Impact of Different Role Types and Gender on Presence and Cybersickness in Immersive Virtual Reality Setups

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2021 International Conference on Graphics and Interaction (ICGI) | 978-1-6654-8343-8/21/$31.00 ©2021 IEEE | DOI: 10.1109/ICGI54032.2021.9655281

***Abstract*—Several factors have been identified to contribute to the sense of presence and cybersickness, including the preponderance users have in the virtual environments (VE) and their gender. This work focuses on studying the Role Type and gender in a VE and their impact on the sense of presence and cybersickness when immersive Virtual Reality (VR) setups are used. For this, a set of psychophysical experiments were conducted to evaluate a VR scenario with three Role Types: Viewer, Explorer, and Searcher. Results revealed statistically significant differences in Spatial Presence, Cybersickness, Nausea, Oculomotor Discomfort, and Disorientation for Role Type. In the evaluated scenario, it was observed that a more dominant Role Type on the VE leads to a higher reported spatial presence (sense of physically being present in the VE) and higher cybersickness scores. We conclude that a higher relevance of the Role Type makes the users more sensitive to the stimuli present in the VE regarding the coherency of the interaction/simulation and, consequently, more prone to develop cybersickness symptoms. No differences were found between the genders.**

***Index Terms*—Virtual Reality, Presence, Cybersickness**

I. Introduction

Virtual Reality (VR) aims to transport users to Virtual Environments (VE) in a way that they develop a sense of Presence [1]. The concept of Presence can be summarily defined as the feeling of "being there", i. e., developing a mental state where the users genuinely believe that they are physically in the virtual world as if it was the real world [2]. Presence has been one of the most common metrics in VR related studies [3]–[6]. Depending on the application domain, the VR application might have different purposes. For instance, while for entertainment VR applications, the main purpose is to entertain users, for training and certification VR applications, we must ensure that knowledge transfer occurs.

Several factors can influence the VR experience. These factors can be broadly divided into three categories: technological, personal, and the features of the VR experience itself [7], [8]. Among the technological factors, there is the type of VR setups that can be non-immersive (based on keyboards, mice, and joysticks), semi-immersive (based on large displays and joysticks, data gloves or similar devices for input) or full-immersive (based on CAVEs, Head-mounted Displays (HMDs), and natural interaction) [9]; and the equipment features such as the field-of-view, frame rate, or the graphics' quality. The personal factors refer to the individual differences in users, such as the user's habituation to the system, cognitive abilities, acceptance of technology, or personality. Focusing on the features of the VR experience, there is the preponderance of the Role Type on the VE. The preponderance of the Role Type is defined by how they can interact with the VE and influence the form and content [10]. Examples of different types of roles that can be given in a VE are to spectate, navigate the point of view, and to interact with inanimate objects and with animated characters [11], [12].

The literature argues that Presence can be affected depending on the preponderance of users in the VE. The more active the Role Type on the VE, the more the potential to elicit Presence [13]. Also, Presence can be affected by adverse factors such as Cybersickness [14]. Cybersickness refers to the development of symptoms similar to motion sickness that users might experience during a VR experience (e.g. nausea, disorientation, vertigo). Research [15] indicates that the likely cause is a mismatch between the vestibular and visual systems (users seeing they are moving, but their vestibular system sensing they are stopped). Thus, controlling our actions and movements (a more active role type) can decrease the likelihood of Cybersickness symptoms. Although Presence seems to be correlated to Cybersickness, there is no consensus if such correlation is positive or negative.

Little research has focused on evaluating the impact of different Role Types in HMD-based immersive VR setups. This paper investigates the impact of different Role Types and user gender in the sense of Presence and Cybersickness when using immersive setups.

II. Related Work

A. Evaluation of VR applications

To evaluate the impact of the different factors in VR applications, it is important to use proper metrics. VR applications

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are often evaluated through the self-reported sense of Presence and Cybersickness.

