The impact of different exposure times to 360° video experience on the sense of presence

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***Abstract*—Equipment such as head-mounted displays are now available for the average consumer at affordable prices. This promotes the usage of this equipment for content consumption and demonstrations, thus it becomes important to establish the best practices for using this technology, namely guidelines in what concerns the recommended exposure time. Therefore, the purpose of this work is to study the impact of the exposure time on the feeling of presence while watching 360° video using an head-mounted display. The independent variables of the study are the exposure time to the stimuli and gender of participants. There were tested four different exposure times: 1 minute, 3 minutes, 5 minutes and 7 minutes. For measuring presence, it was a Portuguese version of the Igroup Presence Questionnaire (IPQ) which considers also 3 presence subscales: spatial presence, realism and involvement. The results have revealed that there are few statistically significant differences for the given exposure times at the level of the sense of presence, apart from spatial presence and realism subscales, which consistently increased with exposure time for male participants and slightly decreased for female ones. Men always needed longer exposure times (> 1 minute) to report the highest scores, while women had the opposite behaviour, frequently reporting maximum scores for the shortest experiences.**

***Index Terms*—Virtual Reality, Presence, 360° Video**

I. Introduction

Virtual Reality (VR) is becoming increasingly relevant regarding both entertainment and commercial applications as it has the capability to immerse the users in a virtual environment (VE), triggering spontaneous reactions to the virtual stimuli. It is of great interest that the virtual environment (VE) can be capable of delivering lifelike stimuli through the usage of comfortable equipment potentiating the sense of presence and avoiding simulator sickness symptoms. The literature establishes the sense of presence to be a metric for evaluating the effectiveness of a VE and it can be defined as the feeling that the user has of "being there". A greater sense of presence means the subject feels present in the VE rather than in the real one, leading to natural reactions to the VE. We seek to improve our understanding of how presence develops in order to provide better VR experiences.

A. Presence factors

IJsselsteijn et al. [1] distinguishes the following categories of factors that influence presence: the extent and accuracy of sensory information (eg. immersion, stereoscopy, field of view (FOV)), content factors (eg. using emotive media content), the correct match between sensors and display (eg. synchronizing visual stimulus with head tracking sensors), and user characteristics (eg. age, gender, ...).

1) Technological and content factors: Hendrix and Barfield [2] evaluate to what extent visual display parameters influence presence in a non immersive VR setup, concluding that presence is enhanced by the usage of head tracking, a sufficiently wide FOV [3][4] and stereoscopy [5][6][7][3][8]. Baños et al. [9] fails to detect a positive influence of stereoscopy on an emotive VR environment, which suggests that the impact of emotion on presence may override the influence of stereoscopy. Effectively, the positive impact that other non technological elements have on presence is strongly highlighted. This comprises the use of emotive content [10][9] and the integration of interactive components [8][11], which contribute to a more engaging experience.

2) Immersive devices: Baños et al. previous work [10] compared three types of VR devices with increasing levels of immersion (traditional monitor, large projection screen and head-mounted display (HMD)) and observed that the sense of presence for (emotionally) neutral media content depended, mainly, on immersion. Interestingly, HMD being the most immersive device, did not achieve the best results in Baños et al. experiences due to its negative effects (induced simulator sickness). The large projection screen was the preferred method for an increased sense of presence versus lower sickness. HMD achieved better presence scores than traditional monitors, which is coherent with Nichols' et al. [12] observations.

3) Video 360°: Kasahara et al. [13] conducted experiments on the usage of an HMD to view omnidirectional first person videos, rather than a computer-generated environment. Their work addresses the conflict between the video motion and the participant real-world perceptions as (s)he does not control the video protagonist movements (eg. a video of a walk through a city). This conflict is the cause of most sickness symptoms. Video stabilization and synchronization between the video and viewer motion is, therefore, of particularly importance to convey realistic sensations and to avoid discomfort. Decock et al. [14] also presents an exploratory work on 360° video display using an immersive system. Some limitations of video setups taken into consideration are the inability to fully use head

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tracking (the direction of viewing can be controlled by rotating the head, but head movements like leaning forward have no reflection on the visual stimulus) and the limited interactivity with the VE (the individual cannot have exploratory initiative, being subjected to the video flow).

II. Pertinence of study

The main goal of this work is to study to what extent the exposure time influences the sense of presence in the context of a 360° video viewed on an immersive setup, namely HMD. Such knowledge will be valuable to one know how much time should it last a stimulus to get the most of it. For instance, in a product demonstration, if the exposure time to the stimulus is too short or too long for the consumer to gain interest in the content it can compromise the whole purpose of the demonstration.

