How to Promote Patients' Adherence to Treatments based on Virtual Reality?

A Preliminary Exploration of Virtual Environments Preferences according to Socio-demographic Factors

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***Abstract*—In the current study, we carried out an online survey that aimed to determine which Virtual Environments (VE) are the most suited to individuals' socio-demographic characteristics such as age and gender. Our preliminary results notably demonstrated that the participants' age influenced preferences concerning the four following VE dimensions: esthetics, the will to spend some time in it, the will to further explore it and its relaxing aspect. Thus, our results provide interesting criteria to comprehensively select a relevant VE regarding the targeted population or patients. By adapting Virtual Reality (VR) tools to maximally fit the population characteristics, patients' adherence to the VR treatment should consequently be enhanced.**

***Keywords*—Virtual Reality (VR); Virtual Environment (VE); Socio-demographic characteristics; VR clinical tool.**

I. INTRODUCTION

During the last decades, the emergence of Virtual Reality (VR) technology has provided new opportunities for developing innovative and relevant clinical applications, adapted to numerous medical contexts and pathologies [1]. Indeed, the ability to create and control dynamic 3-dimensional (3D) environments and stimuli, which are naturalistic and ecologically valid, makes the VR technology extremely valuable for the clinical field [2]. For instance, VR is currently used as an exposure tool in patients with anxiety and post-traumatic stress disorders [3]. Through serious games, VR is also getting employed to promote rehabilitation of motor disorders in post-stroke patients [4], or to enhance training in children with Attention-Deficit Hyperactivity Disorder (ADHD) [5].

Thus, given the myriad of pathologies and clinical applications, one might expect that the Virtual Environment (VE) characteristics (e.g., kind of landscape and atmosphere, virtual 3D or real 3D, etc.) could influence patients' adherence to the VR clinical tools. More specifically, we believe that socio-demographic factors such as the individual's age, gender and socio-professional category - which can be related to the pathology [6] - could have an impact on patients' preferences regarding the used VE, and consequently, on patients' adherence to VR treatments [7].

To test this hypothesis, we conducted an online survey using different samples of Virtual Environments on adult participants, aged from 20 to 85 years old. The visual samples consisted in 2D pictures of various types of landscapes (e.g., mountains, forests, sea, etc.) and were presented in synthetic and real versions (coming from real images) on a computer screen. For each image corresponding to one VE, participants had to rate the four following dimensions: the esthetics of the environment; the will to further explore the presented environment; the will to spend time in the environment and the relaxing power of the environment. Our results demonstrated that some sociodemographic variables such as the participants' age influenced significantly the preference ratings. To our knowledge, the current study is the first to provide statistical results that could be useful to properly select the VE in order to maximally fit the targeted population (in terms of age, gender, etc.). This optimization of VE selection regarding patients' preferences should necessarily increase patients' adherence to the VR treatment. An additional survey targeting children, teenagers and neurological patients is in progress. Moreover, supplementary analyses will be performed to further examine the impacts of gender, socio-professional level and practice of VR technology.

The rest of the paper is structured as follows. The research methods are described in Section 2. Then, we provide the preliminary statistical results in Section 3. Finally, we discuss the data in Section 4 and we suggest future research directions in Section 5.

II. METHODS

A. Participants sample

We recruited N=105 healthy participants (63 females) with a wide range of ages ∈ [20, 85], (M=45.85, SD=17.12) and various Socio-Professional Levels (SPL), going from no higher education (Level 1) to doctorate level (Level 6), as indicated in Table 1 below.

TABLE I. NUMBER OF PARTICIPANTS (N) PER SOCIO-PROFESSIONAL LEVEL (SPL)

SPL	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6
N	3	15	13	22	36	16

B. Material & Procedure

The survey – We used the Google Form platform to build and spread the survey without any restriction criterion. The collection of responses followed a strict anonymous procedure since the participants never gave their names or any kind of information that would have allowed their formal

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identification. The first questions concerned the following socio-demographic characteristics: age, gender, profession and education level. Then, 2D pictures representing samples of VR environments were presented one by one with a landscape orientation. Each image was followed by 4 questions, that could be rated on a 7-point scale going from 1 (lowest score) to 7 (highest score). Those questions aimed to collect participants' opinion regarding 4 different dimensions: the esthetics of the VE, the participant's will to spend more time in this VE, the participant's will to explore further the VE, the relaxing aspect of the VE.

Figure 1. Overview of the 24 virtual environments used for the survey. The letters A-L indicate the matched images. The letters R and V indicate Real 3D and Virtual 3D respectively.