The evaluation of Presence can be achieved using questionnaires. Different proposals have been made for this purpose, such as Witmer & Singer [16] proposed the Presence Questionnaire (PQ) to assess overall Presence considering four factors Involvement, Visual Fidelity, Adaptation/Immersion and Interface Quality. Schubert et al. [17] consider other factors: Spatial Presence, Experienced Realism, Involvement and Sense of Presence. Lombard et al. [18] consider eight dimensions: Spatial Presence, Active Social Presence, Passive Social Presence, Social Presence, Engagement, Social Richness, Social Realism, and Perceptual Realism. Overall, Presence constructs relate to how real the experience appears to be (e.g. how real the social interaction, the visuals, or the interfaces) and how involved/engaged the user is.

Cybersickness corresponds to a set of possible symptoms that can arise after exposure to a VE, including general discomfort, nausea, vertigo, or eye strain [14], [15], [19]. Thus, high levels of Cybersickness can negatively affect the VR experience and even discourage using VR technologies. The evaluation of Cybersickness relies, essentially, on the Simulator Sickness Questionnaire (SSQ) [19], a questionnaire that aims at identifying symptoms felt by users after the exposure to VR. The SSQ comprises 16 items that classify the severity of the user's symptom (none, slight, moderate, severe) categorised into four subscales: Nausea, Oculomotor Discomfort, Disorientation, and Cybersickness. The relation between the sense of Presence and Cybersickness symptoms have already been studied; however, there is no consensus about how both are correlated. Busscher [20] and Witmer [21] concluded in their studies that higher Cybersickness scores results in lower Presence, but Slater [22] and Liu [23] found evidence of a positive correlation between Presence and Cybersickness. A recent systematic review on this topic analysed 20 scientific articles and verified a tendency to a negative correlation between Presence and Cybersickness [24].

B. Impact of Role Type on Presence

Previous work such as the survey developed by Schuemi et al. [7] state that different Role Types (given by the range of interaction in the VE and what is expected from users) affect the sense of Presence. One of the first studies that addressed a spectating Role Type $vs.$ an interactive Role Type was conducted by Welch et al. [25]. The passive scenario consisted of a car scene where the participant was the passenger, and the interactive scenario consisted of that same scene where the participant was the driver, and he could control the direction and speed of the car using a steering wheel and pedals. Results have revealed that the Presence reported in the interactive scenario was higher when compared to the passive scenario.

Another study that addressed the effects of passive $vs.$ active Role Types on Presence was conducted by Gutierrez [13]. For this purpose, it was built a VR application where, in a spectating scenario, participants had a guided tour through the VE but could not interact with it. In the interactive scenario, participants could navigate through the VE and interact with some objects. In this projection-based VR setup, the results have shown that the levels of Presence were significantly higher in the interactive scenario. Messinis e al. [26] analysed VR educational projects regarding the influence of the level of interaction of the user and Presence, finding a positive correlation between them.

C. Impact of gender on Presence

The impact of gender in the sense of Presence has revealed different outcomes across different studies. For instance, inspired by the gender differences in spatial abilities [27], Larson et al. [28] conducted an experiment where the participants had to perform the Mental Rotation Test in a VR environment, and no differences were found across gender. The Mental Rotation Test can be used to evaluate users' spatial intelligence, which, by its turn, can help users generate a mental representation of the VE, allowing them to be more easily immersed in it [29]. Alsina et al. [30] found evidence that spatial intelligence can influence the sense of Presence. However, in their study, the result was only valid for the group of users that scored high on an anxiety test. This topic was further investigated by Felnhofer et al. [31] that conducted a study where participants had to hold a 5-minute presentation in front of a virtual audience. Results have revealed that men tend to report higher spatial Presence levels, experienced realism and overall sense of Presence. In this regard, Lachlan et al. [32] conducted an experiment with 153 participants, playing on an Xbox game console with a joystick. Although the study does not use immersive VR (HMD, CAVE, etc.), the results also support the notion that males have a significantly higher Presence than females.

More recent studies [3], [6], [33] based on immersive setups and have revealed contradictory results. In Bessa et al. [3], participants were exposed to a virtual bicycle ride, and there were significant differences across gender for the overall Presence and spatial Presence where female participants reported higher scores than male participants. This is further corroborated by Gonçalves et al. [33], which used VR games to research differences in Presence between genders. The authors concluded that females have a significantly higher Presence and experienced realism than males contradicting previous studies results. These results are partially corroborated by Melo et al. [6] that conducted a study that consisted of a passive experience in a VE where users stood at a fixed point and were able to explore the environment by looking around. Results have revealed significant differences across gender, being that female participants reported higher levels of experienced realism.

