multimodal. Presence. Virtual Reality. Warnings.

RESUMO

O objetivo deste estudo foi utilizar a realidade virtual como método de validação de um novo aviso multimodal para uso em situações de risco e perigo. Este aviso pretende ser mais eficiente do que os avisos estáticos no que diz respeito à sua capacidade de transmitir informações claras, objetivas e seguras. O ambiente virtual utilizado foi desenvolvido com realidade virtual imersiva, simulando um risco e perigo para o usuário. Esse ambiente virtual permite simular situações que seriam impossíveis na vida real, por colocar em risco a vida das pessoas. Para que a eficiência do alerta fosse avaliada, foram utilizados dois alertas, estático e multimodal, que consistiram na harmonização entre os padrões ISO e ANSI. Como fator de inovação foi utilizado a explicação das consequências do não cumprimento. Os elementos multimodais usados no aviso eram um arquivo com uma voz humana gravada e uma luz vermelha piscando. Esses resultados demonstraram que o ambiente virtual utilizado e o aviso multimodal foram eficientes em seus objetivos. Os resultados das variáveis utilizadas foram positivos e as hipóteses foram validadas com a utilização de testes estatísticos.
Palavras-chave: Projeto. Multimodal. Presença. Realidade virtual. Avisos.

1 INTRODUCTION

Virtual Reality (VR) has proved to be an increasingly useful and promising tool for use in various fields of research. Several areas are increasingly making use of their potential (e.g.: medical, military, announcements). We propose the development of a technology-based warning using the RV for validation. For this, we used a scenario of a game called Bootcamp by Unity3D Technologies®. It is understood that sophisticated equipment is not necessary for VR to obtain reliable results. There are very sophisticated scenarios, including very popular games, but production costs are very high and what our paper shows is that even using the Unity3D allow yet to reach conclusions that are valid and usable due to induced sense of presence in people, so not only required big investments in equipment and sophisticated programs to get good results.

To support this, it developed a narrative that was incorporated into the scenario through a recording at the beginning of the experiment and was later used in the instructions written warnings. To make more reliable can the degree of truthfulness of the scenario that best represents the psychological factors (e.g., characteristics of selfish behavior, perception of urgency, and risk) we tried to create situations that were as similar as possible to the real world. Thus, the scenario provided the simulation conditions of risk and danger to the user without endangering his life.

The paper is organized as follows: section 2 presents the conceptual basis for understanding the multimodal warning. Section 3 presents all the details of the warning and the methodological aspects and instruments used in this research. In Section 4, the results obtained are presented. Finally, sections 5 and 6 bring the discussions and conclusions.

2 BACKGROUND

2.1 WARNING CONCEPTS

In this study, warnings are defined as safety communications used to inform people about possible dangers that are susceptible. Duarte (2011) points out that warnings are one of several risk control methods to prevent injury and damage. As an example, they can warn of unsuspected danger in a workplace, promote safe behaviors and also reduce or prevent a number of problems related to health. The alerts can be used in several ways (e.g., signs, labels, booklets, labels, etc.). They can be static or dynamic. Static warnings use a passive method of communication. In contrast, the dynamic warnings or technology-based, as they are also called, use more advanced technology to inform and alert a particular hazard. Dynamic warnings can be multimodal, allowing customization and can be resistant to habituation. These factors make these warnings more effective than static (DUARTE; REBELO; TELES; WOGALTER, 2013; REBELO; DUARTE, 2008; SMITH-JACKSON; WOGALTER, 2004; WOGALTER; MAYHORN, 2005; WOGALTER; CONZOLA; SMITH-JACKSON, 2002).

The main focus of this work is on technology-based warnings; or multimodal. Systems based on warnings are more effective than traditional warnings. They include dynamic change of message content, compensation for human limitations, interactivity and customization by warnings tailored to meet the needs of special users.

Multimodal warnings are usually more noticeable than static. When something does not change over time, it is less likely to attract the user's attention. In contrast, including movement captures the user's attention (KERCKHOVE, 1997). Warnings are in different contexts such as television and internet. Television advertising for products in the United States includes warnings that combine visual and auditory modalities. A survey conducted by (BARLOW; WOGALTER, 1993), showed that the presentation of printed notices associated with voice prompts are more effective in terms of alert information communication than the use of each type separately.

The basic purpose of warnings is to provide information to enable users to make safe decisions. Thus, on the warning's conception, the type of information they will communicate is very important. In the literature about warnings is that notices must include information about the risks, consequences and instructions for safe behavior (LAUGHERY; WOGALTER, 1997). According to Laughery and Smith (2006), the need of explicit warnings focuses on three categories of information: risks, consequences and instructions. The main problem is that the level of elicitation should be exposed in each category.

