Article

Simulation & Gaming
2019, Vol. 50(2) 136–159

DOI: 10.1177/1046878119831420
journals.sagepub.com/home/sag
SAGE

Gaming in Virtual Reality: What Changes in Terms of Usability, Emotional Response and Sense of Presence Compared to Non-Immersive Video Games?

Federica Pallavicini[1], Alessandro Pepe[1], and Maria Eleonora Minissi[1]

Abstract

Background. **Virtual reality** can provide innovative gaming experiences for present and future game players. However, scientific knowledge is still limited about differences between **player's experience** in **video games** played in **immersive** modalities and games played in **non-immersive modalities** (i.e., on a desktop display).

Materials and method. Smash Hit was played by 24 young adults in immersive (virtual reality) and non-immersive (desktop) condition. Self-report questionnaires (VAS-A, VAS-HP, VAS-SP, SUS, SUS-II) and psycho-physiological measures (heart rate and skin conductance) were used to assess usability, emotional response and the reported sense of presence.

Results. No statistical differences emerged between the immersive and the non-immersive condition regarding usability and performance scores. The general linear model for repeated measures conducted on VAS-A, VAS-HP, VAS-SP scores for the virtual reality condition supported the idea that playing in the immersive display modality was associated with higher self-reported happiness and surprise; analysis on SUS-II revealed that the perceived sense of presence was higher in the virtual reality condition

[1]University of Milano Bicocca, Italy

Corresponding Author:
Federica Pallavicini, Department of Human Sciences for Education "Riccardo Massa", University of Milano Bicocca, Milan, Italy.
Email: federica.pallavicini@gmail.com

Discussion and conclusion. The proposed study provides evidence that (a) playing a video game in virtual reality was not more difficult than playing through a desktop display; (b) players showed a more intense emotional response, as assessed by self-report questionnaires and with psycho-physiological indexes (heart rate and skin conductance), after playing in virtual reality versus after playing through the desktop display; (c) the perceived sense of presence was found to be greater in virtual reality as opposed to the non-immersive condition.

Keywords

commercial virtual reality video games, gaming, simulation/gaming, usability, video games, virtual reality

Background

While in the past, most video game research has focused on understanding outcomes of playing games (e.g., Anderson, 2004; Ferguson, 2007), recently studies have shifted towards understanding how specific game features can impact game playing (Lee, Peng, & Park, 2009; Limperos, Waddell, Ivory, & Ivory, 2014). Technical features of video games, such as display sizes, viewing angles, fidelity and synchrony, as well as features more specifically related to graphic and visual content like resolution, cuts and movements, have been demonstrated to psychologically affect the players (Skalski & Whitbred, 2010). In particular, first with the introduction of motion controls, and now with the stereoscopic three-dimensional (3D) graphics that characterize the new era of video games (Limperos et al., 2014), players have seen an outstanding enhancement in gaming experience (Pallavicini et al., 2017; Rajae-Joordens, 2008; Tan, Leong, Shen, Dubravs, & Si, 2015). Another fundamental breakthrough in the gaming industry began in 2016, thanks to the entry of virtual reality into the videogame market. Just in 2017, over 7249 games developed for virtual reality were released on the Steam platform (Kain, 2017), while by June 2017, Sony Corp had already sold globally more than one million units of its PlayStation VR headset (Reuters, 2017).

A virtual reality video game offers an impressive and enjoyable gaming experience for the player, and it has characteristics that are deeply different from more traditional video games (Munafo, Diedrick, & Stoffregen, 2017; Pallavicini, Ferrari, Garcea, Zanacchi, & Mantovani, 2018; Pallavicini et al., 2017). In particular, what strongly distinguishes these video games from traditional ones is the level of immersion, what could be defined as a “quantifiable description of a technology, which includes the extent to which the computer displays are extensive, surrounding, inclusive, vivid and matching” (Slater, Linakis, Usoh, & Kooper, 1996). A second relevant difference lies in the use of the player’s body itself, as in virtual reality, it becomes the main interface for interacting with the virtual world (Heim et al., 2008). In a virtual reality video game, the player can interact with virtual content not only through a joypad or a keyboard, but also using head rotation, eye movements or specially designed controllers that respond to the position and movements of the player in a defined space. These characteristics lead to incomparable opportunities, combining engagement with amplified emotions while optimally excluding distractions and stress elements coming from the outer world (Parsons & Rizzo, 2008; Price, Mehta, Tone, & Anderson, 2011). Hence, virtual reality seems able to provide innovative gaming experiences for present and future game players (Heineman, 2016).

But how does a game experience change when played in virtual reality as opposed to the classic delivery through non-immersive screen display modalities? To date, scientific knowledge is still limited about differences between players' experience in video games played in immersive modalities and in games played in non-immersive modalities (i.e., on a desktop display) (e.g., Martel et al., 2015; Pallavicini et al., 2018; Pallavicini et al., 2017; Tan et al., 2015).

From Virtual Reality to Virtual Reality Video Games

By definition, virtual reality is an application that lets users navigate and interact in real-time with a three-dimensional computer-generated environment (Burdea & Coiffet, 2003; Pratt, Zyda, & Kelleher, 1995). Although many authors have defined virtual reality as essentially a technology (Heim, 1998), more recent approaches (Riva et al., 2007) propose a more complex vision, considering virtual reality as a human experience, and underlining how "the essence of virtual reality is the inclusive relationship between the participant and the virtual environment" (Fitzgerald & Riva, 2001).

Technologies can immerse their users in a virtual environment to different degrees: from a simple presentation on a computer screen (i.e., non-immersive or desktop virtual reality), to immersive systems, such as head-mounted displays (HMDs) like Oculus Rift (Oculus) or Google's Cardboard (Google), up to a room-size system, often referred to by the trade name of CAVE (C-Automatic Virtual Environment). The HMD is considered the unquestioned leader of immersive virtual reality display (Bowman, Gabbard, & Hix, 2002); it is a device containing two LCD screens, capable of tracking the user's head motions and position in order to portray the virtual world accordingly.

While virtual reality has already proven its potential in many application domains such as the military (Pallavicini, Argenton, Toniazzi, Aceti, & Mantovani, 2016; Rizzo et al., 2011), medicine (Dascal et al., 2017; Seymour et al., 2002), and neuropsychology (Pedroli, Serino, Cipresso, Pallavicini, & Riva, 2015; Saposnik et al., 2010), its potential in the context of gaming experience and added value in comparison with other technologies is still unexplored (Heineman, 2016; Liarokapis, 2006). Even though virtual reality has only recently risen to success among the public, the technology on which it is based cannot be considered new at all; indeed, it was born in research labs during the 1960s (Burdea & Coiffet, 2003). A first trial of commercialization of virtual reality video games happened during the nineties, with the release, in 1991, of the Sega VR headset for the Sega Mega Drive console (Sega), shortly followed by the release of the Virtual Boy (Nintendo). However, the release of these pioneering virtual reality gaming products for consoles became a commercial fiasco, and virtual reality popularity was eclipsed by the advent of the worldwide web and other more accessible computational devices, networks and software (e.g. personal computers, smartphones).

Nowadays, on the contrary, the situation is much different: an extreme variety of video games have been released into the market for several commercial virtual reality systems such as Gear VR (Oculus), HTC Vive (HTC and Valve), and PlayStation VR (Sony Interactive Media). By mid-2017, PlayStation VR had sold 1 million headsets and Samsung Gear VR over 5 million units. As for PC sales, Steam virtual reality game sales in the same period are approximately between 1,000 and 50,000, according to virtual reality developer, Tristan Parrish Moore, indicating an opening to the market of personal computers (Robertson, 2017). Hence, virtual reality video games represent one of the major novelties in the contemporary gaming world. At the same time, it still presents an open challenge for developers and game designers (Parkin, 2016).

Virtual Reality Video Games Usability Issues: Immersive Versus Non-Immersive Display

Virtual reality gaming presently represents a new and increasing portion of the entertainment industry, and its popularity is continuously growing among users (Pallavicini et al., 2017; Parker, 2016; Statista, 2018) it is different from other technological products: while a consumer may be forced to use a particular software to perform a specific task for lack of alternatives, a game is chosen and bought by the consumer because of its specific entertainment value (Cox, 2013; Shelley, 2001). To be entertaining and enjoyable, video games need to be able to motivate consumers to play for hours, and to persist over challenging tasks; this is only possible when the game provides a good user experience (Korhonen, Montola, & Arrasvuori, 2009; Kruijff, Marquardt, Trepkowski, Schild, & Hinkenjann, 2017). This last term includes all the relevant aspects for the subjective assessment of a product (Hassenzahl & Tractinsky, 2006), and refers to the individual perception of the interaction process between the player and the game (Ermi & Mäyrä, 2005; Takatalo, Häkkinen, Kaistinen, & Nyman, 2010).