D. Impact of Role Type on Cybersickness

Regarding the appearance of Cybersickness symptoms when interacting with VR, Stanney et al. [34] has conducted a study based where participants had to configure the walls of 18 different rooms in three different modes (passive, active, and passive-active). The authors concluded that participants in the passive mode reported higher Cybersickness symptoms. Results also revealed that while the active mode mitigated Cybersickness symptoms, the passive-active scenario (active with a task assigned) was where participants reported fewer Cybersickness symptoms.

Davies et al. [14] conducted a systematic review about Cybersickness that identified several factors that can influence Cybersickness, including the type of control the user has over the VE. He states that participants with good control in a VE can better predict future motion, resulting in less Cybersickness. An analogy to this statement could be considered when a passenger in a vehicle is more prone to feel motion sickness than the driver because he/she has no control over the car movement and thus cannot predict its motion. However, such is based on only one reference in the literature [35].

E. Impact of gender on Cybersickness

The gender factor was also considered in literature in studies such as Park et al. [36] where the gender variable was studied using a driving simulation scenario. There was a significant effect for gender in this interactive environment regarding nausea and oculomotor discomfort as female participants reported more Cybersickness symptoms. More recently, Melo et al. [6] conducted a study based on passive scenarios where participants were exposed to a VE, and a 360 video and no significant differences were found across gender nor scenario.

Gonçalves et al. [33] researched this topic using VR games using HMD. When controlling for gender, results showed that females are significantly more prone to Cybersickness than males. Narciso et al. [37] work studied Cybersickness between genders and stereoscopy in 360º videos using HMD. The results indicated that female participants have significantly more nausea in the 2D video conditions while male participants have higher nausea in the 3D video condition. It seems that this result did not change with the improvement of technology and the introduction of new and more sophisticated HMDs, as studies before the year 2000 suggest the same outcome [38], [39]. LaViola [15] suggests that one of the reasons for this tendency is that women have a wider field of view, which might increase the likelihood of noticing flicker. Also, it is suggested that female hormones might affect their susceptibility to Cybersickness [35]. More recently, MacArthur et al. [40] conducted a systematic review of how VR research considers gender and cybersickness and concluded that literature might have contradictory results due to the number of confounding factors associated with the reviewed research more. Thus, as the authors point, more consistent research has to be made in the field. The authors also point as a gap in the literature the lack of consideration of gender as an independent variable.

Despite that some studies already address interaction in VEs as described above, there is a gap in the literature. Few works investigate the impact of different Role Types on the sense of Presence and/or Cybersickness in immersive VR setups. The importance of addressing immersive VR setups is further reinforced by the affordability of VR immersive equipment that contributes to the widespread of VR immersive setups. Such setups enable a higher immersion of the users and, consequently, improve their experience [41]. As so, it is important to establish if such technological advances still corroborate literature's those previous findings. Based on the literature, Presence is higher not only in scenarios where the Role Type is more dominant (more influence in the experience) but also that is even higher in scenarios where top-down attention strategies are used (e.g., using the VE with a purpose) when compared to bottom-up approaches (passive Role Types). Also, due to the diversity of outcomes and lack of consensus in the literature regarding the appearance of Cybersickness across different Role Types and gender, Cybersickness is studied for gaining more understanding about the causes that can originate the appearance of such negative symptoms.

For this paper we propose the following hypothesis:

- H1: A more preponderant Role Type will result in higher Presence.
- H2: A more preponderant Role Type will result in higher Cybersickness.
- H3: There is a difference in Presence scores between genders.
- H4: There is a difference in Cybersickness scores between genders.

III. Methods and Materials

The methodology adopted for the present study was a quasi-experimental, cross-sectional study with a quantitative focus with a between-subject design. Through this approach, one can investigate the impact of the independent variables "Gender" (two levels: male, female) and "Role Type" (three levels: Viewer, Explorer, Searcher) in the dependent variables Sense of Presence and Cybersickness. The Viewer mode consists of a Role Type where the participant is a spectator of the VE in a fixed point-of-view. The Explorer mode consists of a Role Type where the participant is a spectator of the environment but can change his point-of-view through the camera's displacement. As for the Searcher mode, the participants need to perform a task within the VE while moving.

