VISUAL REALISM AND PRESENCE IN A VIRTUAL REALITY GAME

Jonatan Hvass, Oliver Larsen, Kasper Vendelbo, Niels Nilsson, Rolf Nordahl, and Stefania Serafin

Aalborg University Copenhagen

ABSTRACT

Virtual Reality (VR) has finally entered the homes of consumers, and a large number of the available applications are games. This paper presents a between-subjects study (n=50) exploring if visual realism (polygon count and texture resolution) affects presence during a scenario involving gameplay, graphics, and controls that, contrary to much existing research, resemble commercially available VR games. The results suggest that participants exposed to a higher degree of visual realism experienced a stronger sensation of presence, as assessed by means of self-reports, and physiological measures revealed that higher visual realism also was accompanied by stronger fear responses which may be indicative of stronger presence.

Index Terms — Virtual reality, games, presence, realism

1. INTRODUCTION

Decreasing costs of tracking and display technology has finally made Virtual Reality (VR) available to consumes. A defining feature of VR is arguably that it has the potential to elicit an unprecedented degree of presence on behalf of the user. The current paper takes the framework proposed by Slater [1] as its point of departure. Particularly, presence is viewed as the degree to which individuals respond realistically to the virtual environemtn (VE). Thus, the presence response occurs on multiple levels ranging from unconscious and automatic physiological and behavioural responses to higher-level processes involving thoughts and deliberation, including the subjective sensation of "being there" in the VE. Slater [1] has argued that this response-as-if-real (i.e., presence [2]) happens as a function of two illusions: the place illusion (PI) and the plausibility illusion (Psi). PI corresponds to the illusion of "being there" in the VE which is contingent upon the range of sensorimotor contingencies supported by the system (i.e., the degree of technological immersion). Psi refers to the illusion that the events happening virtually are indeed happening, and it is influenced by factors such as the extent to which the VE responds to the presence of the user and the general credibility of the scenario [2]. Despite the numerous potential applications of VR, much of the commercially available content is games. Historically, realistic graphics have been a major selling point for game developers. According to Slater et al. [3] visual realism has two components: geometric realism (the virtual object looks like its real-world counterpart) and illumination realism (the fidelity of the lighting model). Several studies have explored how presence is affected by different sub-components of geometric and illumination realism in VR, including, realistic colors, objects and terrain [4], texture and lighting quality [5], and shadow quality [3, 6, 7]. While the results of this work are not unequivocal, some elements of visual realism do appear to affect presence (e.g., the presence of shadows and reflections [3] and the consistency between the realism of elements [8]). Nevertheless, most existing work has relied on scenarios and hardware that differ notably from those encountered when playing VR games. Furthermore, most studies have exposed participants to graphics that are impoverished by today's standards. Thus, it is worth raising the question: Will increased visual realism elicit stronger presence in regards to contemporary VR games? In this paper we exlaborate upon our previous work [9] and describe a study exploring if increased geometric realism positively affects presence during scenarios involving gameplay, graphics, and controls that better resemble the first generation of VR games.

2. METHODS AND MATERIAL

To meet this aim we performed a between-subjects study comparing the effects of two levels of geometric realism (high and low polygon count and texture resolution) on presence during exposure to a game-like scenario.

2.1. Participants

A total of 50 participants (37 males, 13 females), aged between 16-55 years (M=23.3 years, SD=9.1), took part in the study. Forty participants reported having experience with first-person games, 21 played games for more than 5 hours a week, and 19 had prior experience with VR. The participants were recruited among students and staff at Aalborg University Copenhagen and they were randomly assigned to one of the two conditions.

2.2. Scenario and Setup

The VR scenario was designed to mimic some of the properties of games belonging to the survival-horror genre. Besides from resembling a series of events that a player might encounter in current games, the use of stressful, albeit not supernatural, scenarios has also commonly been used to study if VEs elicit signs of presence in the form of fear responses (e.g., the pit room [10]). Particularly, the participants were tasked with escaping from an abandoned apartment by finding four hidden keys in order to unlock the front door. Meanwhile an unknown threat was knocking on and clawing at the apartment's second door. Moreover, the participants movement around the apartment would trigger a series of scares, in the form of unexplainable events, intended to make the experience increasingly stressful. The kitchen the cabinets and cupboards would suddenly open (kitchen scare), the radio on the couch table emitted loud tuning static (radio scare), the lights started flickering and the sound of electrical short circuits were heard (light scare), and finally a particularly loud knocking on the door was heard (door scare). The scenario ended once the participant escaped the apartment, but the session would be stopped after 10 minutes if the participant failed to escape within that period of time. Figure 1 shows two screenshots of the apartment as it appeared in the condition involving high geometric realism, and Figure 2 illustrates the layout of the apartment, the placement of the keys, and the approximate areas that triggered each of the scares. The VE was presented using an Oculus Rift DK2 and a

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Figure 1. Screenshots of the kitchen (left) and living room (right) as they appeared in the condition involving high geometric realism.