In this context, this research proposes, as an innovation factor, to work with the explanation of the consequences of non-compliance of warnings, including technology-based warnings tested in a virtual environment.

One important aspect of a warning is to draw people's attention. For this, the warning must have the necessary information to get people to make safe decisions and be able to deal with these distractions (LAUGHERY; WOGALTER, 2014). In this sense, the use of sound on warnings increases its efficiency, since it is part of the real world to be a major source of supplementary information. The combination of sensory warning modalities can increase the sense of presence and sense of urgency (BALDWIN; EISERT; GARCIA; LEWIS; PRATT, 2012; VÄSTFJÄLL; LARSSON; KLEINER, 2002).

2.2 MULTIMODAL COMPONENTS

An audio warning may be interpreted only as an alarm. However, auditory warnings and alarms do not have the same meaning. The term alarm refers to a variety of sounds that only attracts attention (for example, the approach used in automobile alarm). Second Judy Edworthy and Hellier (2000) auditory warnings are more complex and are also developed in order to attract attention. Notices hearing may include verbal cues that incorporate human speech, of recorded or synthesized form. Warnings with the recorded human voice are more efficient, and even redundant, because they contain more information than necessary for identification of sound. These warnings are also shown to be more effective in challenging environments, in situations of stress, which can cause a person to not notice the warning or to forget the significance of this (HAAS; ERP, 2014). This type of warning can include verbal and non-verbal sounds. In this study the verbal auditory warnings were used. This type of warning is more appropriate for there to be a better understanding of the warnings in stress situations and in situations of risk and danger. Other sounds were used in this experiment (fire and explosion) but as this type of sound cannot be considered as an audio warning will not display more details about the same.

For the sound to be efficient on a verbal warning, in their understanding among other sounds, it must not be too long. Jang (2007) argues that the voice prompts must be written in short sentences. The size of the phrase suggested by the author, to optimize the listener's attention, understanding and intelligibility of the message are four to eight syllables. We can find references also about the earliest indication of a verbal warning alarm on (HAAS; EDWORTHY, 2006) when he says that the sound duration is very important in designing an alarm as soon as the notice is, it will be more readily understood. So very long sounds can disturb the understanding and are unnecessary.

As previously noted, the use of verbal auditory warnings proves to be more efficient than warnings containing only visual signals. However, which voice is most suitable in terms of efficiency and understanding for use in verbal warnings? According to research conducted by (EDWORTHY; HELLIER, 2003), there are practical interests in determining which voice (e.g.: male or female) is most suitable for use in warnings. Studies show that there is a preponderance regarding the use of the female voice in spite of men (BARZEGAR; WOGALTER, 1998; EDWORTHY; HELLIER, 2003; HELLIER; EDWORTHY; WEEDON; WALTERS; ADAMS, 2002) female voices produce a higher intonation and produce a better perception of urgency in comparison with the male voice. These effects result from a wider range of heights of the female voice. As seen in Miller (2015), it also explained that most people, however, prefer a female voice to computerized instructions, which is why, for example, the "apple`s siri" and the North American train company "Amtrak's" use the voice called "Julie", being both female voices. He theorizes that the female

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voice is usually more attractive because, from the beginning, we hear the voices of our mother first, which shows how deeply rooted in our subconscious popular interactions with technology can be.

2.3 VIRTUAL REALITY

A warning, whether static or multimodal, isolated from its context cannot be understood. In addition, it is important to be able to evaluate its effectiveness, simulate extreme situations that are consonant with the goal of warning. For this we chose to use virtual reality to make this validation process.

The term Virtual Reality (VR) was created or first used in the late 1980s by the artist and computer scientist Jaron Lanier (FUCHS; MOREAU; GUITTON, 2011). He managed to unite two opposite concepts in a new concept, being able to assimilate the essence of this technology: the search for integration of real with virtual elements. However, despite being related to high-end computer technology, which is true, the VR is not such a new area of research as it may seem, not restricted to computer professionals. A filmmaker created it in the 1950s, which created the first device that allowed the immersion of the user senses in a three-dimensional virtual world. However, it fell to the engineer Ivan Sutherland in the 1960s, the construction of the first virtual reality helmet. Sutherland worked on what he called "Ultimate Display" (PACKER; JORDAN, 2001) and produced on the late 60's the first virtual reality helmet, a precursor of a series of subsequent research.