A. Sample

The sample consisted of 48 participants (24 male and 24 female) evenly distributed between the three "Role Type" scenarios while ensuring gender balance (N = 16 per scenario). Participants were aged between 19 and 50 years (M = 24.42, $Std.Dev.$ = 6.18). Regarding academic qualifications, 27.1% had finished high school, and 72.9% had a B.Sc. degree. Participants reported having strong (29.2%) to very strong (78.8%) experience with computers (from a 5-point scale: none, low, medium, strong, very strong). Concerning gaming habits, 58.3% declared to play occasionally (1 to 2 times per week), 29.2% often (3 to 4 times per week) and 12.5% very often (5 or more times per week). Regarding previous knowledge about VR technologies and how they work, 12.5% no knowledge, 22.9% little knowledge, 35.4% average knowledge, 29.2% strong knowledge. Regarding previous experiences with immersive VR, 35.4% of the participants reported having experienced it before, while 64.6% had not.

B. Instruments and materials

An immersive VR application was developed for the study, considering the independent variable “Role Type". A challenge/task had to be included for the User Role Searcher, so users had a goal to accomplish in this condition. Considering such requirements, the research team developed a scenario that consists of a pair of cabins in the woods (Fig. 1). The playable area is limited by virtual wooden fences. Inside the area, there are abandoned buildings and cabins where the participants can enter. Trees and grass populate the outside area. The VE comprises three modes: Viewer mode, Explorer mode, and Searcher mode. In the Viewer mode, the users are transported to the VE, and they can contemplate the scenario by looking omnidirectionally at the surrounding environment using an HMD. In the Explorer mode, users are allowed to move the camera through the VE. A gamepad was used as an interface as it is the most representative device for navigating in VEs. For the Searcher mode, the VE was populated with teapots, where users had to catch the maximum of teapots they could. The teapots were scattered in different places, some of the teapots hidden and not visible from the starting point to challenge and have users explore the environment with a goal as they would in a gaming scenario. All the modes included audio stimulus that was coherent with the context. The sounds included are ambient sounds typical of the depicted scenario: the wind, trees, and subtle birds. Also, footstep sounds correspond to steps in a grassy terrain such as the one depicted in the environment. Additionally, it was also added a sound was triggered when a teapot was collected, so the participant had audio feedback. All modes had a duration of three minutes - the time was defined following the work of Melo et al. [6] which shows that VR experiences with a duration of one to seven minutes are enough to develop a sense of presence and do not affect the VR experience negatively.

The data was collected using three questionnaires: a sociodemographic questionnaire, to allow a sample characterisation; the IPQp [42], an adapted and validated to the Portuguese version of the IPQ [17] which measures presence considering four dimensions (spatial presence, involvement, experienced realism, and overall sense of presence); and the adapted Portuguese version of the SSQ [19] that measures Cybersickness considering four dimensions (nausea, oculomotor discomfort, disorientation, and Cybersickness). An open-ended interview was conducted at the end of the experiment to gather more information from users about their virtual experience.

The experiment was delivered using the Oculus Rift DK2 HMD for providing the visual stimulus and the Bose QuietComfort 15 headphones with acoustic noise cancellation technology for providing the audio stimulus. The gamepad used for navigation in the VE was the Xbox 360 gamepad. The VR simulations were run in a desktop computer with an Intel i7-5820K CPU, a Nvidia GeForce GTX 980 Ti graphics card and 16GB of RAM that ensured that the VR application was executed without having performance issues. All the experiments were conducted in a controlled experimental room.

C. Experimental protocol

The research team received the participants in the experimental room, where they were briefed about the study without being disclosed its goals to avoid bias. Next, participants asked to sign a written consent to express their agreement in participating in the experience. Next, the participant was also asked to fill out a short socio-demographic questionnaire. Then, the research team briefly described the equipment that the participant would use during the experiment and how they would participate in the experiment according to the experimental scenario that was going to be evaluated. In the first scenario, the participant was asked to watch the surrounding environment. For the second scenario, it was asked to the participant to explore the VE freely. In the third scenario, the participant was asked to explore the environment and find the maximum number of teapots as possible. Before starting the experiment, the researcher confirmed with the participant if he/she felt comfortable with the equipment and, if so, the experience began.