Figure 3. Screenshots of the VEs used for the study: low geometric realism (left) and high geometric realism (right).

pair of circumaural headphones. The participants were standing and their orientation derived from the native tracking of the DK2. Locomotion and interaction with objects in the environment were performed using an Xbox 360 game controller; i.e., forward, backward and lateral movement was controlled using the left analog stick, selection was performed using the right trigger, and manipulation controlled using the right analog stick (e.g., opening/closing cabinets or inspecting objects). The combination of the DK2 and the game controller was chosen since it resembles the setup likely to be used for many of the initial games launched for the Oculus Rift. Prior to experiencing the game-like scenario, the participants were required to complete a tutorial level involving a series of simple tasks ensuring that they were familiar with the control scheme and the experience of wearing the head-mounted display. The tutorial level was identical for both conditions.

2.3. Study stimuli

The VE was generated using Unreal Engine 4 and all 3D geometry and textures were created specifically for the scenario in order to ensure a consistent visual style. The two conditions were produced by initially creating a version of the environment with high polygon count and texture resolution. Subsequently, the low realism condition was created by reducing both the polygon count and texture resolution to one fifth of the original. The only difference between the two conditions was the polygon count and texture resolution, and great care was taken to ensure that the reduction in polygon count only affected surface details, thus leaving the general shape of the objects intact. Figure 3 illustrates the appearance of the VE during the two conditions. The auditory stimuli was identical across the two conditions and included the sound of the scares (e.g., radio tuning static), sounds generated from user-environment interaction (e.g., the user's foot steps), and ambient noises (e.g., refrigerator humming).

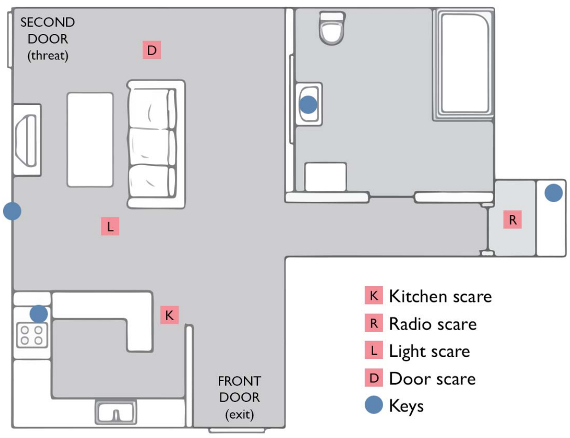

Figure 2. Schematic drawing of layout of the apartment. The location of the keys are indicated with blue circles, and the approximate areas that triggered each of the scares are highlighted with red squares.

2.4. Measures

The participants' subjective sensation of presence was measured using the three items featured in the original version of the Slater-Usoh-Steed (SUS) questionnaire [11] that assesses presence based on three factors: (1) The extent to which the participants had a sensation of "being there" in the VR. (2) The extent to which the VE was perceived as the dominant reality. (3) The extent to which exposure to the VE gave rise to a sense of having visited a place as opposed to viewing images. Each item is rated on a 7-point scale where a high rating is indicative of presence.

Moreover, since an increased fear response should be indicative of higher presence when the user is exposed to a stressful VE [10], two measures of affect were employed; namely, the Self-Assessment Manikin (SAM) questionnaire and two physiological measures. The SAM questionnaire required the participants to report on their affective state through three 9-point pictorial scales corresponding to three affective dimensions: (1) valence (negative-positive), (2) arousal (calm-excited), and (3) dominance (submissive-controlling) [12]. Both the SUS and SAM questionnaires were administered after exposure to the VE. The two physiological measures were Blood Volume Pulse (BVP) and Electrodermal Activity (EDA) which previously have been used as physiological indicators of arousal [13]. Particularly, BVP was used to assess the participants' response to the individual scares. This was done by recording the peak BVP during the four second intervals following the onset of each scare. In order to minimize the effect of individual differences we considered the peak BVP relative to a baseline BVP recorded during the tutorial where the participants presumably would be in a more relaxed state; i.e., we relied on $\Delta BVP = BVP_{scare} - BVP_{baseline}$. EDA was recorded once the session was over and the recorded EDA was similarly considered relative to the baseline measure obtained during the tutorial session ($\Delta EDA = EDA_{end} - EDA_{baseline}$).