A fundamental aspect of user experience in video games is usability, namely “the extent to which a product can be used, by specified users, to achieve specified goals with effectiveness, efficiency and satisfaction, in a specified context of use” (Malone, 1980, 1982; Nielsen, 1994). To assess usability, game metrics data (e.g., total time played, level reached, number of errors, etc.), represent important aspects of how players interact with a game (Gerling, Klauser, & Niesenhaus, 2011), paired with dedicated questionnaires and, occasionally, psycho-physiological signals (Bowman, Kruijff, LaViola, & Poupyrev, 2005; Nielsen, 1993).

The effects of immersive (i.e., HMD or CAVE) versus non-immersive (i.e., desktop) display modalities on usability have been investigated by numerous studies involving a variety of tasks; for instance, high immersive displays have been shown to have a positive effect on performance in a visual search task, which is one of the most investigated tasks in literature (Pausch, Proffitt, & Williams, 1997). Concerning data visualization tasks, even in this case, a better performance has been reported using immersive versus non-immersive systems (Arms, Cook, & Cruz-Neira, 1999). Less consistent results have been observed for navigation tasks: although some studies have highlighted an increased performance while using immersive systems (e.g., Aoki, Oman, Buckland, &

Natapoff, 2008; Elmqvist, Tudoreanu, & Tsigas, 2008), other researchers reported opposite results, showing a better performance with non-immersive systems (e.g., Sousa Santos et al., 2009; Swindells et al., 2004; Waller, Hunt, & Knapp, 1998).

Regarding the specific case of virtual reality video games, a product that entered the market quite recently, the number of studies so far that have been directed towards comparing the usability of this kind of video game with non-immersive modalities is still limited (see supplementary file). Non-commercial virtual reality video games, developed ad hoc by researchers, have demonstrated a better performance and a higher usability in non-immersive systems than in immersive one (Brade et al., 2017; Sousa Santos et al., 2009). As regards commercial virtual reality video games, whereas some studies have reported greater performance and usability in non-immersive systems compared to immersive ones (Martel et al., 2015; Tan et al., 2015), other research has not showed significant difference between immersive and non-immersive systems (Pallavicini et al., 2018; Pallavicini et al., 2017; Shelstad, Smith, & Chaparro, 2017). For instance, even though the immersive condition seemed to reduce performance in the first person shooter (FPS) game, *Team Fortress 2* (Valve Software), players reported preferring this system to the desktop condition (Martel et al., 2015). Analogous results have been obtained in an another study, in which playing another FPS game - *Half Life 2* (Valve Software) – in an immersive modality resulted in a more intense gaming experience, both at a psychological and physiological level, compared to the desktop condition, even though all participants reported being comparatively more in control of the game in the non-immersive condition (Tan et al., 2015). However, a more recent study did not show differences in usability and player performance between a strategy video game – *Defense Grid* and *Defense Grid 2: Enhanced VR Edition* (Hidden Path Entertainment) – played through either a commercial HMD or a computer monitor (Shelstad et al., 2017). Analogous results emerged from two recently conducted studies, which reported no differences in usability and game performance between a FPS game – *Smash Hit* (Mediocre AB) – as well as a commercial horror video game – *Resident Evil 7: Biohazard* (Capcom) – played in an immersive modality versus a non-immersive screen one (Pallavicini et al., 2018; Pallavicini et al., 2017).

Emotional Responses and Sense of Presence in Immersive and Non-Immersive Video Games

Virtual reality systems may completely alter the emotional experiences of gamers, as well as significantly enhance the users' sense of being in the game. Presence, defined as "the perceptual illusion that a mediated environment is not mediated" (Lombard & Ditton, 1997), or as a "cognitive state that results from information processing of stimuli in the environment from various senses (Slater & Wilbur, 1997), is of central importance in connection with the design and development of enjoyable virtual reality video games. Games (Ryan, Rigby, & Przybylski, 2006; Tamborini & Bowman, 2010) as well as virtual reality content (Lombard & Ditton, 1997) provide a strong sense of presence; in fact, it would be expected to be highly entertaining. In particular, video games eliciting a higher sense of presence seem to be capable of enhancing not only in-game performance, but also of increasing attention levels towards stimuli that are perceived as belonging to the real world and consequently cause a greater psychological and physiological arousal (Ravaja et al., 2004; Tamborini & Bowman, 2010).

The perceived sense of presence and emotional response in virtual environments have been studied mainly in relation to system factors linked to the level of display immersion. With few exceptions (e.g., Baños et al., 2008; Freeman et al., 2005) data show that more advanced and sophisticated virtual reality devices providing a higher sense of immersion cause an increase in the sense of presence (e.g., Estupiñán, Rebelo, Noriega, Ferreira, & Duarte, 2014; Kim, Rosenthal, Zielinski, & Brady, 2014; MacQuarrie & Steed, 2017). For instance, reactivity to stressful virtual environments was examined in three representative virtual reality systems that differed in terms of immersion, from desktop to high-end fully immersive systems (CAVE); the fully immersive system induced the highest sense of presence and positive emotion, at both a physiological level and according to self-reported data (Kim et al., 2014).

Concerning the specific case of virtual reality video games, a higher intensity in terms of perceived emotions and sense of presence has been reported in comparison with non-immersive modalities. In particular, the display type played a significant role in engagement and presence in a serious game-based training for aviation safety procedures: the game played using the HMD led to a significant increase in self-reported engagement with respect to the monitor display condition (Buttussi & Chittaro, 2018). Regarding commercial virtual video games, players reported a more intense experience while playing a FPS game in an immersive modality through an HMD compared to the same game played on a monitor (Tan et al., 2015). Analogous results have been observed in a recent series of studies, in which both a survival horror game and an FPS game induced a stronger emotional response at both a psycho-physiological level and through self-reported questionnaires when played in immersive modalities compared to non-immersive ones (Pallavicini et al., 2018; Pallavicini et al., 2017).

Material and Methods

Research Objective

Within the context described above, this within-subjects study followed a pretest/posttest design, with the aim to explore differences in terms of usability, emotional response (measured both through psychological and psycho-physiological data), and experienced sense of presence, in a video game played by healthy adults through an immersive (i.e., virtual reality) compared to a non-immersive (i.e., desktop) display modality.

Hypotheses

The main hypotheses of this study were:

- H1. No differences in performance and usability between virtual reality compared to the desktop condition: no differences in usability, as perceived by players and in game performance, will be found between the two conditions of the game (virtual reality compared to non-immersive display).

HO. Differences in performance and usability between virtual reality compared to the desktop condition.

- H2. The video game played in virtual reality will elicit a more intense emotional response than the non-immersive display modality: in particular, differences will be found at a psychological and physiological level.

HO. The video game played in virtual reality will not elicit a more intense emotional response than the non-immersive display modality.

- H3. Sense of presence in the immersive condition will be more intense compared to the non-immersive condition.

HO. Sense of presence in the immersive condition will be less intense compared to the non-immersive condition.

Participants

Twenty-four participants were recruited from students and personnel of the University of Milano-Bicocca and of other universities in Milan. No credits or economic rewards were provided during the research. In order to be included in the study, individuals had to meet the following criteria: (1) age between 18 and 35 years old; (2) no major medical disorders (heart disease or high blood pressure, neurological disorders, epilepsy); (3) not left-handed; (4) no presence of pharmacotherapy (psychoactive drugs, anti-hypertensive, anti-depressants); (5) no significant visual impairment (all with normal or corrected-to-normal visual acuity). Left-handers were not included in the study as it was reported in the literature that they often outperform right-handers at fast or difficult tasks involving a large amount of information or stimuli, such as playing fast-paced video games (Cherbuin & Brinkman, 2006). Before participating, all participants were provided with written information about the study and were required to give written consent to be included. The study received ethical approval by the Ethical Committee of the University of Milano-Bicocca.

Psychological Assessment

At the beginning of the experimental session, the following self-report questionnaire was given to participants:

- *Demographics*: participants were asked to indicate their gender ("female or male") their age, whether they had previous experience with virtual reality ("yes" or "no"), and the mean hours spent gaming per week.