VR is a wide area of expertise that has different definitions in the literature. Virtual reality consists of a sophisticated interface between people and computers, used for generating Virtual Environments (VEs) to be experienced by the participants (BURDEA; COIFFET, 2003). In a much broad sense, VR is a way to transport people to a reality where they are not physically present, making it seem, however, that they are present. Additionally, the Virtual Environment (VE) responds in real time to the user inputs (i.e., gestures, etc.), which, according to Burdea and Coiffet (2003), defines a fundamental characteristic of VR, which is interactivity. In this research, the term VR is used to designate an immersion system that is able to generate interactive artificial worlds. The term VE is used to designate the virtual environment generated by the VR system. Immersion concepts, presence and interaction/interactivity are important for understanding the physical and psychological experience of users in VR (GUTIERREZ *et al.*, 2008). Furthermore, Burdea and Coiffet (2003), suggest another concept related to the VR, imagination, which refers to the ability of the mind to perceive things that are not there. Therefore, for these authors, VR is an integrated trio of immersion, interaction and imagination. The definition and the meaning of each of these concepts can be different for each author.

As seen above, there are many areas using the VR and consequently the existence of many virtual reality definitions involving general or technological aspects and connected to experiences and sensations (BURDEA; COIFFET, 2003; DUARTE *et al.*, 2010; FUCHS *et al.*, 2011).

According to Witmer and Singer (1998) though the underlying factors of involvement and immersion are susceptible of variation, their levels are interdependent, i.e. the increased involvement level can lead users to experience greater immersion in an immersive environment and Another related concept is presence, which is defined as "the a user's psychological response to patterns of sensory stimuli, resulting in the psychological sensation of being there in the computer-generated space" (SLATER; STEED, 1994). Experience and presence are a combination of factors affecting both the involvement as immersion.

The main goal of VR systems is to decrease the gap between virtual and real elements. Because of this, those systems require specific equipment such as high-end stereoscopic displays (e.g., CAVEs, etc) and equipment able to track the user's body, improving the interactivity of the user with the virtual environment. Those traditional virtual reality systems are very complex and have high costs involved. But nowadays, with the popularization of VR reality equipment such as the Microsoft Kinect and the Oculus Rift, it made affordable for end users to use in even more areas of expertise, such as the game industry. The popularization of these devices makes it even more important the ease of use of these devices, since most users are not used to spend more than a few minutes to familiarize themselves with normal devices.

Currently, VR, thanks to technological developments, has been used in such diverse areas (REBELO; DUARTE; NORIEGA; SOARES, 2011) such as medicine, aviation, military training, education, engineering, architecture, games, treating disorders and phobias, ergonomics and design (BOGDANOVYCH; RODRIGUEZ; SIMOFF; COHEN, 2009; BRUNO; MUZZUPAPPA, 2010; DUARTE; REBELO; WOGALTER, 2010; FERRER-GARCIA; GUTIÉRREZ-MALDONADO; RIVA, 2013; FERRER-GARCÍA; GUTIÉRREZ-MALDONADO, 2012; FUCHS *et al.*, 2011; IBÁÑEZ; DELGADO-MATA, 2011; VILAR, 2012; WOGALTER; MAYORN, 2006). In the field of warnings, this technique presents itself as an alternative research. An example is the study of (GLOVER; WOGALTER, 1997) develops a virtual coal mine to evaluate the warnings' success. They compared the workers' behavior at the pit during an emergency and exit for lunch. These results, although limited, have allowed verifying that this is a promising technique. Some of the advantages associated with the use of VR is the high level of control of the variables, the rigorous observation of behavior during task performance, the richness of contexts, ease of handling variables, the ability to evaluate the behavior towards dangerous situations. Other studies using VEs in warnings can be viewed at: (DUARTE; REBELO; TELES; WOGALTER, 2014; DUARTE, 2011; MAYHORN; WOGALTER; LAUGHERY, 2014).

Duarte *et al*. (2010) discussed the potential of VR as a technique to investigate the efficiency of warnings, particularly regarding behavioral consonance. Still, according to these authors, two information-processing stages that can more easily be benefited by VR are the attention and behavior. Increasingly, according to these authors, the VR may provide a higher quality in virtual environments, for use in research alerts, and can also provide an experimental control without physical damage.

3 MULTIMODAL WARNING

This warning was designed to be a multimodal warning (technology-based). Its design is oriented to be used on smartphones screens or devices that can convey visual and auditory information. It is consonant with the harmonization ANSI and ISO: ANSI Z535 and ISO 3864-1 and ISO 9186.

The multimodal elements used were: flashing red light, which was applied around the warning (consisting of 3 frames), and sound files (text recording used in the warnings). Divided into 3 parts of different proportions with the same hierarchy of information: type of information area (e.g., attention, warning, and danger), image and instruction/consequences. The three frames are displayed in sequence on the smartphone screen.