All the scenarios had a duration of three minutes regardless of the experimental scenario. The end of the experience was announced by fading the screen to a neutral grey background with the text “Your participation in this study has ended, thank you for your participation.”. Then, after removing the equipment, the participant was asked to complete the Presence and Cybersickness questionnaires. After the questionnaires being completed, a short debriefing was conducted to gather participant’s feedback about the virtual experience regarding their opinion over their experiment.

D. Statistical Procedures

To investigate whether there are group differences between the two independent variables (“Role Type” and “Gender”) regarding the different dependent variables, a two-way ANOVA statistical analysis was performed. The two-way ANOVA assumptions were verified using box plots to assess whether there were any outliers and Shapiro Wilk’s test of normality to assess the normality. All pairwise comparisons were run for each simple main effect with reported 95% confidence intervals and p-values Bonferroni-adjusted within each simple main effect. When the assumptions of the two-way ANOVA were not met, a Kruskal-Wallis H test was performed. In the cases that statistically significant differences were found after the Kruskal-Wallis H test, pairwise comparisons were performed using Dunn procedure [43] with a Bonferroni correction for multiple comparisons.

IV. Results

A preliminary analysis to verify outliers through boxplot inspection was performed. For this purpose, it was followed Tukey et al. [44] procedures where data had to be more than three times the interquartile range below the first quartile

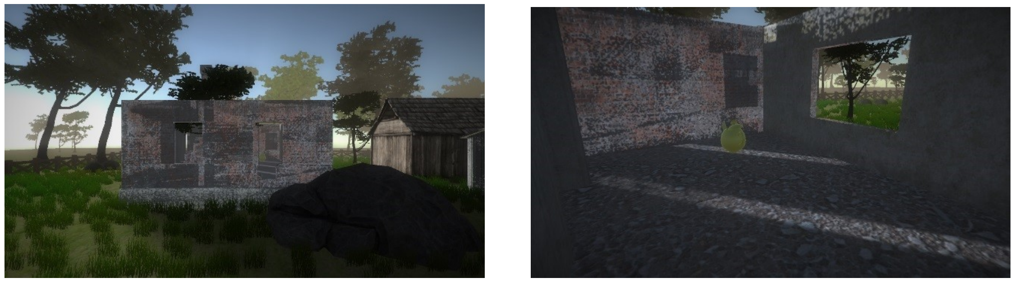

Fig. 1. Screenshots of the VR application developed for the study.

or three times above the third quartile range to be considered an outlier. Such analysis returned 4 outliers that were consequently removed from the sample to proceed with the statistical analysis.

A. Presence

Shapiro Wilk's test showed that only the dependent variables Spatial Presence, Involvement, Experienced Realism and Overall Sense of Presence normally distributed ($p > 0.05$). For this dependent variables, there was homogeneity of variances as assessed by Levene's test for equality of variances (p = 0.459, p = 0.934, p = 0.227, and p = 0.973, respectively). Thus, a two-way ANOVA was conducted to examine the interaction effects of "Gender" $\times$ "Role Type" and the simple main effects of "Gender" and "Role Type" on the above-identified dependent variables. Data are Mean $\pm$ Standard Deviation unless otherwise stated. Mean scores are illustrated in Fig. 2 and ANOVA results are presented in Table I.

As Table I shows, Spatial Presence mean scores showed no statistically significant interaction between "Gender" and "User Role" . There was also no statistically significant main effect of "Gender" on Spatial Presence mean scores. For "Role Type", there was a statistically significant main effect on mean Spatial Presence scores. The mean Spatial Presence scores for Explorer, Viewer and Searcher modes were 3.21 $\pm$ .39, 3.74 $\pm$ .21 and 3.84 $\pm$ .41, respectively. The Viewer mode had a significantly lower mean "Spatial Presence" score than the Explorer mode 0.53 (95%CI, -.819 to -.235) and the Searcher mode 0.63 (95%CI, -.919 to -.347) at $p < 0.0005$. The mean "Spatial Presence" scores for the Explorer and Searcher modes were not statistically significant, 1.00 (95%CI, -.185 to .398). No other interaction or main effects were found

B. Cybersickness

Two-way ANOVA's assumptions were not met regarding Cybersickness subscales as the data was not normally distributed. Thus, a Kruskal-Wallis H test was run to determine if there were differences in Nausea, Oculomotor Discomfort, Disorientation, and Cybersickness scores. As data had similarly shaped distributions, the use of medians was privileged.