In addition, to assess the self-reported indexes concerning usability, perceived emotional state, and sense of presence, the following questionnaires were used:

- *System Usability Score (SUS)* (Sauro, 2011): a reliable tool for measuring usability: it consists of a 10-item questionnaire with five response options for respondents (from "strongly agree" to "strongly disagree") concerning the ease of use or possible difficulty encountered by participants while using the system;
- *Visual Analogue Scale* (Aitken, 1969): a horizontal line, 100 mm in length, anchored by word descriptors at each end; participants mark on the line the point that they feel visually represents their perception of their current level of Anxiety (VAS-A), Happiness (VAS-HP), and Surprise (VAS-SP);
- *Slater-Usoh-Steed Presence Questionnaire (SUS-II)* (Slater, Usoh, & Steed, 1994): a custom questionnaire concerning the perceived sense of presence, divided into 6 items on a 7-point Likert scale; a single total score is obtained.

Psycho-Physiological Assessment

At the start and during the experimental sessions, the following psycho-physiological data were recorded to assess the arousal response of the players:

- *Heart Rate (HR)*: HR mean value, measured in beats per minute (BMP), was calculated through R-to-R peak detection, as an index of arousal response (Kleiger, Stein, & Bigger, 2005; Shaffer & Ginsberg, 2017); in addition, the sympathovagal ratio (LF/HF) was estimated: a low LF/HF ratio reflects parasympathetic dominance (e.g., tend-and-befriend behaviors), while a high LF/HF ratio indicates sympathetic dominance, which occurs during fight-or-flight behaviors or parasympathetic withdrawal (Shaffer, McCraty, & Zerr, 2014);
- *Skin Conductance Response (SCR)*: a physiological measure extensively used for assessing the arousal response (Boucsein, 2012; Christopoulos, Uy, & Yap, 2016).

The psycho-physiological signals were acquired using a ProComp Infiniti device from Thought Technology, including Biograph Infiniti 5.0.2 software to record and export all raw signals. Every signal was exported at a 256 Hz sampling rate.

Video Game

The videogame tested in the study was *Smash Hit*, a mobile FPS game developed in 2014 by Mediocre AB and presented in an immersive version (i.e., *Smash Hit VR)* in September 2015, at the same time as the release of the Gear VR (Oculus) HMD. This title was selected since during the time of the design and execution of the experiment (i.e., between January and March 2016) it was the only off-the-shelf video game that included a version in virtual reality and a game version on the desktop with the same features. In the following months and years, other games were developed both in non-immersive and immersive versions, such as *Resident Evil 7: Biohazard VR* (Capcom), which can be played on the PS4 (Sony Corp.) desktop or with the PlayStation VR (Sony Corp) HMD, and *Doom VFR* (Bethesda Softworks), also compatible with the PS4 virtual reality systems or even with the HTC Vive (Valve) headset.

In *Smash Hit* on mobile, the player taps the screen to unleash a ball that arcs through space in front of them. The aim is to hit crystals that shatter like glass. The players start with an inventory of metallic spheres, and to proceed in the game they must hit pyramids and polyhedral objects to obtain more spheres and continue shooting the obstacles. If the players miss the target, they will lose one sphere. The game is over when the players have no more spheres to shoot. In *Smash Hit VR*, the game is the same except the players choose where to aim the ball with their gaze: a ball is launched by pressing the touchpad on the Gear VR headset. In this study, the dependent variables used to evaluate the video game performance were: (a) the total time played, and (b) the last level reached by the players.

Experimental Design

A within-subjects design was used to compare the usability, the emotional response (both in terms of arousal and self-reported emotions), and the perceived sense of presence in the two experimental conditions. Specifically, the study compared:

- *Virtual Reality (Immersive) Condition*: participants were seated at a desk and were asked to wear a Gear VR (Oculus), connected to a Samsung S6 (Samsung) smartphone; after a brief training about the HDM's controls, participants played the game until they lost;
- *Desktop (Non-immersive) Condition*: individuals were seated at a desk on which an Ipad2 (Apple) was positioned; participants were asked to play the game until they lost.

The players were asked to play in a sitting position as it is the classic mode of use of *Smash Hit*, both in the immersive and in the non-immersive version. This game, in fact, is also typically played while sitting in the virtual reality modality: it requires the use of only the movement of the head, unlike other video games developed for more complex virtual reality systems (e.g., HTC Vive or PlayStation VR), such as *Beat Saber* (Beat Games), or *Rick and Morty: Virtual Rick-ality* (Owlchemy Labs). The order of presentation of each condition (i.e., virtual reality and desktop) was counterbalanced for each participant following a previously established randomization schema; in particular, players were assigned to *Group 1* (i.e., participants were asked to play the desktop version of the game first and then the virtual reality version) or *Group 2* (i.e., individuals played first in virtual reality and then used the desktop display modality).

Procedures

At the start of the experimental session, participants were asked to complete the demographic questionnaire, and the VAS-A, VAS-HP, VAS-SP. Participants were then connected to biosensors that recorded their HR and SCR. A baseline measure of these signals was registered for 3 minutes in rest condition, with eyes opened. Once the psycho-physiological baseline was recorded, the experimental session started, beginning with the assigned condition following the previously established randomization schema. Psycho-physiological signals were recorded until the participants completed the game. After completing each gameplay modality, participants answered the following self-reported questionnaires: VAS-A, VAS-HP, VAS-SP, SUS, and the SUS-II. The complete experience was about one hour long.

Results

Data Analytics Strategy

First, common procedures of data cleaning were conducted [i.e., missing value analyses, uni- and multivariate outlier analysis (Mahalanobi's distance was set to $p < .001$)]. The data revealed no presence of either type of outliers and, consequently, no cases were deleted from the study. In a similar fashion, no missing values were found. Due to the multivariate nature of the data strategy, data were then explored to check for main required statistical assumptions. In doing so, main descriptive statistics were computed (including both kurtosis and skewness measures of distribution). All measures adopted in the research design reported values within the range –1 and + 1 (George & Mallery, 2003), and suggested a normal distribution of data. Finally, chi-square and t-test for independent sample were used to explore spurious associations between demographic statistics and the research condition.

For statistical analysis, in relation to H1, multivariate analysis of covariance (MANCOVA) was set to evaluate the effects of the experimental condition in relation to performance scores. The assessment of H2 was conducted by using a generalized linear model (GLM) for repeated measures. In this regard, statistical differences were evaluated between baseline measures of psychological (i.e, self-reported emotional state) and psycho-physiological (i.e., HR and SCR) responses, and the same measures gathered after the experience. Normality of residual distribution was tested when necessary. Finally, H3 was tested by multivariate analysis of covariance for repeated measures with paired observation. The test was used here to establish whether the mean difference between the two sets of observations (i.e., sense of presence in virtual reality versus desktop condition) was statistically significant. The magnitude of effect sizes was reported for all analyses. In line with the size of the sample (and to offset for type I errors), the threshold for statistical significance (p) was set to .025 (Bonferroni correction; Bland & Altman, 1995).

Demographics and Correlational Analyses

The presence of spurious associations among demographic variables and experimental groups was evaluated by using a chi-square test of independence, and t-test analyses for independent samples (see Table 1). Results highlighted that no statistically significant associations were found among considered variables in the two groups.

Table 1. Chi-Square Test of Independence on Gender, and Previous Experience With Virtual Reality in the Two Experimental Groups (Note: Group 1 = Desktop-VR, Group 2 = VR-Desktop).

Variables		Group 1	Group 2	Chi-square (df)	p
Gender	Female	5	4	.178	.672
	Male	6	8		
Previous experience with VR	Yes	3	5	.750	.380
	No	9	7		

Table 2. Mean Comparison on Age, Hours Spent Gaming per Week, and Preference for Shooter Games (Group 1, n=12; Group 2, n=12).

Variables		M	SD	t (df)	p
Age	Group 1	23.01	2.41	1.67 (22)	.108
	Group 2	25.25	3.98		
Hours per week in gaming	Group 1	15.01	12.99	.474 (22)	.640
	Group 2	12.75	10.08		
Skin conductance response	Group 1	6.85	3.19	.594 (22)	.559
	Group 2	6.03	3.52		
Heart Rate BPM	Group 1	83.7	19.3	.258 (22)	.799
	Group 2	82	12.4		
LF/HF Ratio	Group 1	2.28	1.47	.530 (22)	.601
	Group 2	2.83	2.44		
VAS-A	Group 1	24.1	17.1	1.619 (22)	.12
	Group 2	13.3	15.5		
VAS-HP	Group 1	74.5	19	.401 (22)	.692
	Group 2	71.6	16.5		
VAS-SP	Group 1	45.4	29.5	.259 (22)	.798
	Group 2	42.1	33.4		

With regard to other participants' characteristics, baseline measures did not report statistically significant differences between the two groups, meaning that variables scores were homogeneous (see Table 2).