Even though little work was found specifically investigating the impact of exposure time on the sense of presence, following the scientific principle of parsimony, the team speculated that it can influence presence to a certain extent.

As it may take some time to users to adapt to the VR system and perceive the VR environment taking the most of it, it becomes pertinent to understand if short periods of exposure time are as effective as longer exposure times. Considering this, we speculated that presence would increase with time until a certain duration was reached, which would be when the user had completely adapted to the VR system. We advanced no hypothesis regarding possible differences between genders, being an exploratory study on this matter.

With the present work, we aim to:

- Compare 4 levels of exposure time at the level of the sense of presence;
- Compare by gender and the 4 levels of exposure time at the level of the sense of presence.

Such findings will contribute to establishing good practices for VR demos using HMDs, namely determining how long should take a session in order to achieve a credible and comfortable experience for users.

III. Experimental setup

The study presented is a quasi-experimental, cross-sectional study with a quantitative focus. Its main goal is to study if different exposure times can have influence on the feeling of presence. The experiences were conducted following a subjective evaluation approach using a presence questionnaire applied to a VR context where the subject assisted to a 360° video stimulus using a HMD and a pair of headphones with active noise cancellation. Gender is also considered to characterize the sample and better understand the obtained results.

A. Instruments

The goal was to measure the level of presence reported by participants. For this, the IPQp presence questionnaire was used. The IPQp is a properly validated translation of the IPQ [15] for the Portuguese language by the authors [16] that maintains the original validity of the IPQ. It is composed by 14 items that have to be scored using a five-point rating scale and, besides the overall sense of presence, it provides three subscales that can provide additional insights: Spatial Presence, Involvement and Experienced Realism. A sociodemographic questionnaire was also used to collect data about participants that could allow to characterize the sample groups and support theoretical interpretations.

The stimuli presented consisted of an omnidirectional video that transported users to Batalha Square, an historic square located at Porto (Portugal) during the afternoon where it is possible to watch people and cars walking by (Fig.1). The HMD used were the Oculus Rift DK2 while the audio stimulation was achieved with a pair of headphones with active noise cancellation (Bose QuietComfort 15). Head tracking enabled participants to look in any direction to explore the given scene. Other body movements were disregarded.

The user's position in the VE was always the same, limiting the sensory conflict caused by video motion as referred in the previous section [13]. The research team had great care to ensure that possible issues related to the synchronism of the stimuli regarding head movements and video position were minimized to avoid bias.

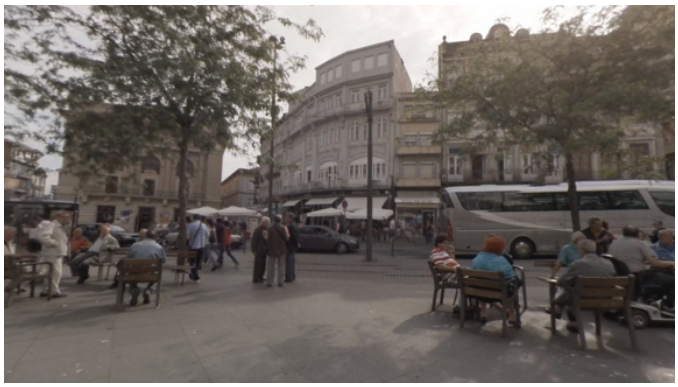


Fig. 1. Print screen of the video stimuli.

B. Variables

The independent variables of this study were exposure time and gender. The dependent variables consisted of the subscales of the IPQp questionnaire (immersion, realness, spatial presence).

C. Sample

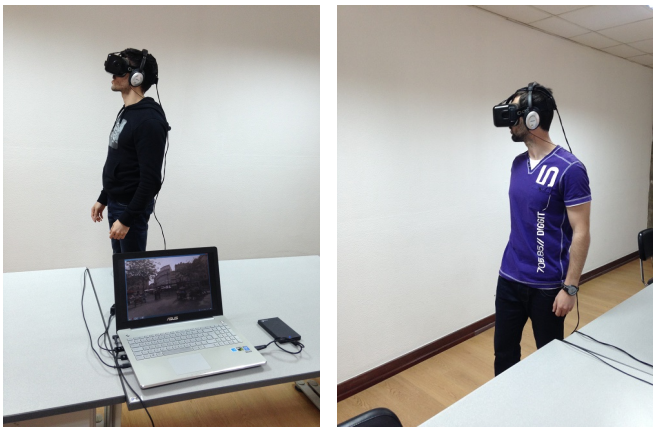
The sample consisted of 65 participants (32 male and 33 female) with ages between 19 and 43 years old ($mean$ = 21, $std.dev.$ = 5.497). Participants were divided into four groups: the first group (N = 16) was exposed 1 minute to the stimuli, the second group has been exposed 3 minutes to the stimulus (N = 16), the third group has been exposed 5 minutes to the stimulus (N = 17), and the fourth group was exposed 7 minutes to the stimulus (N = 16). All participants reported normal or corrected to normal vision. All participants completed the experiment.