3. RESULTS

The data obtained from the SUS and SAM questionnaires were treated as ordinal, and Mann-Whitney U tests used to identify differences in scores between high and low geometric realism for the individual questionnaire items. The distributions of scores for the two conditions were in many cases not similar, as assessed by visual inspection. Thus, our comparisons are focussed on mean ranks rather than medians. Figure 4 and 5 illustrates the distribution of ratings across the different questionnaire items, and Table 1 summarizes the corresponding mean ranks.

The pairwise comparisons using Mann-Whitney U tests revealed statistically significant differences between scores in relation to all three items on the SUS questionnaire: the sensation of

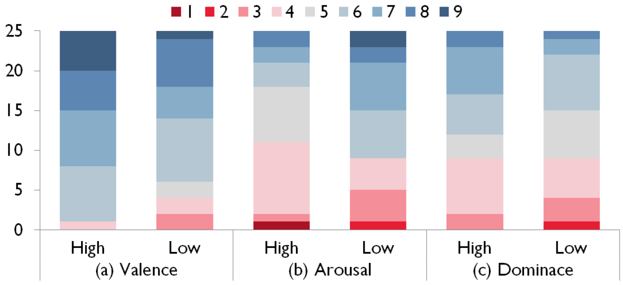

Figure 4. Visualization of the distribution of ratings (1-7) across the three SUS questionnaire items.

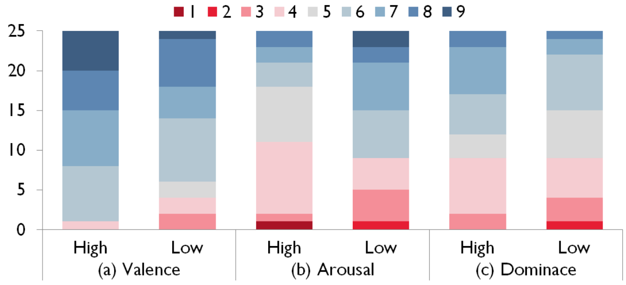

Figure 5. Visualization of the distribution of ratings (1-9) across the three SAM questionnaire items.

"being there" in the VR ($U = 183, z = -2.661, p = .008$), the extent to which the VE was perceived as the dominant reality ($U = 190, z = -2.445, p = .014$), and the extent to which the VE gave rise to a sense of having visited a place as opposed to viewing images ($U = 205, z = -2.116, p = .034$). In all three cases the scores related to high geometric realism were significantly higher than the scores related to low geometric realism. In regards to the SAM questionnaire a statistically significant difference was only found in relation to valence ($U = 212, z = -1.991, p = .047$). Again, the score was significantly higher for the condition involving high geometric realism.

Shapiro-Wilk's tests were used to assess whether the data obtained from the physiological measures met the assumption of normality, and violations were found in relation to all measures for one or both of the conditions. Thus, the pairwise comparison across conditions was performed using Mann-Whitney U tests. Except from the data related to the ΔBVP measure obtained after the radio scare, all distributions were similar, as assessed by visual inspection. Figure 6 shows boxplots pertaining to the physiological data and Table 1 summarizes the corresponding mean ranks. Statistically significant differences were found for ΔBVP in relation to the fear inducing event involving flickering lights ($U = 204, z = -2.105, p = .035$) and in regards to the measure of ΔEDA ($U = 207, z = -2.050, p = .040$). Both ΔBVP and ΔEDA were higher for high geometric realism.

4. DISCUSSION

The results suggest that the condition involving high geometric realism yielded statistically significantly higher scores in relation to all three items of the SUS questionnaire. Thus, after exposure the higher geometric realism the participants reported having a stronger sensation of "being there" in the VE, they found the VE to be the dominant reality to a higher degree, and they were more likely to think of the VE as a place they had visited rather than images they saw. In regards to the SAM questionnaire, high geometric realism yielded significantly higher scores in relation to valence. Notably, this suggests that the participants responded more positively to this condition.

The physiological measures revealed a significantly higher ΔBVP after the light scare for high geometric realism, and this condition also produced significantly higher ΔEDA. This may be viewed as an indication that the participants experienced a stronger fear response during the condition with more realistic graphics, which in turn may be seen as a sign of stronger presence.