Hypothesis 1

Results of MANCOVA showed no significant difference in performance scores between virtual reality and desktop conditions; indeed, the model [$F(4,19)= 1.82$, $p= .191$, $\eta2= .077$] revealed that, regardless of the display modality condition, performance was similar both in terms of total time played [$F(1,23)= 1.82$, $p= .191$, $\eta2= .077$] (see Figure 1 for mean value comparison), and in the final level reached by players [$F(1,23)= 2.77$, $p= .110$, $\eta2= .112$]. With regard to usability, the model was

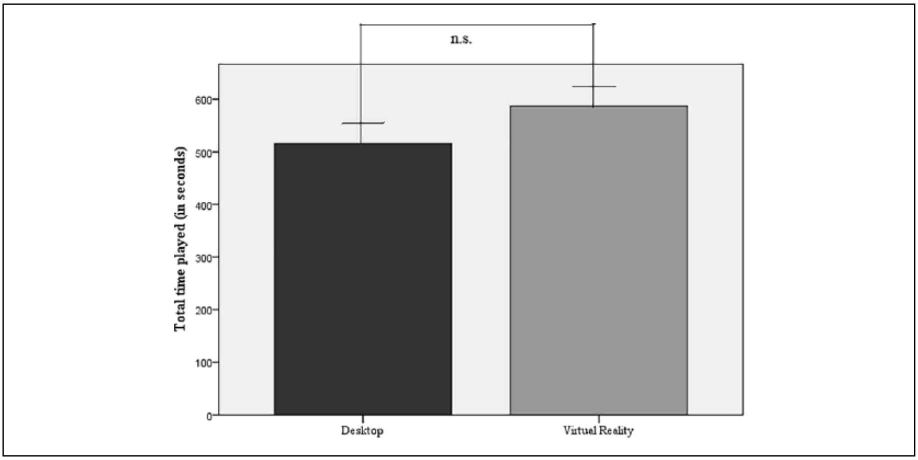

Figure 1. Between-condition mean scores comparison: Effect of display condition on the total time played.

statistically significant [F(2,21)= 8.90, p= .002], suggesting that the effect of display condition (virtual reality versus desktop) was medium in size (η2= .459), regardless of the display condition order.

Hypothesis 2

In relation to H2, GLM for repeated measures was used to test whether and to what extent the pre-post differences in psycho-physiological (HR and SCR) and self-reported (VAS-A, VAS-HP, VAS-SP) scores on emotional response were related to the experience, taking into account the effect of display condition.

Concerning the self-reported scores of emotional states, GLM for repeated measures conducted on VAS-A, VAS-HP, VAS-SP scores for the virtual reality condition supported the idea that playing in the immersive display modality was associated with higher self-reported happiness and surprise, regardless of the display condition order. Furthermore, the difference between baseline and post-experience measures was medium in size in correspondence to VAS-SP (η2= .235) and VAS-HP (η2= .277). With regard to the experience with the desktop display condition, the multivariate models on VAS-A, VAS-HP, VAS-SP scores were mostly not statistically significant (see Table 3), and effect sizes were generally trivial.

With regard to psycho-physiological indexes, in relation to the experience in the desktop condition, the multivariate models were generally not statistically significant (see Table 4) and effect sizes were mostly trivial. Therefore, the experience with the non-immersive condition did not elicit a strong emotional arousal. The only indicator with a statistically significant difference between the baseline and the post-measure was skin conductance (F= 73.25, p< .0001), which showed a large effect size (η2= .728). A different picture emerged from the analysis of psycho-physiological data in

Table 3. Summary of Self-Reported Emotion Scores in Relation to Differences Between Desktop and Virtual Reality Display Conditions (Note: η2=effect size, n.s.= not statistically significant).

Variables		Effects	F	p	η2
VAS-A	Desktop	Time	3.42	n.s	.135
		Group	0.296	n.s.	.013
VAS-HP	Desktop	Time	1.12	n.s.	.490
		Group	2.27	n.s.	.940
VAS-SP	Desktop	Time	0.83	n.s.	.370
		Group	1.55	n.s.	.660
VAS-A	Virtual reality	Time	.249	n.s.	.011
		Group	.359	n.s.	.016
VAS-HP	Virtual reality	Time	6.74	.016*	.235
		Group	3.12	n.s.	.124
VAS-SP	Virtual reality	Time	8.43	.008*	.277
		Group	2.49	n.s.	.102

Table 4. Summary of Physiological Measures in Relation to Differences Between Desktop and Virtual Reality Display Conditions (Note: η2=effect size, n.s.= not statistically significant).

Variables		Effects	F	p	η2
Skin conductance response	Desktop	Time	59.02	.001*	.728
		Group	2.35	n.s.	.097
Heart Rate BPM	Desktop	Time	2.62	n.s.	.107
		Group	1.40	n.s.	.060
LF/HF Ratio	Desktop	Time	3.58	n.s.	.140
		Group	.021	n.s.	.001
Skin conductance response	Virtual reality	Time	73.25	.001*	.769
		Group	.861	.363	.038
Heart Rate BPM	Virtual reality	Time	8.11	.009*	.269
		Group	0.494	.490	.022
LF/HF Ratio	Virtual reality	Time	6.76	.016*	.235
		Group	0.492	.490	.022

relation to the virtual reality condition. In this case, all considered measures reported statistically significant increases due to playing in virtual reality, regardless of the display condition order; in particular, analysis of effect size revealed values ranging from low-medium (HR BPM mean AND LF/HF) to large (SCR).

Hypothesis 3

In relation to H3, the GLM analysis supported the statistical significance of the model: ($F(1,22)= 47.51$, $p< .001$) and suggested that the game played in virtual reality was

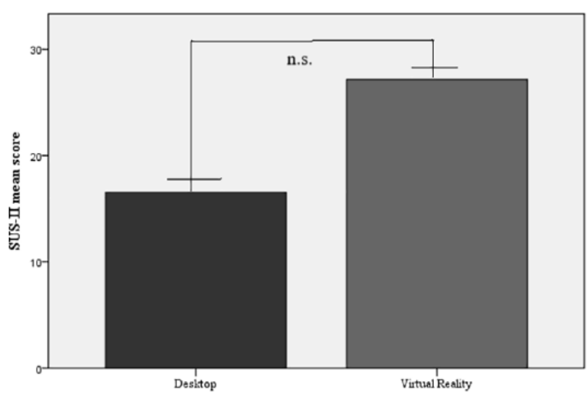

Figure 2. Between-condition mean scores comparison: Effect of display condition on SUS-II scores.

associated with higher levels of participants' sense of presence (see Figure 2). The observed effect size was large ($\eta2=.683$), and it adequately summarized differences between raw scores: mean of SUS-II scores in the virtual reality condition was 27.1 (SD= 6.61) whereas in the desktop condition, it was 16.42 (SD=6.05). Moreover, the difference in perceived sense of presence between the two display conditions was statistically significant, regardless of the display condition order ($F(1,22)= 1.03$, $p= .321$, $\eta2= .045$). All in all, the results provided full support for H3.

Discussion

Starting with the first main hypothesis of this study, results confirmed that playing the FPS game in virtual reality was not more complex than the desktop gameplay. In particular, participants' performance, quantified through the time spent playing before the game was over and the final level reached by the player, was not statistically different between the immersive and the non-immersive versions of the video game. Furthermore, results showed no significant differences in usability reported by players between the video game played in virtual reality or on the desktop display. These findings seem similar to what has been observed in recent previous studies: in particular, in an exploratory study, no differences in game performance and usability were found between the immersive and the non-immersive version of the same off-the-shelf game used in this study, *Smash Hit* (Mediocre AB) (Pallavicini et al., 2017). Similarly, no differences emerged testing a horror videogame, *Resident Evil 7: Biohazard* (Capcom), played though an immersive and a non-immersive system (Pallavicini et al., 2018).