The VE samples – Twenty-four VE images were presented in the survey. Half of them came from "real" 3D environments and were developed by Wake Up & Smile enterprise in Madrid. Those real 3D samples were matched with virtual 3D samples that corresponded in terms of landscape types and atmospheres, as presented in Figure 1, where virtual and real samples were coupled by letters. Then, seven main types of environments/atmospheres were analyzed: snowy lands (images A), forest & jungle (images B, G and L), mountainous lands (images H & J), city/town (images E), Buddhist temple (images F), pastures (images C), beach & sea (images D, I, and K).

C. Data analysis

We examined how VE features such as the type of VR content (real 3D vs. virtual 3D) and landscape kinds (e.g., sea, mountain, etc.) could interact with participants socio-demographic characteristics (i.e., age, gender and Socio-Professional Level (SPL)). The factor age was split into three bins of equivalent length and equal distance. Thus, the first group of "young participants" (n=35) showed a mean age of 26.2±4.51 , while the second group of "medium age" (n=38) had a mean age of 46.71±7.02, finally the third group of "elderly participants" (n=32) showed a mean age of 66.31±6.23.

We standardized participants ratings and we ran linear mixed models using the R package lme4 [8]. The following five factors as well as their interactions were entered as fixed effects: VR content, landscape type, participants' age, participants' gender and SPL. The random intercepts associated to subjects' and items' (i.e., VE) effects were entered as random effects.

We used the same model's structure for all the four measured dimensions (esthetics, will to spend time, exploration will, and relaxation).

Regarding the results presented in the next section, degrees of freedom (df) and p-values were approximated with the Satterthwaite's method [9].

III. PRELIMINARY RESULTS

A. Etheticism ratings

We found a main effect of the landscape type ($F(6, 10.04) = 3.36$, $p = 0.044$), regardless of the participants' socio-demographic factors. More specifically, participants preferred the esthetics of mountainous lands samples relative to the town images ($t(10) = 1.35$, $p = 0.0302$), whatever their age, gender and SPL. More interestingly, we found a significant interaction between the group of ages and the landscape kind ($F(12, 2468) = 9.75$, $p < 0.0001$), meaning that esthetics preferences for landscapes were influenced by participants' age. For instance, as presented in Figure 2, young participants were more inclined ($t(2309.4) = 5.914$, $p < 0.0001$) to find snowy lands esthetic than older participants, who preferred Buddhist temple images.

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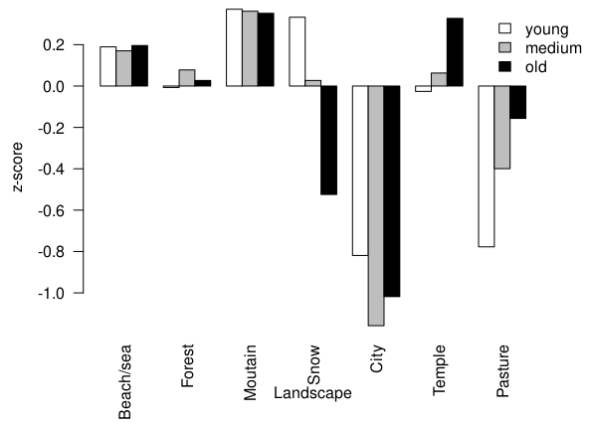

Figure 2. Esthetics ratings according to the group age.

B. *Exploration will ratings*

We found a main effect of the content type ($F(1, 10.04) = 8.448$, $p = 0.014$), regardless of the participants' socio-demographic factors. More specifically, participants' ratings concerning their exploration will were significantly higher for real 3D VE than for virtual 3D VE ($t(10) = -2.91$, $p = 0.016$), whatever their age, gender and SPL.

We also found a significant interaction between the group of ages and the landscape kind ($F(12, 2449) = 2.95$, $p = 0.0004$), meaning that landscapes' exploration preferences were influenced by participants' age, as presented in Figure 3.

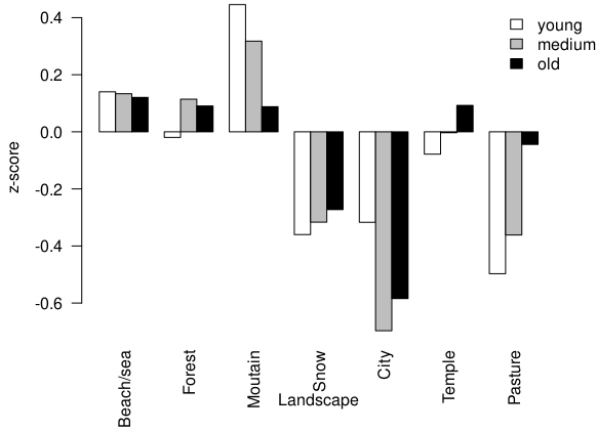

Figure 3. Exploration will ratings according to the group age.