On the warning design definition phase, from the generation of graphic design alternatives, we decided to use the focus group, held in 6 stages. The first stage involved the presentation of the study and the purpose of the meeting that consisted on validating the 4 variables that make up the multimodal notice. In the four subsequent steps were presented, discussed and defined the four variables to be used in multimodal warning, which are symbols to be used, with the explicit text of the consequences of non-compliance, amount of frames and validation of multi-modal concept notice. The final step involved filling out a questionnaire with 14 questions using a Likert scale of 6 points.

The sample of this focus group was composed of 57.1% female and 42.9% male, ranging from 21-54 years where 57.1% aged up to 35 years. Involved students and teachers in the area of Design, most with PhD (71.4%) and 28.6% with master's degrees.

3.1 DIMENSIONS

As the standards used, the dimensions of safety signs, which are located in the warnings, are determined according to the distance of observation, the critical details of size (for example, details the symbol), the luminance signal and your contrast (see details in ISO 3864-1). Typically, such slabs have a measured 27 x 40 cm. According to ISO 3864-1 (ISO 2002), the warnings/plates must have dimensions

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that can be readable at a distance of 10 meters. In the case of warnings developed in this research, it was not possible to use these and other sizing. The media (media used) completely differs from what is provided in the rules and was not found any reference to design safety and hazard warnings for use in electronic devices (e.g.: mobile phones and GPS). So, we chose to use the distribution of information and adapt the design, trying to observe the proportions of these standards and also the design of cigarette packets. To the warnings, used as reference the screen of a smartphone iPhone 4 (50x80mm) (Figure 1 and 2).

Figure 1 – Multimodal warning composed by three photgrams presented in sequence

(a) Danger - No trespassing. Interdicted bridge. Use bridge on your left 1km
(b) Danger – If pass, will die!
(c) Danger - Use bridge on your left, or you will die!

(a) (b) (c)

Source: Elaborated by the author

Figure 2 – Static warning. Danger – Content of the warning: No trespassing. Interdicted bridge. Use bridge on your left 1km. If pass, you will die!

Source: Elaborated by the author

3.2 METHODOLOGY

The experimental method was based on the use of VR. This research used the VR as an interactive environment to study multimodal warnings in risk and danger situations.

There is a growing number on experimental studies conducted in interactive environments, including those with the use of VR, on areas such as design, architecture, medicine, military industry. VR-based methodology has been used, for example, in warnings' research (DUARTE *et al.*, 2010; DUARTE, 2011; MAYHORN *et al.*, 2014), on the spatial orientation process, or wayfinding: (CUBUKCU; NASAR, 2003, 2005A, 2005B; VILAR, 2012). Researchers defend the use of VR as an important tool to overcome some ethical, methodological and security limitations found in interaction environments that use the "real environment" (DUARTE *et al.*, 2010; REBELO *et al.*, 2011; REIS; DUARTE; REBELO, 2013; VILAR, 2012). The high financial costs and time spent with changes in the environment, for supporting the needs of research in a real environment, for example, can be overcome with the use of VR. Issues related to security, where people are exposed to situations that may involve risks to physical and mental integrity, can be perfectly developed in VR environments. The control over the environment to be analyzed, where disturbance variables (such as light, noise and other people moving in the environment) can be better controlled interactive environments with the VR, as well as the influence of the researcher while observing participants/subjects.

3.3 EXPERIMENT DESIGN

For this study, convenient independent samples were used, randomly assigned to two experimental conditions:

- Static Warning
- Multimodal Warning

The total sample consisted of 84 college students' volunteers of both genders (male: 51.2% and female: 48.8%), aged between 18 and 35 years (M = 22; SD = 4.96), for each experimental condition (static and multimodal warning notice).

3.4 MATERIAL AND DATA COLLECTION TOOLS

For this study and its experimental condition (static warning and multimodal warning) developed a questionnaire containing images, a virtual environment with narrative and with separate equipment. In

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the pivotal studies, prior to this study, it was observed the occurrence of socially desirable behavior on some issues and because of this it was decided to use later interviews to fill the questionnaire.

3.4.1 Equipment

For the experiment made we used a low-cost virtual reality setup. The advantage of this setup is being easy to set, easy for the user to get used to it and is proven to have a good response from end users on similar scenarios (TAUNAY *et al*, 2014). Another reason for the choice of this setup is its portability, what allowed the researchers to recruit a bigger amount of volunteers.

The Oculus Rift is a head-mounted display (HMD) device, which consists of a screen, which is projected on the user's eye by lenses. The Oculus Rift also incorporates a gyroscope and an accelerometer, which is capable of informing the rotation of the head of the user to the system. The Oculus also has an accessory that can estimate the position of the head of the user, but because of precision problems we decided not to use this feature. For this feature we used the Microsoft® Xbox Gamepad.