Nonetheless, results of this study seem to be discordant with other previous literature, according to which better performances were obtained in other commercial FPS video games when using desktop displays (Martel et al., 2015; Tan et al., 2015). It is worth noting that such non-homogenous results may be due to a variety of reasons: one possible explanation could be the different type of HMD adopted. In this study, as well as in a few others (Pallavicini et al., 2018; Pallavicini et al., 2017), recently released commercial HMDs have been used [i.e., Samsung Gear VR (Oculus), and PlayStation VR (Sony Interactive Media)]. In contrast, in the studies that observed a better performance and usability in non-immersive compared to immersive display modalities (Martel et al., 2015; Tan et al., 2015), a much less technologically advanced HMD was adopted [i.e., Oculus Rift Developer Kit 1 (Oculus)]. Thus, it could be hypothesized that with the rapid progress in the technical level of HMDs that has been observed in these last few years, the differences in terms of performance and usability between immersive and non-immersive systems have strongly decreased compared to what has been observed in the past (e.g., Brade et al., 2017; Sousa Santos et al., 2009; Swindells et al., 2004). However, studies that have so far adopted advanced and commercial HMDs are few in number, and future research is needed.

Furthermore, as expected on the basis of the second main hypothesis of this study, results showed that the video game experienced through virtual reality was associated with stronger emotional responses when compared to the video game played on the desktop display. In particular, players experienced an increase in self-reported happiness and surprise after playing the game in virtual reality, but not after the desktop gameplay. Regarding psycho-physiological responses, a significant increase in the SCR was observed after both the immersive and the non-immersive version of the game, while at the level of HR (i.e., BPM and LF/HF) an increase emerged only after the virtual reality gameplay.

Results of this study appear to be consistent with previous literature (e.g., Pallavicini et al., 2018; Shelstad et al., 2017; Tan et al., 2015), about a greater increase of positive emotions, such as happiness and surprise, after virtual reality game experiences compared to non-immersive ones. Moreover, what emerged with respect to physiological responses (i.e., SCR), suggests, also in accordance with what was observed in previous studies (Pallavicini et al., 2018; Pallavicini et al., 2017), that the video game, regardless of the display on which it is played, is able to elicit in the player a response of emotional arousal. In this research, interestingly, only after the experience in virtual reality was a significant increase observed even in the cardiac parameters, suggesting that the arousal response was more intense after the immersive version of the game.

The fact that at the emotional level, both in self-report questionnaires and in psycho-physiological responses, a more intense response was observed after the game in virtual reality compared to the desktop gameplay could be due to several reasons. First of all, several previous studies have shown that virtual reality is an effective tool to evoke positive emotions (e.g., Baños et al., 2014; Felnhofer et al., 2015), with generally greater effectiveness than traditional non-immersive media (i.e., audio, video; e.g., Chirico et al., 2017; Estupiñán et al., 2014; Higuera-Trujillo, López-Tarruella Maldonado, & Llinares Millán, 2017). In addition, since virtual reality is a novel experience for most people, especially because it was not widely commercialized to the general public until 2016 (Cellan-Jones, 2016; Morris, 2015), this technology can elicit the so-called "wow-effect", commonly defined as a temporary state of awe triggered in the individual when surprised by something wonderful (Reunanen, Penttinen, & Borgmeier, 2017). This unique hedonic feature of virtual reality gaming could be particularly relevant if confirmed by future studies: presently, immersive video games represent the highest point of the gaming experience, as players are involved through physical, emotive and cognitive stimulation, thus becoming the protagonists of their own game (Hemenover & Bowman, 2018). Virtual reality represents a tool with enormous potential in the gaming industry, offering the possibility to create unforgettable video games, leaving an emotional connection and engaging players with innovative ideas. Doing this right means connecting the player on a much deeper level, contributing to video games' popularity and motivational pull (Ryan et al., 2006; Tamborini & Bowman, 2010). Furthermore, as suggested also by recent studies (Lin, 2017; Pallavicini et al., 2018), the strong emotional feature of virtual reality could be an effective tool not only for entertainment purposes, but also for clinical applications, such as the assessment and training of individuals' emotional abilities (e.g., stress management, emotional regulation, etc.).

Finally, with regard to the third main hypothesis of this study (i.e., sense of presence in the immersive condition will be more intense compared to the non-immersive condition), as hypothesized, players reported a statistically higher sense of presence after the virtual reality game compared to the level of presence perceived after the desktop gameplay. Such results corroborate what has been reported by previous literature (Brade et al., 2017; Pallavicini et al., 2018) about the strong potential of virtual reality to enhance the sense of presence in gamers, one of the most desired aspects for making more engaging video games (Ravaja et al., 2004; Weibel & Wissmath, 2011). Thanks to the virtual reality technology, people have the possibility, unlike in the traditional non-immersive gaming experience, "to be in the game" (Lombard & Ditton, 1997; Westerman & Skalski, 2010), and the games have a strong potential to alter emotional experiences of the players. Although this feature has potentially positive effects on one side, since enhanced immersive experiences likely evoke enhanced emotions, including enjoyment and surprise (e.g., Egan et al., 2016; Pallavicini et al., 2018), it also raises a problem regarding some genres of video games played in virtual reality. In particular, violent FPS or horror video games may have too intense emotional effects on the players (Wilson & McGill, in press), and future research needs to deeply investigate this sensitive aspect.

Limitations and Suggestions for Further Future Research

Although the results of this study could be interesting, especially in the video game research field, this study has some limitations that could affected the generalizability of the findings.

First of all, it is important to note that the obtained results refer to a specific virtual reality system in use [i.e., Samsung Gear VR (Oculus)]. It would be interesting to replicate this study using other commercial virtual reality systems with different characteristics in terms of immersion and possible interactions with the game, including for instance, other off-the-shelf virtual reality systems, such as HTC Vive (Vive). Moreover, results emerging from this study refer to a specific video game, in this case *Smash Hit*, a FPS game developed by Mediocre AB. It would be interesting to study other genres of video games played in virtual reality (e.g., driving-racing games, exergames), since scientific knowledge is still very limited.

Secondly, this study has evaluated only some aspects of the virtual experience and their effects on the player. Such choice was dictated by the necessity to limit the length of the questionnaires, with the objective of not tampering with the user experience; however, it may have limited the focus of the study. For instance, it would be interesting for future studies to include an assessment of the level of cybersickness perceived by the player during the gaming experience, because of its possible negative impact on user experience (e.g., Lin, Chen, Cheng, & Sun, 2015; Merhi, Faugloire, Flanagan, & Stoffregen, 2007). Moreover, it would be interesting to deeply investigate the impact of graphic aspects of the video game played in virtual reality as perceived by the users, particularly concerning the effects of colors, contrasts, shapes and level of graphic realism on self-reported emotions and sense of presence (e.g., Naz, Kopper, McMahan, & Nadin, 2017).

Finally, it is important to underline the small sample size and the specificity of the included sample (i.e., young adults, who played often per week and had a medium knowledge of virtual reality systems). Future studies should be conducted on a heterogeneous sample in terms of age, gender, and level of interest in technology and virtual reality, and means of randomization should be introduced in the recruiting process in order to avoid bias (Lachlan & Krcmar, 2011). Another relevant factor may be the weekly time spent playing, as responses to immersive and non-immersive setups vary according to the frequency of gameplay, with an increased arousal for the immersive condition among frequent players (Limperos et al., 2014).

Conclusion

One of the most important points in time in the evolution of contemporary gaming is certainly 2016, the year in which there was an actual breakthrough in the gaming business thanks to the entry to the mass market of virtual reality video games, following the mass diffusion of brands such as PlayStation VR (Sony Interactive Media), Oculus Rift (Oculus) and HTC Vive (Vive). A virtual reality video game, while representing an equally effective and enjoyable gaming experience for the player, has deeply different characteristics compared to a traditional computer game (Parkin, 2016). Thanks to its unique characteristics, virtual reality leads to incomparable opportunities of engagement for either regular players or naive users, opening the doors to much more than entertainment (e.g., Lin, 2017; Pallavicini et al., 2018). Within this context, the proposed study provides evidence that (a) playing a video game in virtual reality was not more difficult than playing through a desktop display; (b) players showed a more intense emotional response, as assessed with self-report questionnaire and with psycho-physiological indexes (heart rate and skin conductance), after playing in virtual reality versus after playing through the desktop display; (c) the perceived sense of presence was greater in virtual reality as opposed to in the non-immersive condition.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The authors disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This work was supported by the "Virtual Video Games" project, which is a part of the research plan of the first author, a post-doctoral research fellow at the University of Milano-Bicocca (Italy). The authors would like to thank our PhD Ambra Ferrari and post-graduate students Giacomo Garcea, Andrea Zanacchi and Andrea Zini for helping with data acquisition.