For "Gender", Nausea, Oculomotor Discomfort, Disorientation, and Cybersickness scores were similar, as assessed by visual inspection of a box plot. Median scores were not statistically significant for Nausea ($\chi^2(1)$ =.376, p = .540, η^2=0.015), Oculomotor Discomfort ($\chi^2(1)$ = 1.060, p = .303, η^2=0.001), Disorientation ($\chi^2(1)$ =.018, p = .894, η^2=0.020), and Cybersickness ($\chi^2(1)$ =.815, p = .367, η^2=0.133). The median scores for these subscales are shown in Fig. 3.

Regarding "Role Type", a Kruskal-Wallis H test was run to determine if there were differences in Nausea, Oculomotor Discomfort, Disorientation, and Cybersickness scores. These scores' distributions were also similar for all the experimental scenarios, as assessed by visual inspection of a box plot.

The Nausea scores were statistically significantly different between groups, $\chi^2(2)$ = 9.043, p = .011, η^2=0.172. The post hoc analysis revealed statistically significant differences in median Nausea scores between the Viewer and Explorer modes (66,78 vs. 85,60 - p = .010, respectively) as well as between the Viewer and the Searcher modes (66.78 vs. 85.60 - p = .010, respectively).

Median Oculomotor discomfort scores were statistically significantly different between groups, $\chi^2(2)$ = 9.347, p = .009, η^2=0.179. The post hoc analysis revealed statistically significant differences in Oculomotor discomfort scores between the Viewer and the Searcher modes (60,64 vs. 90,96 - p = 0.019, respectively) as well as between the Explorer and the Searcher modes (56,85 vs. 90,96 - p = 0.033, respectively).

Median Disorientation scores were statistically significantly different between groups, $\chi^2(2)$ =10.337, p = .006, η^2=0.203. The post hoc analysis revealed statistically significant differences in Disorientation scores only between the Viewer and the Searcher modes (97,44 vs. 153.12 - p = 0.005, respectively).

Regarding Cybersickness, the median scores were statistically significantly different between groups, $\chi^2(2)$ =10.138, p = .006, η^2=0.198. The post hoc analysis revealed statistically significant differences in Cybersickness scores only between the Viewer and the Searcher modes (82.28 vs 115.94 - p = 0.006, respectively).

C. Participants' Feedback

The participants' feedback was consensual about the virtual experience: they enjoyed using the environment and felt comfortable interacting with the system (when applicable). The feedback was also similar between genders, not being possible to discriminate any differences in how different genders described their experience and feelings. Participants reported, in general, that the environment was tranquillising. Particularly in the Searcher mode, it was observed that participants reported

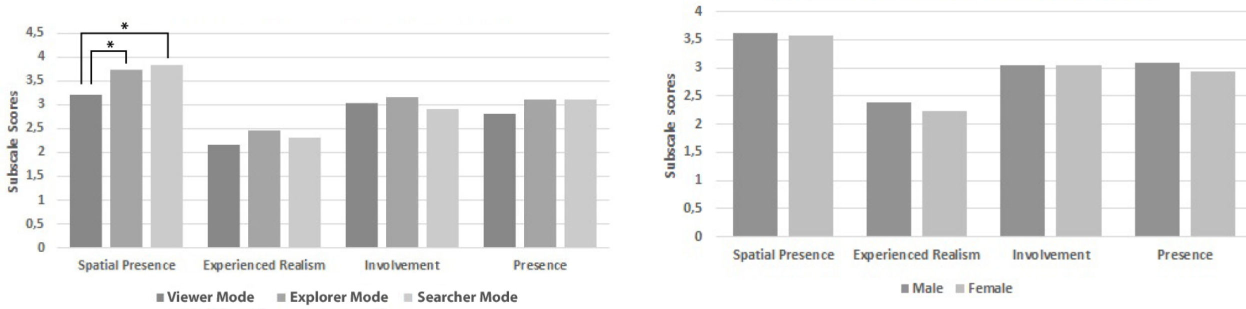

Fig. 2. Mean scores for presence subscales across Role Types (left) and across genders (right).