For improving the sensorial experience and comprehension of the multimodal elements on the virtual environment we used the high-quality wireless *Sony®* MDR-RF810 headphones, shown on Figure 3.

To run all these devices, we used a Macbook pro Retina with the following specs:

- Intel Core i7 quad-core 2,2 GHz
- 16 GB memory;
- 256 GB flash HD;
- Intel Iris Pro Graphics.

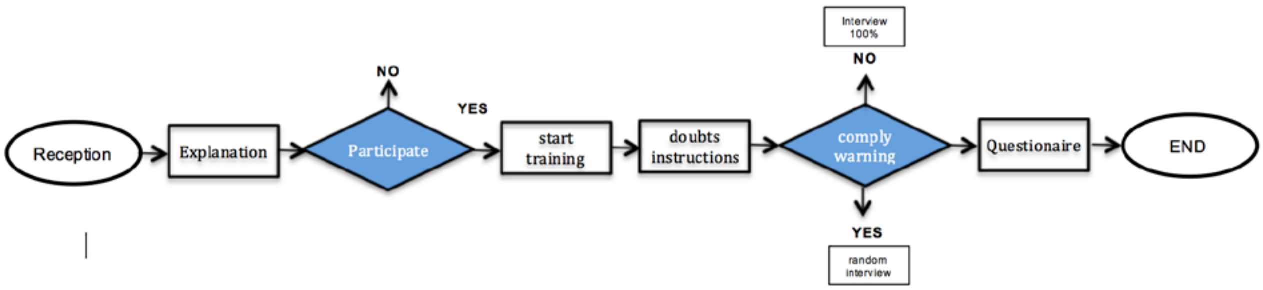
Figure 3: Equipment's used

Source: Internet

3.4.2. Experiment's protocol

For a better understanding of how the data collection procedure was performed, a flowchart was developed (Figure 4).

Figure 4: Research flowchart



Source: Elaborated by the author

The student volunteers were received individually in the laboratory. Following, was held the presentation of the researchers and the purpose of the study. A number of questions were asked to the volunteers to evaluate whether they had physical and health conditions to participate on the experiment. After the acceptance of the students to participate in this research, they filled the consent form. The test was started with a training phase, to make the users comfortable with the study procedure and the equipment used. The VE used on the training was the same used on the main experiment and also allowed the users to get used to the warnings regarding elements such as font's size and legibility.

After the training phase, the users performed the main experiments. Upon completion of the experiment, each student filled out a questionnaire. For students who did not obey the warning was also carried a semi-structured interview.

3.4.3 Questionnaires

The questionnaire used in the study was divided into two sections: the first to evaluate variables such as Virtual Environment (2), warning Efficiency (10) and warning design (6). We used a Likert scale of 6 points. The questions asked were the same for both experimental conditions, except for specific issues for multimodal warning (2).

The second section of the questionnaire involved the collection of demographic data (age, gender, educational level).

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3.4.4 Interviews

Interviews were applied after the completion of each study. For those who disobeyed the warning presented (static and multimodal), identified by direct observation, and randomly, for the remaining people in each study. Thus, 18 interviews were applied to the sample in this study in Immersive VR. The purpose of the interviews was to identify elements in the warning and in the virtual environment that led individuals to take certain decision, and to identify the occurrence of "socially appropriate behavior" earlier identified in the pre-testing phase:

Qualitative analysis of the interview's answers followed the method of Bardin (2012) and identifies categories of analysis in terms of registration units in speech excerpts of individuals. Three open-ended questions were applied to each sample of the two experimental conditions, as follows:

- Why did you take this decision (obey/disobey) the presented warning?
- The clarification of the consequences of non-compliance with the warning was important to your decision?
- You preferred Reading or hearing the information of the warning (multimodal)?

3.4.5 Narrative

The narrative used in this VE was as follows:

> *"Good day. Welcome to our forest reserve. This consists of a bucolic environment that has a forest, quarries, rivers, bridges and a small village. For your safety is used an information system that interacts with the phone via GPS. The goal is to help you along the visit with location and security information. You will also find signs to point the way. Please go to the viewpoint near the bridge- Have a good ride and have fun."*

3.4.6 Description and characteristics of the Virtual Environment (VE)

This VE was developed through the elaboration of a scenario consisting of a narrative (see section 3.4.5). This scenario is characterized by the use of a "selfish" metaphor, that is, one has to face the danger to save his own life. The objective was to evaluate the warning efficiency through the behavioral intention of users.