Supplemental Material

Supplemental material for this article is available online.

References

Aitken, R. C. (1969). Measurement of feelings using visual analogue scales. *Proceedings of the Royal Society of Medicine*, *62*(10), 989-993.

Anderson, C. A. (2004). An update on the effects of playing violent video games. *Journal of Adolescence*, *27*(1), 113-122.

Aoki, H., Oman, C. M., Buckland, D. A., & Natapoff, A. (2008). Desktop-VR system for preflight 3D navigation training. *Acta Astronautica*, *63*(7-10), 841-847.

Arms, L., Cook, D., & Cruz-Neira, C. (1999). The benefits of statistical visualization in an immersive environment. In L. Rosenblum, P. Astheimer, & D. Teichmann (Eds.), *Proceedings IEEE Virtual Reality* (Cat. No. 99CB36316) (pp. 88-95). Los Alamitos, CA: IEEE Computer Society.

Baños, R. M., Botella, C., Rubió, I., Quero, S., García-Palacios, A., & Alcañiz, M. (2008). Presence and emotions in virtual environments: The influence of stereoscopy. *Cyberpsychology & Behavior*, *11*(1), 1-8.

Baños, R. M., Etchemendy, E., Farfallini, L., García-Palacios, A., Quero, S., & Botella, C. (2014). EARTH of well-being system: A pilot study of an Information and Communication Technology-based positive psychology intervention. *The Journal of Positive Psychology*, *9*(6), 482-488.

Bland, J. M., & Altman, D. G. (1995). Comparing methods of measurement: Why plotting difference against standard method is misleading. *The Lancet (London, England)*, *346*(8982), 1085-1087.

Boucsein, W. (2012). *Electrodermal activity*. Boston, MA: Springer US.

Bowman, D. A., Gabbard, J. L., & Hix, D. (2002). A survey of usability evaluation in virtual environments: Classification and comparison of methods. *Presence: Teleoperators and Virtual Environments*, *11*, 404-424.

Bowman, D. A., Kruijff, E., LaViola, J. J., & Poupyrev, I. (2005). *3D user interfaces: Theory and practice*. Boston, MA: Addison-Wesley.

Brade, J., Lorenz, M., Busch, M., Hammer, N., Tscheligi, M., & Klimant, P. (2017). Being there again—Presence in real and virtual environments and its relation to usability and user experience using a mobile navigation task. *International Journal of Human-Computer Studies*, *101*, 76-87.

Burdea, G., & Coiffet, P. (2003). Virtual reality technology. *Presence: Teleoperators and Virtual Environments*, *12*(6), 663-664.

Buttussi, F., & Chittaro, L. (2018). Effects of different types of virtual reality display on presence and learning in a safety training scenario. *IEEE Transactions on Visualization and Computer Graphics*, *24*(2), 1063-1076.

Cellan-Jones, R. (2016). *2016: The year when VR goes from virtual to reality*. Retrieved from https://www.bbc.com/news/technology-35205783

Cherbuin, N., & Brinkman, C. (2006). Hemispheric interactions are different in lefthanded individuals. *Neuropsychology*, *20*, 700-707.

Chirico, A., Cipresso, P., Yaden, D. B., Biassoni, F., Riva, G., & Gaggioli, A. (2017). Effectiveness of immersive videos in inducing awe: An experimental study. *Scientific Reports*, *7*(1), Article 1218.

Christopoulos, G. I., Uy, M. A., & Yap, W. J. (2016). The body and the brain. *Organizational Research Methods*, *27*(1), 1-27.

Cox, J. (2013). What makes a blockbuster video game? An empirical analysis of US sales data. *Managerial and Decision Economics*, *35*(3), 189-198.

Dascal, J., Reid, M., IsHak, W. W., Spiegel, B., Recacho, J., Rosen, B., & Danovitch, I. (2017). Virtual reality and medical inpatients: A systematic review of randomized, controlled trials. *Innovations in Clinical Neuroscience*, *14*(1-2), 14-21.

Egan, D., Brennan, S., Barrett, J., Qiao, Y., Timmerer, C., & Murray, N. (2016). An evaluation of Heart Rate and ElectroDermal Activity as an objective QoE evaluation method for immersive virtual reality environments. In *Eighth International Conference on Quality of Multimedia Experience (QoMEX)* (pp. 1-6). New York, NY: IEEE.

Elmqvist, N., Tudoreanu, M. E., & Tsigas, P. (2008). Evaluating motion constraints for 3D wayfinding in immersive and desktop virtual environments. *In* M. Burnett, M. F. Costabile, T. Catarci, B. de Ruyter, D. Tan, M. Czerwinsky, & A. Lund (Eds.), *Proceeding of the Twenty-Sixth Annual CHI Conference on Human Factors in Computing Systems - CHI '08* (pp. 1769-1778). New York, NY: *ACM Press*.

Ermi, L., & Mäyrä, F. (2005). Fundamental components of the gameplay experience: Analysing immersion. In S. de Castell & J. Jenson (Eds.), *Changing views: Worlds in play. Selected papers of the 20005 DiGRA's Second International Conference* (pp. 15-27). Vancouver: DiGRA & University of Vancouver.

Estupiñán, S., Rebelo, F., Noriega, P., Ferreira, C., & Duarte, E. (2014). Can virtual reality increase emotional responses (Arousal and Valence)? A pilot study. In A. Marcus (Ed.), *Design, User Experience, and Usability. User Experience Design for Diverse Interaction Platforms and Environments* (pp. 541-549). New York, NY: Springer.

Felnhofer, A., Kothgassner, O. D., Schmidt, M., Heinzle, A.-K., Beutl, L., Hlavacs, H., & Kryspin-Exner, I. (2015). Is virtual reality emotionally arousing? Investigating five emotion inducing virtual park scenarios. *International Journal of Human-Computer Studies*, *82*, 48-56.

Ferguson, C. J. (2007). The good, the bad and the ugly: A meta-analytic review of positive and negative effects of violent video games. *The Psychiatric Quarterly*, 78(4), 309-316.

Fitzgerald, M., & Riva, G. (2001). Virtual reality. In L. Beolchi (Ed.), *Telemedicine glossary* (pp. 327-329). European Commission-DGINFSO.

Freeman, D., Garety, P. A., Bebbington, P., Slater, M., Kuipers, E., Fowler, D. . . . Dunn, G. (2005). The psychology of persecutory ideation II: A virtual reality experimental study. *Journal of Nervous and Mental Disease*, *193*(5), 309-315.

George, D., & Mallery, P. (2003). *SPSS for Windows step by step: A simple guide and reference, 11.0 update*. Boston, USA: Allyn & Bacon.

Gerling, K. M., Klauser, M., & Niesenhaus, J. (2011). Measuring the impact of game controllers on player experience in FPS games. In A. Lugmayr (Ed.), *Proceedings of the 15th*

International Academic Mindtrek Conference on Envisioning Future Media Environments - Mindtrek '11 (p. 83). New York, NY: ACM Press.

Hassenzahl, M., & Tractinsky, N. (2006). User experience—A research agenda. *Behaviour & Information Technology*, *25*(2), 91-97.

Heim, M. (1998). Virtual reality and the tea ceremony. In J. Beckmann (Ed.), *The virtual dimension* (pp. 1-28). Princeton, NJ: Princeton Architectural Press.

Heim, M., Rothbaum, B. O., Hodges, L. F., Kooper, R., Opdyke, D., Williford, J. S. . . . Bainbridge, W. S. (2008). Affective outcomes of virtual reality exposure therapy for anxiety and specific phobias: A meta-analysis. *Studies in Health Technology and Informatics*, 8(3), 250-261.

Heineman, D. S. (2016). Porting game studies research to virtual reality. *New Media & Society*, *18*(11), 2793-2799.

Hemenover, S. H., & Bowman, N. D. (2018). Video games, emotion, and emotion regulation: Expanding the scope. *Annals of the International Communication Association*, 42(2), 125-143.

Higuera-Trujillo, J. L., López-Tarruella Maldonado, J., & Llinares Millán, C. (2017). Psychological and physiological human responses to simulated and real environments: A comparison between Photographs, 360° Panoramas, and Virtual Reality. *Applied Ergonomics*, *65*, 398-409.