Finally, we observed a significant interaction between participants' gender and the landscape kind ($F(6, 2449) = 2.23$, $p = 0.038$), meaning that landscapes' exploration preferences were influenced by participants' gender. However, due to Bonferroni corrections, our post-hoc analyses were not significant.

C. *Relaxation dimension ratings*

Interestingly, we observed a significant interaction between the group of ages and the landscape kind ($F(12, 2449) = 2.95$, $p = 0.0004$), meaning that the relaxing aspect of landscapes depended on participants' age, as presented in Figure 4. Notably, older participants found the snowy landscapes less relaxing than young participants ($t(2449)=-5.85$, $p < 0.0001$).

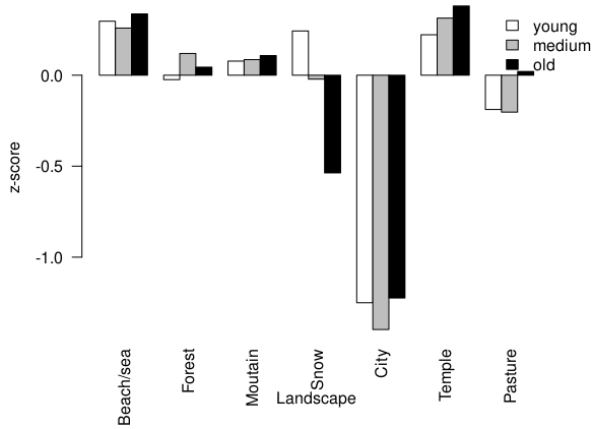

Figure 4. Relaxing dimension ratings according to the group age.

D. *Time dimension ratings*

Regarding the time participants were ready to spend within the different landscapes, we observed a significant interaction between the type of landscape and the group of ages ($F(12, 2449) = 4.08$, $p < 0.0001$), as presented in Figure 5. For instance, older participants preferred to spend less time in snowy landscapes than young participants ($t(2449) = -3.1$, $p = 0.002$), while young participants were even less inclined to spend some time in VE representing pastures than medium age ($t(2449) = 2.31$, $p = 0.021$) and older participants ($t(2449) = 3.14$, $p = 0.0017$).

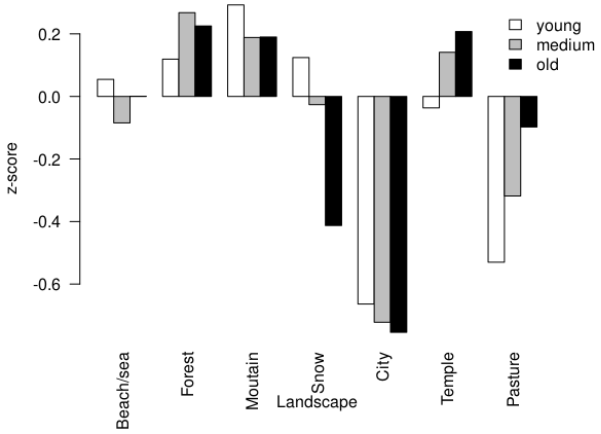

Figure 5. Ratings relative to the time participants are ready to spend in VE according to the group age.

IV. DISCUSSION

The present study aimed to explore whether specific socio-demographic variables could influence users' preferences regarding different types of Virtual Environments (VE). We found that participants' age had a significant impact on all the rated dimensions, relative to VE esthetics, exploration will, relaxing aspects and the will to spend time in the presented VE. Thus, these preliminary results could guide clinicians and developers to select the right VE while creating serious games or VR therapeutic contents, in order to design a task and a gameplay that would fit the patients' characteristics. For instance, a rehabilitation program designed for post-stroke patients could take into account the preferences that were expressed by the group of elderly participants. Such adaptation of gameplays and programs would necessarily increase the patients' adherence to the VR tools and consequently the efficiency of the clinical application.

However, we recognize that the generalization of the current results is limited by several aspects. First, even if the VE items were counted as random effects in our statistical models, the selected images could not be completely representative of a whole landscape category such as forest or sea. Second, to facilitate the survey spread, VE samples consisted in 2D images so that we can not guarantee that the exact same effects would be observed with 3D images displayed through VR headsets. Finally, for ethical and practical reasons, this survey was completed by healthy adults only.

V. CONCLUSION

Socio-demographic variables, and more specifically users' age, are linked to specific preferences in terms of Virtual Environments. Such preferences must be considered while designing VR programs and gameplays intended for clinical applications, to notably improve patients' adherence to treatments. Further studies are now required to specifically evaluate patients' adherence to treatments using VR headsets.

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