D. Experimental protocol

The experiments took place in an experimental room where all the environment variables were controlled, being the luminance level for the experiments dim (approx. 40 cd/m^2). Any external sources of sounds that could have influence in the experiment were also eliminated. Each experimental scenario (exposure time of 1, 3, 5, or 7 minutes) was randomly assigned between the participants.

The experimental procedure started by receiving the participants at the experimental room and explaining on what the experiment consisted of and how participants would participate in the experiment without revealing the purposes of the study in order to avoid bias. Participants were asked to sign a consent form and to fill the sociodemographic questionnaire. The next step was to forward participants to the experimental apparatus and help them equip the HMD and headphones (Fig.2). After finishing the stimuli delivery, the experimenter helped participants un-equipping the instruments used. Next,questionnaires were handed so participants could fill them in and conclude their experimentation.

Regarding the duration of the procedure, it took on average 10 minutes to participants fill the questionnaires and equip/unequip the equipment plus the exposure time that was randomly assigned (1, 3, 5, or 7 minutes).



(a) (b)

Fig. 2. Participants performing the experiments (illustrative photos).

IV. Results

First, an exploratory data analysis was conducted to eliminate outliers. In total 10 outliers were detected and removed from the sample in order to further analyse the collected data (N = 55). For the purposes of the present study, the normal distribution of the data was determined through $Skewness$ and $Kurtosis$. The values obtained showed a normal distribution for all variables. $Skewness$ values varied from 0.454 to 1.813, and $Kurtosis$ ranged from 0.094 to 2.558; thus, parametric statistics were used.

To study the effect of the independent variables (2 (gender) $\times$ 4 (exposure time)), we performed a multivariate analysis of variance (MANOVA), and the results showed no significant effects. The effect of each of the variables sub-scales was also evaluated using an ANOVA.

A. Exposure time

A MANOVA analysis showed that comparisons based on exposure time demonstrated that there was no statistically significant difference ($p < 0.05$) on the sense of presence, $F(9, 109.669)$ = 0.752, p = 0.661; $Wilks\ \lambda$ = 0.864, ηp^2 = 0.047, OP = 0.285.

The ANOVA analysis considering the exposure time as independent variable has revealed that the exposure time to the stimulus does not have a statistically significant impact on Spatial Presence, Realism, Involvement nor Overall Sense of Presence (Table I).

B. Gender

A MANOVA analysis showed that comparisons based on gender demonstrated that there was no statistically significant difference ($p < 0.05$) regarding the sense of presence, $F(3, 45)$ = 0.426, p = 0.735; $Wilks\ \lambda$ = 0.972, ηp^2 = 0.028, OP =0.128.

This ANOVA analysis for the independent variable gender, results have also shown that statistically there is no significant differences between males and females (Table II).

C. Exposure time $vs.$ gender

When we analysed the combined effect of exposure time and gender in a MANOVA analysis, results showed that there were no significant effects ($p < 0.05$) on presence scale differentiating the groups $F(9, 109.669)$=1.141, p=0.341; $Wilks\ \lambda$ = 0.804, ηp^2 = 0.070, OP = 0.435.

As one can verify on Table III, illustrating a ANOVA analysis for Exposure Time $\times$ Gender, results suggest that the combination of these variables does not have a statistically significant impact ($p < 0.05$) on Spatial Presence, Realism, Involvement and Overall Sense of Presence. Regarding the statistical effect, it is moderate for the Experienced Realism and Spatial Presence ($0.06 < \eta p^2 < 0.14$) and small for the Involvement and Overall Experience sub-scales ($0.01 < \eta p^2 < 0.06$).

V. Discussion

Despite the growing popularity of HMD usage, little work has been done with the purpose of studying the impact of increasing exposure times on the sense of presence felt.