Kain, E. (2017). *The most disappointing video games of 2017*. Retrieved from https://www.forbes.com/sites/erikkain/2017/12/19/the-top-11-most-disappointing-video-games-of-2017/#1b2595fc76c6

Kim, K., Rosenthal, M. Z., Zielinski, D. J., & Brady, R. (2014). Effects of virtual environment platforms on emotional responses. *Computer Methods and Programs in Biomedicine*, *113*(3), 882-893.

Kleiger, R. E., Stein, P. K., & Bigger, J. T. (2005). Heart rate variability: Measurement and clinical utility. *Annals of Noninvasive Electrocardiology*, *10*(1), 88-101.

Korhonen, H., Montola, M., & Arrasvuori, J. (2009). Understanding playful user experiences through digital games. In *Proceedings of the 4th International Conference on Designing Pleasurable Products and Interfaces, DPPI 2009* (pp. 274-285). New York, NY: ACM Press.

Kruijff, E., Marquardt, A., Trepkowski, C., Schild, J., & Hinkenjann, A. (2017). Designed emotions: Challenges and potential methodologies for improving multisensory cues to enhance user engagement in immersive systems. *The Visual Computer*, 33(4), 471-488.

Lachlan, K., & Krcmar, M. (2011). Experiencing presence in video games: The role of presence tendencies, game experience, gender, and time spent in play. *Communication Research Reports*, 28(1), 27-31.

Lee, K., Peng, W., & Park, N. (2009). Effects of computer/video games and beyond. In J. Bryant & M. B. Oliver (Eds.), *Media effects: Advances in theory and research* (pp. 551-556). Mahwah, NJ: Lawrence Erlbaum.

Liarokapis, F. (2006). An exploration from virtual to augmented reality gaming. *Simulation Gaming*, *37*(4), 507-533.

Limperos, A., Waddell, T. F., Ivory, A. H., & Ivory, J. D. (2014). Psychological and physiological responses to stereoscopic 3D presentation in handheld digital gaming: Comparing the experiences of frequent and infrequent game players. *Presence: Teleoperators and Virtual Environments*, *23*(4), 341-353.

Lin, C. J., Chen, H.-J., Cheng, P.-Y., & Sun, T.-L. (2015). Effects of displays on visually controlled task performance in three-dimensional virtual reality environment. *Human Factors and Ergonomics in Manufacturing & Service Industries*, *25*(5), 523-533.

Lin, J. H. T. (2017). Fear in virtual reality (VR): Fear elements, coping reactions, immediate and next-day fright responses toward a survival horror zombie virtual reality game. *Computers in Human Behavior*, *72*, 350-361.

Lombard, M., & Ditton, T. (1997). At the heart of it all: The concept of presence. *Journal of Computer-Mediated Communication*, *3*(2), JCMC321.
MacQuarrie, A., & Steed, A. (2017). Cinematic virtual reality: Evaluating the effect of display type on the viewing experience for panoramic video. In E. S. Rosenberg, D. M. Krum, Z. Wartell, B. Mohler, S. V. Babu, F. Steinicke, & V. Interrante (Eds.), *2017 IEEE Virtual Reality (VR)* (pp. 45-54). New York, NY: IEEE.
Malone, T. W. (1980). What makes things fun to learn? Heuristics for designing instructional computer games. In G. W. Gorsline (Ed.), *Proceedings of the 3rd ACM SIGSMALL Symposium and the First SIGPC Symposium on Small Systems - SIGSMALL '80* (pp. 162-169). New York, NY: ACM Press.
Malone, T. W. (1982). Heuristics for designing enjoyable user interfaces. In *Proceedings of the 19 Conference on Human Factors in Computing Systems - CHI '82* (pp. 63-68). New York, NY: ACM Press.
Martel, E., Su, F., Gerroir, J., Hassan, A., Girouard, A., & Muldner, K. (2015). Diving headfirst into virtual reality: Evaluating HMD control schemes for VR games. In *Proceedings of the 10th International Conference on the Foundations of Digital Games (FDG 2015)*. New York, NY: ACM Press.
Merhi, O., Faugloire, E., Flanagan, M., & Stoffregen, T. A. (2007). Motion sickness, console video games, and head-mounted displays. *Human Factors*, *49*(5), 920-934.
Morris, C. (2015). *Is 2016 the year of virtual reality?* Retrieved from http://fortune.com/2015/12/04/2016-the-year-of-virtual-reality/
Munafo, J., Diedrick, M., & Stoffregen, T. A. (2017). The virtual reality head-mounted display Oculus Rift induces motion sickness and is sexist in its effects. *Experimental Brain Research*, *235*(3), 889-901.
Naz, A., Kopper, R., McMahan, R. P., & Nadin, M. (2017). Emotional qualities of VR space. In E. S. Rosenberg, D. M. Krum, Z. Wartell, B. Mohler, S. V. Babu, F. Steinicke, & V. Interrante (Eds.), *IEEE Virtual Reality Conference* (pp. 3-11). New York, NY: IEEE.
Nielsen, J. (1993). *Usability engineering*. San Francisco, CA: Morgan Kaufmann Publishers Inc.
Nielsen, J. (1994). Usability inspection methods. In C. Plaisant (Ed.), *Conference Companion on Human Factors in Computing Systems - CHI '94* (pp. 413-414). New York, NY: ACM Press.
Pallavicini, F., Argenton, L., Toniazzi, N., Aceti, L., & Mantovani, F. (2016). Virtual reality applications for stress management training in the military. *Aerospace Medicine and Human Performance*, *87*(12), 1021-1030.
Pallavicini, F., Ferrari, A., Garcea, G., Zanacchi, A., & Mantovani, F. (2018). Effectiveness of virtual reality survival horror games for the emotional elicitation: Preliminary insights using Resident Evil 7: Biohazard. In M. Antona & C. Stephanidis (Eds.), *Universal access in human-computer Interaction. Virtual, augmented, and intelligent environments: 12th international conference, UAHCI 2018, held as part of HCI International 2018*. Cham, Switzerland: Springer.
Pallavicini, F., Ferrari, A., Zini, A., Garcea, G., Zanacchi, A., Barone, G., & Mantovani, F. (2017). What distinguishes a traditional gaming experience from one in virtual reality? An exploratory study. In T. Ahram & C. Falcão (Eds.), *Advances in Human Factors in Wearable Technologies and Game Design: Proceedings of the AHFE 2017 International Conference on Advances in Human Factors and Wearable Technologies* (pp. 225-231). Cham, Switzerland: Springer.

Parker, L. (2016, March 6). Virtual reality is a disappointment? Not in the world of video gamers. *The New York Times*. Retrieved from https://www.nytimes.com/2017/06/22/technology/personaltech/virtual-reality-video-games.html

Parkin, S. (2016). *PlayStation boss: Virtual reality throws out the game-design rule book*. Retrieved from http://www.theguardian.com/technology/2016/mar/16/playstation-virtual-reality-vr-headset-game-andrew-house?CMP=share_btn_gp

Parsons, T. D., & Rizzo, A. A. (2008). Affective outcomes of virtual reality exposure therapy for anxiety and specific phobias: A meta-analysis. *Journal of Behavior Therapy and Experimental Psychiatry*, *39*(3), 250-261.

Pausch, R., Proffitt, D., & Williams, G. (1997). Quantifying immersion in virtual reality. In *Proceedings of the 24th Annual Conference on Computer Graphics and Interactive Techniques - SIGGRAPH '97* (pp. 13-18). New York, NY: *ACM Press*.

Pedroli, E., Serino, S., Cipresso, P., Pallavicini, F., & Riva, G. (2015). Assessment and rehabilitation of neglect using virtual reality: A systematic review. *Frontiers in Behavioral Neuroscience*, *9*, Article 226

Pratt, D. R., Zyda, M., & Kelleher, K. (1995). Virtual reality: In the mind of the beholder. *Computer Archive*, *28*(7), 17-19.

Price, M., Mehta, N., Tone, E. B., & Anderson, P. L. (2011). Does engagement with exposure yield better outcomes? Components of presence as a predictor of treatment response for virtual reality exposure therapy for social phobia. *Journal of Anxiety Disorders*, *25*, 763-770.

Rajae-Joordens, R. J. (2008). Measuring experiences in gaming and TV applications. In J. H. D. M. Westerink, M. Ouwerkerk, T. J. M. Overbeek, W. F. Pasveer, & B. de Ruyter (Eds.), *Probing experience* (pp. 77-90). Dordrecht, The Netherlands: Springer.