TABLE I
INTERACTION EFFECTS OF "GENDER" × "ROLE TYPE" AND THE SIMPLE MAIN EFFECTS OF "GENDER" AND "ROLE TYPE" FOR PRESENCE SUBSCALES.

		F	p	η_p^2	$O.P.$
Spatial Presence	Gender × Role Type	1.223	0.306	0.060	0.251
	Gender	0.086	0.772	0.002	0.059
	Role Type	16.736	< 0.001	0.468	0.999
Experienced Realism	Gender × Role Type	1.412	0.256	0.069	0.284
	Gender	0.453	0.505	0.012	0.101
	Role Type	0.599	0.555	0.031	0.142
Involvement	Gender × Role Type	0.754	0.577	0.038	0.169
	Gender	0.001	0.982	0.000	0.050
	Role Type	0.357	0.702	0.018	0.103
Overall Presence	Gender × Role Type	1.889	0.165	0.090	0.368
	Gender	0.177	0.676	0.005	0.070
	Role Type	1.964	0.154	0.094	0.381

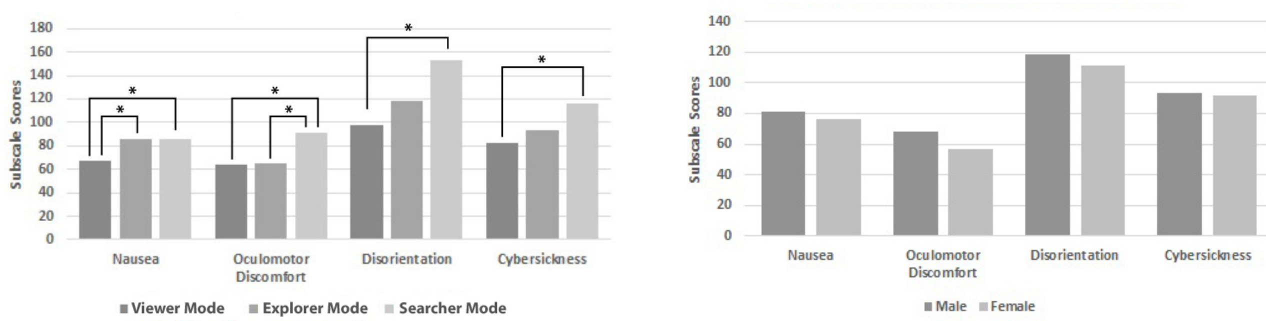

Fig. 3. Mean scores for cybersickness subscales across Role Types (left) and across genders (right).

being more engaged with the virtual environment as they felt challenged and wanted to complete the task successfully. Some of the participants that underwent the Explorer and the Searcher modes reported slight symptoms of cybersickness.

V. DISCUSSION

This study compared different Role Types regarding Presence and cybersickness. Overall, results only showed statistically significant differences for the presence subscale "Spatial Presence". At the same time, cybersickness revealed statistically significant differences for all the subscales when "Role Type" was changed. A fact is that there is no consensus among the literature regarding the relationship between the sense of presence and cybersickness [16], [20]. Based on our results and considering some comments that arose during the debriefing session at the end of each trial, our understanding is that the relation between Presence and cybersickness is a complex equation. Participants revealed less spatial Presence in the Viewer mode than on Explorer and Searcher modes, indicating that increasing the preponderance of the Role Type is important to develop a higher spatial presence. However, in these same conditions (Explorer and Searcher modes), participants revealed to be more prone to cybersickness. We believe the vestibular system's incoherent stimulation may have induced cybersickness symptoms: participants were walking in the VE while they were sitting in reality. Such outcome suggests that when the levels of spatial Presence are higher, participants may be more sensitive to the presented stimuli, thus requiring coherent stimulation to mitigate these adverse effects. But we can also speculate that a higher cybersickness was not a direct function of a higher sense of Presence, but simply due to moving throughout the environment while seated.