Despite the indication that more realistic graphics elicit higher self-reported presence, it is worth stressing that the reliability of questionnaires as a measure of presence has been brought into question [14]. Nevertheless, the results of the SUS questionnaire were relatively unambiguous, and they appear to be corroborated by the physiological measures. Thus, we feel that we with reasonable confidence can conclude that the more realistic graphics yielded higher presence; i.e., the participants reported stronger presence and responded more realistically.

It seems possible to offer an explaination of the results based on Slater's [1] theory of presence as a function of the two illusions PI and Psi. Insofar as PI results from the range of valid actions the user can perform in order to perceive (sensorimotor contingencies), it seems possible that the added detail offered by the higher geometric realism indeed did play a role; e.g., when approaching an item in the VE, the higher realism would have allowed the participant to perceive a level of detail closer to the one expected from everyday, real-world interactions. It is less certain whether the increased realism had an influence on Psi since this illusion is not believed to require physical realism [1]. Nevertheless, it does seem possible that some degree of Psi may have been experienced. In case of both version of the VE, the participants would experience that the environment seemingly responded to their presence (e.g., entering the kitchen caused cabinets and cupboards to suddenly open) which is believed to be important for Psi. Interestingly, these responses to the participants' presence were supernatural in nature and should therefore not conform to the participants' knowledge and expectations accrued through a lifetime of interactions with non-mediated environments.

Finally, it is worth highlighting some limitations of the current study. Most notably the study design confounded the two variables polygon count and texture resolution, making it impossible to conclude whether both contributed equally to the observed effect. Moreover, the choice of only comparing two conditions makes it difficult to comment more specifically on the relationship between presence and polygon count and texture resolutions. Lastly, the study sought to rely on a scenario the resembled a

Table 1. Mean ranks pertaining to the self-reported measures of presence (SUS) and affect (SAM) and the physiological measures of arousal (ΔBVP and ΔEDA)

SUS:	**High**	**Low**
"being there"	30.7	20.3
Dominant reality	30.4	20.6
Images or place	29.8	21.2
SAM:	**High**	**Low**
Valence	29.5	21.5
Arousal	22.8	28.2
Dominance	27.6	23.4
Physiological:	**High**	**Low**
ΔBVP (kitchen)	28.6	22.4
ΔBVP (lights)	29.8	21.2
ΔBVP (radio)	27.9	23.1
ΔBVP (door)	28.0	23.0
ΔEDA	29.7	21.3

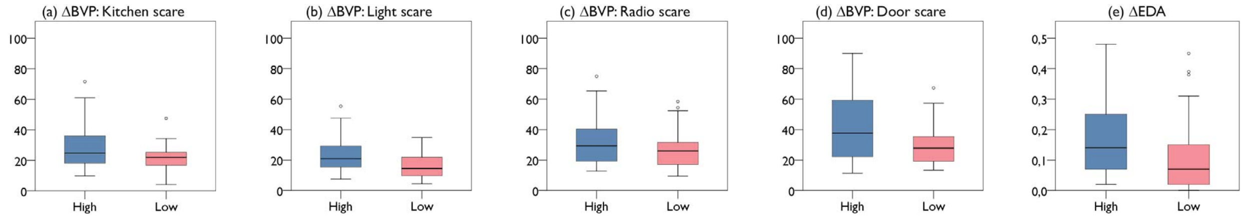

Figure 6. Boxplots summarizing the results of the measures of ΔBVP (a-d) and ΔEDA (e) in terms of medians, interquartile range, minimum and maximum ratings, and outliers.

likely consumer VR experience in terms of the hardware (Oculus Rift DK2 and game controller) and content (survival-horror game). However, it cannot be ruled out that the limited resolution of the DK2 may have influenced the results by making it harder to see some of the finer details present in the condition involving high geometric realism. Thus, the differences between the two conditions may have appeared more pronounced if a better display had been used.

5. CONCLUSION

Existing research on the effect of visual realism on presence has not involved scenarios resembling the ones encountered when playing current VR games, and much of this research has been based on graphics that would be considered impoverished by today's standards. This paper detailed a between-subjects study investigating if polygon count and texture resolution influenced presence during a scenario involving gameplay, graphics, and controls that better resemble commercially available VR games. The results indicated that higher geometric realism yielded a stronger presence and fear responses as assessed by means of self-reports and physiological measures. Thus, it seems possible that, higher geometric realism may be worth the cost consider the potential benefits to presence. While techniques such as foveated rendering [15] may help bring down this cost, it would be relevant for future work to involve more detailed studies of the features of geometric realism that affect presence in VR games.

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