Ravaja, N., Salminen, M., Holopainen, J., Saari, T., Laarni, J. J., & irvinen, A. (2004). Emotional response patterns and sense of presence during video games. In A. Hyrskykari (Ed.), *Proceedings of the Third Nordic Conference on Human-Computer Interaction - Nordichi '04* (pp. 339-347). New York, NY: *ACM Press*.

Reunanen, T., Penttinen, M., & Borgmeier, A. (2017). "Wow-factors" for boosting business. In J. I. Kantola, T. Barath, S. Nazir, T. Andre (Eds.), *Advances in Human Factors, Business Management, Training and Education: Proceedings of the AHFE 2016 International Conference on Human Factors, Business Management and Society* (pp. 589-600). Cham, Switzerland: Springer.

Reuters. (2017, June 7). *Sony's PlayStation VR headset sales top 1 million units*. Retrieved from https://www.cnbc.com/2017/06/07/sonys-playstation-vr-headset-sales-top-1-million-units.html

Riva, G., Mantovani, F., Capideville, C. S., Preziosa, A., Morganti, F., Villani, D. . . . Alcañiz, M. (2007). Affective interactions using virtual reality: The link between presence and emotions. *Cyberpsychology & Behavior*, *10*(1), 45-56.

Rizzo, A., Parsons, T. D., Lange, B., Kenny, P., Buckwalter, J. G., Rothbaum, B. . . . Reger, G. (2011). Virtual reality goes to war: A brief review of the future of military behavioral healthcare. *Journal of Clinical Psychology in Medical Settings*, *18*(2), 176-187.

Robertson, A. (2017, October 11). How virtual reality developers are surviving the hype cycle. *The Verge*. Retrieved from https://www.theverge.com/2017/10/11/16458806/oculus-rift-htc-vive-vr-hype-game-developers

Ryan, R. M., Rigby, C. S., & Przybylski, A. (2006). The motivational pull of video games: A self-determination theory approach. *Motivation and Emotion*, *30*(4), 344-360.

Saposnik, G., Teasell, R., Mamdani, M., Hall, J., McIlroy, W., Cheung, D., … Stroke Outcome Research Canada (SORCan) Working Group. (2010). Effectiveness of virtual reality using

Wii gaming technology in stroke rehabilitation: A pilot randomized clinical trial and proof of principle. *Stroke*, *41*(7), 1477-1484.
Sauro, J. (2011). *A practical guide to the system usability scale: Background, benchmarks & best practices*. Denver, CO: Measuring Usability LLC.
Seymour, N. E., Gallagher, A. G., Roman, S. A., O'Brien, M. K., Bansal, V. K., Andersen, D. K., & Satava, R. M. (2002). Virtual reality training improves operating room performance: Results of a randomized, double-blinded study. *Annals of Surgery*, *236*(4), 458-463.
Shaffer, F., & Ginsberg, J. P. (2017). An overview of heart rate variability metrics and norms. *Frontiers in Public Health*, *5*, Article 258.
Shaffer, F., McCraty, R., & Zerr, C. L. (2014). A healthy heart is not a metronome: An integrative review of the heart's anatomy and heart rate variability. *Frontiers in Psychology*, *5*, Article 1040.
Shelley, B. (2001). *Guidelines for developing successful games*. Retrieved from https://www.gamasutra.com/view/feature/131
Shelstad, W. J., Smith, D. C., & Chaparro, B. S. (2017). Gaming on the rift: How virtual reality affects game user satisfaction. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, *61*(1), 2072-2076.
Skalski, P., & Whitbred, R. (2010). Image versus sound: A comparison of formal feature effects on presence and video game enjoyment. *PsychNology Journal*, *8*(1), 67-84.
Slater, M., Linakis, V., Usoh, M., & Kooper, R. (1996). Immersion, presence, and performance in virtual environments: An experiment with tri-dimensional chess. In M. Green, K. M. Fairchild, & M. Zyda (Eds.), *Proceedings of the 3rd ACM Symposium on Virtual Reality Software and Technology (VRST 1996)* (pp. 163-172). New York, NY: ACM Press.
Slater, M., Usoh, M., & Steed, A. (1994). Depth of presence in virtual environments. *Presence: Teleoperators and Virtual Environments*, *3*(2), 130-144.
Slater, M., & Wilbur, S. (1997). A Framework for Immersive Virtual Environments (FIVE): Speculations on the role of presence in virtual environments. *Presence: Teleoperators and Virtual Environments*, *6*(6), 603-616.
Sousa Santos, B., Dias, P., Pimentel, A., Baggerman, J. W., Ferreira, C., Silva, S., & Madeira, J. (2009). Head-mounted display versus desktop for 3D navigation in virtual reality: A user study. *Multimedia Tools and Applications*, *41*(1), 161-181.
Statista. (2018). *Global VR gaming market size 2020 Statistic*. Retrieved from https://www.statista.com/statistics/499714/global-virtual-reality-gaming-sales-revenue/
Swindells, C., Po, B. A., Hajshirmohammadi, I., Corrie, B., Dill, J. C., Fisher, B. D., & Booth, K. S. (2004). Comparing CAVE, wall, and desktop displays for navigation and wayfinding in complex 3D models. In *Proceedings of Computer Graphics International Conference, CGI* (pp. 420-427). Los Alamitos, USA: IEEE Computer Society.
Takatalo, J., Häkkinen, J., Kaistinen, J., & Nyman, G. (2010). Presence, involvement, and flow in digital games. In R. Bernhaupt (Ed.), *Evaluating User Experience in Games* (pp. 23-46). London, England: Springer.
Tamborini, R., & Bowman, N. D. (2010). Presence in video games. In C. Campanella-Bracken & P. Skalski (Eds.), *Immersed in media: Telepresence Theory, Measurement & Technology* (pp. 87-109). New York, NY: Routledge.
Tan, C. T., Leong, T. W., Shen, S., Dubravs, C., & Si, C. (2015). Exploring gameplay experiences on the Oculus Rift. In L. E. Nacke & T. C. N. Graham (Eds.), *Proceedings of the 20 Annual Symposium on Computer-Human Interaction in Play - CHI PLAY '15* (pp. 253-263). New York, NY: *ACM Press*.
Waller, D., Hunt, E., & Knapp, D. (1998). The transfer of spatial knowledge in virtual environment training. *Presence: Teleoperators and Virtual Environments*, *7*(2), 129-143.

Weibel, D., & Wissmath, B. (2011). Immersion in computer games: The role of spatial presence and flow. *International Journal of Computer Games Technology*, 2011, *282345*.

Westerman, D., & Skalski, P. D. (2010). Presence and computers: A ghost in the machine? In C. Bracken & P. D. Sklaski (Eds.), *Immersed in media: Telepresence in everyday life* (pp. 63-86). New York, NY: Routledge.

Wilson, G., & McGill, M. (in press). Violent video games in virtual reality: Re-evaluating the impact and rating of interactive experiences. In *CHI PLAY '18 Proceedings of the 2018 Annual Symposium on Computer-Human Interaction in Play* (pp. 535-548). New York, NY: ACM Press.

Author Biographies

Federica Pallavicini (PhD) is a psychologist fellow researcher with strong expertise in the study of the applications of advanced technologies (especially virtual reality and video games) for the health and neuroscience. Since July 2014, she has been working at the Human Sciences Department of the University of Milano-Bicocca (Italy) as a research fellow and since September 2018 she is contract professor at the University of Bergamo (Italy).

Contact: federica.pallavicini@gmail.com

Alessandro Pepe is senior fellow researcher at the "R. Massa" Department of Human Sciences for Education at the University of Milano-Bicocca (Italy). He has an MSc in Psychology and a PhD in Organizational Development. He is internal member of the laboratory He.Co.Psy (Health Conflict and Psychology) at the University of Milano-Bicocca (Italy). His expertise covers the analysis of quantitative and qualitative data in population at-risk of trauma living in contexts of military crisis or political violence.

Contact: alessandro.pepe1@unimib.it

Maria Eleonora Minissi is master science in cognitive psychology at University of Padua (Italy). Actually she is doing a post-master internship at the Human Sciences Department of the University of Milano-Bicocca (Italy) and at BCBL (Donostia- San Sebastián). Her research interests includes cognitive processes, cognitive enhancement and assessment through new technologies use, video games, virtual and augmented reality.

Contact: lela.minissi@gmail.com