The research team speculated that short exposure times could have negative impact on the sense of presence reported as users might not have time to adapt to the VR scenario and, consequently, have a negative impact on immersion. This happens on Spatial Presence and Rrealism scores of male participants: scores seem to increase with time, reaching its maximum values for 5 minutes experience duration and then stabilize. Female spatial presence and realism scores, however, seem to decrease slightly but consistently with time, having its highest values for 1 minute experiences. This does not match our hypothesis and could possibly suggest a difference

TABLE I
PRESENCE VARIATIONS ACCORDING TO EXPOSURE TIME

	Exposure Time				Anova analisys			
	1 minute	3 minute	5 minute	7 minute	Z	p	ηp^2	PO
Spatial Presence mean (sd)	22,13 (2,825)	21,94 (4,28)	24,00 (2,132)	23,75 (3,793)	1,365	0,265	0,080	0,339
Realism mean (sd)	12,80 (3,448)	13,19 (3,250)	13,83 (3,070)	13,50 (2,236)	0,242	0,867	0,015	0,092
Involvement mean (sd)	12,60 (2,667)	12,88 (4,241)	13,92 (2,610)	11,92 (2,746)	0,763	0,520	0,046	0,201
Overall experience mean (sd)	47,53 (5,502)	48,00 (10,093)	51,75 (5,242)	49,17 (6,264)	0,843	0,477	0,051	0,219

TABLE II
PRESENCE VARIATIONS ACCORDING TO GENDER

	Gender		Anova Analisys			
	female	male	Z	p	ηp^2	PO
Spatial Presence mean (sd)	22,52 (3,683)	23,14 (3,240)	1,034	0,314	0,022	0,169
Realism mean (sd)	13,44 (2,979)	13,14 (3,100)	0,008	0,931	0,000	0,051
Involvement mean (sd)	12,56 (3,344)	13,07 (3,090)	0,246	0,622	0,005	0,077
Overall experience mean (sd)	48,52 (7,623)	49,36 (6,951)	0,425	0,518	0,009	0,098

in perception: while women seem to perceive spatial presence and realness within a very short period of time, devaluing these perceptions for longer exposures, men seem to need more time (5 minutes) to develop the same feelings. Even though these results do not achieve statistical significance, spatial presence and realism observed powers (OPs) for exposure time $\times$ gender are moderate (Spatial Presence OP=0.457 and Realism OP=0.375), which supports the observed patterns.

As for Involvement, scores of both genders seem to increase until 5 minutes duration and then decrease, with greater variations for women, but without statistical significance.

The 5 minutes exposure time condition achieved higher presence scores, except for women on Spatial Presence and Realness subscales. However, considering the lack of significance of ANOVA analysis, we cannot validate any of the exposures length as the most effective in terms of presence, especially because participants tend to overestimate the duration of the experience (this was one of the questions on the questionnaire), and, if the VE lacks interactivity, one speculate that it can have a negative impact on the sense of presence.

VI. CONCLUSIONS

We found no significant evidence that presence increases with exposure time, but observed consistent variations for two of the presence subscales as exposure time increased. Spatial presence and realism scores varied differently for males - increasing with time - and females - slightly decreasing. Even though 5 minutes exposures obtained the highest presence scores on most cases, there is no statistical support to recommend any of the exposure times tested. One fact is that participants tended to overestimate the duration of the experience.

By means of direct observation it was verified that men needed longer exposure times (always $>$ 3 minutes) to report the highest presence scores. Opposingly, women frequently reported maximum scores for 1 minute experiences. Longer experience durations would be advisable for men to guarantee a correct perception.

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TABLE III
PRESENCE VARIATIONS ACCORDING TO EXPOSURE TIME AND GENDER

	Exposure Time × Gender								Anova analisys			
	1 minute		3 minute		5 minute		7 minute		Z	p	ηp^2	PO
	female	male	female	male	female	male	female	male				
Spatial Presence mean (sd)	22,71 (3,25)	21,63 (2,50)	22,63 (5,24)	21,25 (3,28)	22,50 (1,64)	25,50 (1,38)	22,17 (4,07)	25,33 (3,01)	1,885	0,145	0,107	0,457
Realism mean (sd)	14,00 (2,89)	11,75 (3,73)	13,87 (3,52)	12,50 (3,02)	13,17 (3,19)	14,50 (3,08)	12,50 (2,59)	14,50 (1,38)	1,521	0,221	0,088	0,375
Involvement mean (sd)	12,00 (3,06)	13,13 (2,36)	12,38 (5,24)	13,38 (3,25)	14,00 (1,27)	13,83 (3,66)	12,00 (1,90)	11,83 (3,60)	0,155	0,926	0,010	0,076
Overall experience mean (sd)	48,71 (5,65)	46,50 (5,53)	46,50 (5,53)	47,13 (8,10)	49,67 (5,01)	53,83 (5,00)	46,67 (4,63)	51,67 (7,06)	0,909	0,444	0,055	0,234

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