The context to be used should contain graphics and visual characteristics (visual characteristics means the properties that replicate the real visual world such as: colors, textures, shadows, detail, depth, etc.), which would allow the creation of an environment that provides the user a high level of concentration

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and strong sense of presence to that experience in the virtual environment to be closer to reality as possible regarding the simulation of a situation of risk and danger. Besides these visual graphic elements, we tried to isolate the user from the outside world. For we used the virtual reality head-mounted display as described and the use of sound through headphones, as can be seen in section 3.4.1. Interaction with the environment is similar to First Person Shooter games (FPS). In our implementation the user controls the direction of the walk with the head (through the sensors present on the Oculus Rift) and its translation is controlled by a Gamepad command, as described before. The used scenario is taken from the game *Bootcamp by Unity3D Technologies®*, chosen because of its free-of-charge availability and because it has the required complexity for the purposes of the experiment. This VE is characterized by an open and rugged countryside, filled with trees, rocks and built elements such as houses, quarry, a river and a bridge. For this we tried to create an extreme situation, in which the individual was taken to disobey the warning (inserted into a mobile phone that is in a virtual environment). This notice is multimodal and technology based. To operationalize the study were used in life-threatening situations. So, we tried to use a situation where unexpectedly explosions and fire arise around the user. In this context, as previously explained in the narrative (see Section 3.4.5) he receives messages on his phone explaining what is happening and indicating the action to be taken. The shift within the virtual environment starts after the message (narrative) that is given at the beginning of the experiment. In this narrative is in the order and the person starts moving in the AV amid the forest. Along the path directing signs are presented. Halfway the first warning comes on the phone simultaneously with the explosions and fire. At this point one can observe the reactions of users in relation to the sound of explosions and fire. There is a momentary disorientation, and it is observed that even with the existence of steering boards, people are distressed and panicked. After a few moments resumes calm and one follows towards the bridge. When the user arrives near the bridge the second and final warning appears on the phone. It is at this point that the efficiency of the warning is evaluated. Still with explosions one has to make the decision to obey the warning and look for another safe bridge or disobey the warning and go through the forbidden bridge this next. Reactions were varied, such as: confusion, fear, body temperature rise, panic and anxiety, as observed by the investigator and which were reflected in the responses of the interviews after the experiment.

The images of the warnings were adapted regarding the static and multimodal characteristics. For this adaptation we used the *software Adobe Photoshop* CC®. We used consistent warnings with the harmonization propositions ANSI-ISO and adapted with the use of the *software Corel Draw®*. This VE is depicted on the figure 5.

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Figure 5: Images of the scenario used

Source: Elaborated by the author

4 RESULTS

To describe the data in this section we used frequency tables that show the distribution of answers on a Likert scale of six points used in the questionnaire (item 3.4.3) also containing the Mode and Standard Deviation.

The description of the survey results ends with the hypothesis test, whose goal is to identify statistically significant differences between the two experimental conditions, through the nonparametric Mann-Whitney (U). These tests the equality of medians and is suitable for independent samples that do not meet the assumptions of normality and homogeneity of variances. Depending on the distribution of the sample obtained in this study homogeneous but does not reach normal, it was decided to choose the non-parametric tests for independent samples, specifically the Mann-Whitney test. In this case, given the null hypothesis and an alternative of this research, we have chosen a priori by using a one-tailed test on the right, since the distribution of scores of multimodal warnings is, in general, the right of distribution of scores static warning, (MAROCO, 2011). The results are presented in two groups: Notice of Efficiency and Virtual Environment.

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4.1 WARNING EFFICIENCY

With regard to the results in warnings of efficiency, it is observed that the level of urgency and danger warning is transmitted at very high on both the warnings: static and multimodal, as can be seen in Table 1.

In both experimental conditions the sample obtained high levels of probability to comply the warning presented and the perception of explanation of the consequences of non-compliance with the warning, according to data presented in the table below.

Table 1: Distribution of answers to the questions' group "warning efficiency."

		Likert scale							
Variable	Warning	1	2	3	4	5	6	M_o	SD
Urgency	Static	0.0	0.0	14.3	33.3	42.9	9.5	5	0.86
	Multimodal	0.0	0.0	7.1	26.2	47.6	19.0	5	0.84
Danger	Static	0.0	0.0	7.1	26.2	52.4	14.3	5	0.79
	Multimodal	2.4	0.0	2.4	16.7	47.6	31.0	5	0.98
Comply the warning	Static	0.0	0.0	7.1	21.4	47.6	23.8	5	0.86
	Multimodal	2.4	0.0	7.1	9.5	38.1	42.9	6	1.10
Explicit the consequences	Static	4.8	0.0	14.3	31.0	28.6	21.4	4	1.25
	Multimodal	0	2.4	7.1	19.0	45.2	26.2	5	0.97
Global comprehension	Static	0.0	0.0	2.4	11.9	71.4	14.3	5	0.60
	Multimodal	2.4	0.0	4.8	4.8	64.3	23.8	5	0.93

Source: Research data

4.2 VIRTUAL ENVIRONMENT

The virtual environment was evaluated by the sensation of presence and the level of risk and danger transmitted by Immersive virtual environment. It is expected that the perception of the sample in relation to the transmitted sense of presence in the virtual environment, is the same for both experimental conditions used for the VE is the same for both. In this study it is found in very high rates of sense of presence and equality between the two notices (Mode = 5). The level of risk and danger transmitted by the virtual environment was assessed as too high for the sample in both analyzed warnings (Table 2).