Regarding Presence, statistically significant differences were found between the three Role Types only for Spatial Presence, partially confirming H1. The Searcher mode achieved higher spatial presence levels was the Searcher mode, followed by the Explorer mode and the Viewer mode. This outcome relates to previous studies (e.g., [8], [13]). Results revealed that the higher the Role Type preponderance, the more the reported sense of spatial presence. We theorised that the increase in Role Type could directly contribute to the user's engagement with the VE. This theory is reinforced by previous work that establishes the relationship between what is expected from the user and sense of presence [45], [46]. We further theorised that the sense of being inside a VE and having the sensation of motion control contributes to the sense of being physically in the VE - which is exactly what the spatial presence scale refers to. Our study did not reveal significant differences across gender (rejecting H3) and, thus, not corroborating recent studies with similar immersive setups [3], [6], [33] that verified that female participants reported higher levels of Presence, spatial presence, and experienced realism.

As for cybersickness, statistically significant differences were found for every subscale, being that the higher the preponderance of the Role Type, the higher the severity of cybersickness reported (confirming H2). The exception to these results is the oculomotor discomfort where the Explorer mode (56,85) and the Viewer mode (60,64) reported similar values. In contrast, in the Searcher mode (153,12), significantly higher scores were reported. These findings do not corroborate previous work [47] where it was shown that cybersickness symptoms could be mitigated when users have a task-oriented scenario instead of an open interaction scenario. The results also do not corroborate Davis et al. [14] that argues that the higher the control over the simulation, the lesser the cybersickness. Our results can be explained by the navigation metaphor used in the study. In a perfect simulation of reality, users would use their movement to navigate the VE, decreasing cybersickness by decreasing the possibility of a mismatch between vestibular and visual system [15]. However, using a joystick could have introduced a sensory conflict: the participants saw themselves moving while their actual body position always remained the same. This resulted in contradictory cues since the virtual stimulus induced the participant to think that he was walking through the VE while sitting, leading to motion sickness and, consequently, a generalised cybersickness. Regarding the oculomotor discomfort, we attribute such results to the fact that participants had to search and focus on the objects they had to collect, which could induce some eye strain compared to the other scenarios. These results can also be associated with [3] study, which shows that conflicting sensory information affected presence negatively. No differences in cybersickness were found between genders, rejecting H4. This result goes against the literature [15], [33], [36], [37]. A possible justification could be due to the exposure time, although enough to elicit presence [6] it might not being enough to evoke differences in cybersickness symptoms between genders.

The present study is not free of limitations. One limitation is associated with the length of the VR experience: the study considers a VR experience with a duration of three minutes. It is reported in the literature that such duration allows eliciting presence [6]. However, longer exposure times should also be studied as a future research line. Another limitation of the study is related to the navigation metaphor: a gamepad. Using HMDs, the user has a first-person perspective. The lack of vestibular stimulation due to using a gamepad caused a sensory conflict between the visual stimulus and vestibular system, which negatively affects cybersickness. However, this fact is not only a limitation as it is also evidence that the paradigm of immersive VR setups demands different navigation approaches than non-immersive setups. Thus, future research lines should address presence and cybersickness across different Role Types using navigation methodologies such as natural walk, walk-in-place, teleport or gaze-based navigation.

VI. Conclusions

As VR applications address critical application fields such as training and certification or medicine, it is essential to understand how the different dimensions of a VR application should be addressed to leverage such applications. We evaluated the impact of Role Type and gender in VR applications using immersive setups on Presence and Cybersickness.

We conclude that Role Types with more preponderance over the virtual world result in higher user engagement and, consequently, a higher sense of physically being in the environment. We also conclude that providing users with a task/purpose on the VE, did not reduce Cybersickness scores but increased them. However, more studies are needed to verify if the Cybersickness increase was solely due to vestibular and visual system mismatch or if an increase of the spatial Presence played a part in turning users more sensitive to these symptoms. No differences were found between genders, both on Presence and Cybersickness.

Acknowledgments

This work is financed by the ERDF – European Regional Development Fund through the Operational Programme for Competitiveness and Internationalisation - COMPETE 2020 Programme and by National Funds through the Portuguese funding agency, FCT - Fundação para a Ciência e a Tecnologia within project POCI-01-0145-FEDER-031309 entitled “PromoTourVR - Promoting Tourism Destinations with Multisensory Immersive Media.".

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