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Table 2: Distribution of answers on the set of questions "virtual environment"

Variable	Warning	Likert scale 1	2	3	4	5	6	M_o	DP
Sensation of presence	Static	0.0	0.0	0.0	11.9	57.1	31.0	5	0.63
	Multimodal	0.0	2.4	2.4	9.5	50.0	35.7	5	0.87
Risk and danger	Static	7.1	0.0	11.9	23.8	54.8	2.4	5	1.16
	Multimodal	0.0	2.4	7.1	35.7	47.6	7.1	5	0.83

Source: Research data

4.3 HYPOTHESIS TEST

The hypotheses of this study in Immersive VR are:

H1: The multimodal warning with elicitation of the consequences of non-compliance in virtual immersive environments is more efficient than the static notice.

H0: The multimodal warning with explanation of the consequences of non-compliance in virtual environments immersive, it is equal to or less efficient than the static warning.

Following are the results of the Mann-Whitney test (LUDBROOK, 2013; MAROCO, 2011) to the issues/variables, namely: warnings efficiency. In the group of nominated issues "virtual environment" (AV), they were not tests of hypotheses or comparisons between the two experimental conditions, due to the fact that that AV is the same and thus, must be perceived also by the sample in the two experimental conditions (Table 3). Regarding the efficiency of warnings, statistically significant differences are detected between the two warnings to the regards "transmitted by the hazard warning" (p = 0.038, ie, p <0.05) "transmitted by emergency warning" (p = 0.054, p = or 0:05), "comply the warning" (p = 0.054, ie, p = 00:05), and "elicitation of the Consequences" (p = 0.049, ie, p <0.05), and significance is 95% margin of error of 5%. Regarding the composite measure (formed by multiple variables that reflect the unique concept), the table 03 has p-value = 0.025 ie, <0.05. This result identifies statistically significant differences between the two warnings and again rejects the null hypothesis H0, because the multimodal warning demonstrates to be more efficient than the static warning. Regarding danger and urgency, compliance of the warning and explanation of the consequences of non-compliance.

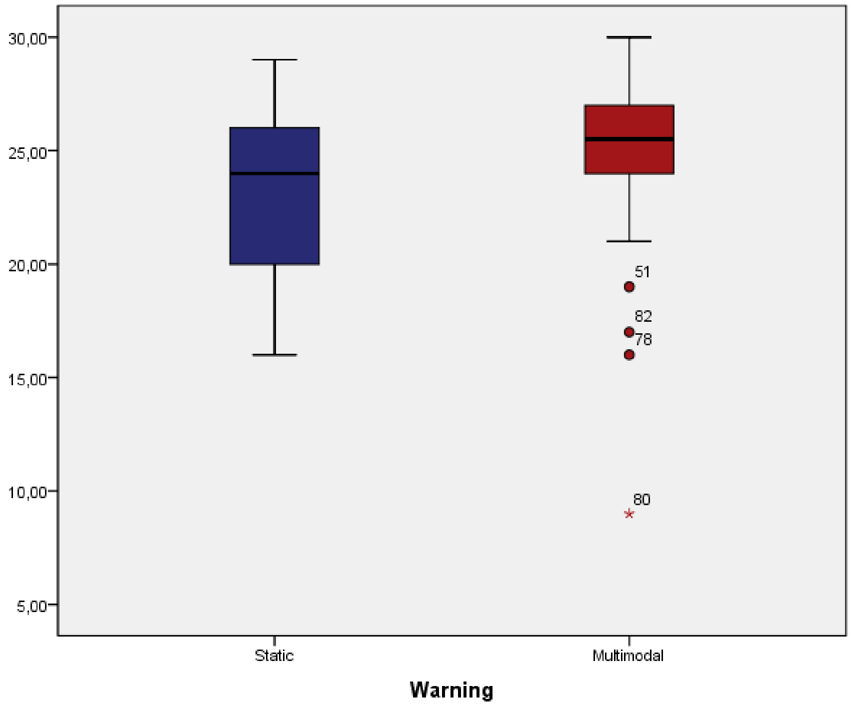
Table 3: Mann-Whitney test for the group issues "warning efficiency."

Variables	U	W	*p-value*
Urgency transmitted by warning	712.000	1615.000	**0.054**
Danger transmitted by warning	696.000	1599.000	**0.038**
Comply the warning	711.500	1614.500	**0.054**
Explicit the consequences	705.500	1608.500	**0.049**
Global comprehension of warning	799.000	1702.000	0.211
Composite measure of warnings efficiency	665.000	1568.000	**0.025**

Source: Research data

The graphic 1 represents these values mentioned above on the composite variable in the static and multimodal warning (Graphic 1).

Graphic 1: Box plot of the composite measure of the efficiency of the warning



Source: Research data

5 DISCUSSION

The results obtained in this study were positive and validated the proposed hypothesis: The multimodal warning with elicitation of the consequences of non-compliance in virtual environments is more efficient than a static warning.

The assumption of warning's efficiency was positive, i.e., the statistical results showed significant differences in favor of multimodal warning and thus the hypothesis was validated. This group consisted of five questions used in the questionnaire, as can be seen on the item 3.4.3. In separate, the result of the issue "global understanding of the warning" has shown that both warnings are equal, thus having no significant differences between them. This result can be explained by the fact that the elicitation of the consequences and warning's design being high, or efficient for both experimental conditions.

The results obtained in the group of questions "Virtual environment" demonstrated high levels for both experimental conditions, it was expected because the VE was strictly the same and this results in parity demonstrate its efficiency regarding the sensation of presence and perceived risk hazard. We also observed through the results of the interviews analysis there was a great sense of presence in the used scenario as can be seen by the statement of the results of the interviews concerning questions related to notice and AV, as follows: "There was no time to read the warning to the end because of the urgency and as was said that it was prohibited, I obeyed."-"I was very frightened by the explosions and not only went through because he said I was going to die."-"Yes it was totally scared and hurry to get out of there fast and do not want to risk dying."

The major elements that composed these warnings were: Design, elicitation of the consequences of non-compliance and multimodal elements used (movement of frames, sound and flashing red light). All contents on these questions were raised even when there were no statistically significant differences between the experimental conditions. In addition to being an objective achieved, which results are relevant not only for academic community, but also for application in wide range of products, allows its use as a starting point for further study.

6 CONCLUSION

The warning, as a means of communication nowadays, is presented in various ways, across multiple platforms, and targeted to multiple users. In addition, several are uses for the warnings. In the case of this research, we seek to develop a technology-based warning directed to risk and dangerous situations. The main function of a warning is to inform. However, it is important that in the context of this warning, the information transmission process is done in a clear, direct, fast and efficient. The seriousness, truth and conviction capability of information, or rather a set of information that makes up a security warning, you must allow the user to view and decode the signals contained therein without margin for error and doubt, because in situations he intended to be used, any mistakes and doubts may endanger the user's life.

In this sense, the use of new technologies that can be incorporated and perceived in the new warnings, simply and quickly, allowed the research to reach a positive result. In addition to these new technologies (multimodal) using Virtual Reality (VR) as a research method made possible the development of virtual environments of low cost, with a great sense of immersion and presence. This demonstrated that one cannot only obtain valid conclusions but also that people tend to react to situations they know to be completely virtual in the same way they would react in a real situation. This is why the VR is suitable to study danger signs. Statistical results showed that there are elements of the signs that are most effective in terms of security and allowed to simulate situations of risk, danger without jeopardizing the lives of users.

Thus, this research demonstrated through the results achieved, not only through literature review, that the use of technology-based warnings (multimodal) is promising and efficient and can be used in various situations (e.g.: automotive industry and electronics) and not only in extreme situations of risk and danger. In addition, such alerts may be used in different products' interfaces, whether of producer goods and household goods.

But the positive results of this research are due not only to the technology used in warnings. It is important to note that one of the innovative and decisive factors for achieving this was the breaking of a paradigm that, often confronts our decisions, including our attitudes and beliefs: WHAT WILL HAPPEN TO ME IF I DO NOT OBEY WARNING? In this regard, one of these innovative points of the research was to notice the "explanation of the consequences of non-compliance." People were confronted not only with signs and symbols of danger and death but also with the form of written and recorded oral information, on what would happen if they did not comply with the warning. Thus, the results of this research, translated in the form of a multimodal warning contribute to a breakthrough in the warning area, not only with a more efficient warning and by permitting the expansion of its use to other platforms and interfaces.

In addition to these contributions, these results allowed to demonstrate the possibility of using a low cost in scientific research. Another important contribution is the use of VR multimodal warnings as a guideline for creating a discipline for use in graphic design courses without implying major investments in laboratories.

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