Don't Stand So Close To me: Investigating the effect of control on the appeal of virtual humans using immersion and a proximity-based behavioral task

Katja Zibrek
Trinity College Dublin
College Green 2
Dublin, Ireland
kzibrek@tcd.ie

Elena Kokkinara
Trinity College Dublin
College Green 2
Dublin, Ireland
redarahel@gmail.com

Rachel McDonnell
Trinity College Dublin
College Green 2
Dublin, Ireland
ramcdonn@scss.tcd.ie

ABSTRACT

In recent years, there has been much research and media attention devoted to investigating virtual reality environments. In this paper, we are investigating if there are differences in how characters are perceived in immersive virtual reality as opposed to more common, screen–based environments. We were particularly interested if the spatial and immersive components play an important part in perception of interactive, game–like settings, where characters can either be controlled (avatars) or observed (agents). We focus on the subjective reports on perceived realism, affinity, co–presence and agency. Since appearance of the character is an important component of affinity, we introduced the changes in render style, ranging in three realism levels, to test if appearance would even further influence the perception in relation to control condition and platform. Furthermore, we adapted a behavioural method (proximity task) as a novel approach to establishing if behavioural changes could be recorded based on the introduced conditions and compared those values with the subjective reports of the participants. The conclusions have an important value to character design specific to platform and character control.

CCS CONCEPTS

•**Computing methodologies →Graphics systems and interfaces; Perception; Virtual reality;**

KEYWORDS

character appeal, rendering style, uncanny valley, character control

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1 INTRODUCTION

Recent advances in graphics have allowed game, movie and virtual reality experiences to display high levels of rendering and animation realism with virtual characters closely resembling real people. However, audience reaction has not always been favorable towards photo-realistic humans, which has been attributed to a feeling of fear of the unknown or discomfort [Geller 2008; Levi 2004]. This effect ("Uncanny Valley") has been a subject of much investigation but remains poorly understood due to operationalization and methodological issues (for review, see [Kätsyri et al. 2015]). New approach is needed to analyze the impact of character realism on human perception.

In terms of collecting the attitudes of the participants, subjective questionnaires provide useful feedback. However, we propose the use of an additional measure: proximity–based behavioral task. This measure is implicit and aims to describe unconscious levels of comfort towards another human [Hall 1966]. It has been successfully implemented in virtual reality (e.g., Bailenson et al. [2005]) and was found to be more sensitive than the subjective reports [Bailenson et al. 2004]. We aimed to test if this measure could identify the sense of unease with a realistic character and could possibly be used as a measure of affinity. The link between appearance realism and proximity was investigated in previous work but no conclusive answer was found, mainly due to different implementations of character realism (see Bailenson et al. [2005]). In our study, we manipulated the appearance realism by changing the render style of the character only, similar to the study of McDonnell et al. [2012]. In this study, the realistic character was not found to be particularly unappealing or eerie, but we argue that a behavioral measure could possibly detect the lack of comfort triggered by the uncanny valley effect with near–realistic characters, towards which the minimum distance should increase.

Finally, we introduced agency as a way of interacting with the character, typically encountered in a game-like environment, where characters can be controlled (avatars) or observed (agents). While avatars are representations of the player, they could be seen as more likable and less threatening, as they do not exhibit unexpected behaviors. Agents are more unpredictable and can be seen as "possessing their own will", which should increase the minimum distance towards them.

The aim of this paper is therefore to explore possible interactions between render style and agency, by implementing subjective as well as behavioral measures. We do not ignore the modern context and the availability of novel interactive systems, therefore we compare these effects on different platforms (screen–based, Oculus Rift and HTC Vive systems). To our knowledge, these relations have not been investigated yet.

2 BACKGROUND

Positive affinity towards characters is related with their appearance. The original theory of the "Uncanny Valley" [Mori 1970], which describes a feeling of unease when observing an artificial human-like representation, emphasised the importance of visual realism on affinity. Several studies found indications that this effect could be associated with increased sensitivity to imperfections when the character is approaching photo-realism [MacDorman et al. 2009; Seyama and Nagayama 2007] but they also contradict Mori's graph by showing that face is not necessarily eeriest when it looks nearly human. A different study, using characters with a realistic shape and render style ranging from low to high level of visual realism, found that lowering the level of realism does not necessarily increase the perceived appeal of the character [McDonnell et al. 2012]. In addition, the realistic characters in this study were rated relatively high on appeal. A different study investigated how animation styles affect people's viewing patterns and found that increased attention to faces is related to perceived unpleasantness [Carter et al. 2013]. Another study [Zell et al. 2015] analysed the effect of realism further by separating the realism of shape and material. Material was found to be the main predictor of appeal (e.g., blemish-free skin is most appealing) and shape the dominant predictor of realism (e.g., exaggerated features of the character are common in cartoons, but not typical for real humans). These studies show that there are many factors associated with appeal and eeriness, and while increasing visual realism could expose the character to a harsher judgement, realism itself is not necessarily a predictor of affinity towards the character. In our study, we therefore used examples of characters of varying material stylizations in order to explore people's perceptions and reactions to them.

Another important factor of affinity is motion. Motion carries a lot of information about the moving person, even without the body being fully visible [Johansson 1973]. An fMRI study analysed brain processing of people watching biological and synthetic motion of characters ranging from dot representations to anthropomorphic shapes [Chaminade et al. 2007]. According to this study, increasing the level of detail produces noticeable artifacts which influence the perception of overall realism. Several other studies confirmed that adding motion to the characters might increase eeriness, especially if the realism levels of motion and appearance don't match [Saygin et al. 2011], if the character's appearance is unappealing [McDonnell et al. 2012] or if some anomalies to the motions are added to realistic human characters, especially in the facial expressions of emotion [Hodgins et al. 2010; Tinwell et al. 2013]. In conclusion, motion is an important marker of realism and can influence the perception of the character's overall realism, therefore the perception of motion and its interaction with appearance of the character was included in our design.

Not much is known about the relation between agency and affinity. Previous studies mainly used static images or pre-rendered videos and did not explore these effects in an interactive environment. Game and virtual reality environments provide this dimension and add options of control over the character or even identification with him [Yee et al. 2009]. Moreover, virtual reality can provide a feeling of virtual embodiment – a sense of ownership over the body of a virtual character (see work of Slater and colleagues [Banakou et al. 2013]). Some studies found that ownership positively effects the perception of the avatar itself. Specifically, if the motion of the observer's body is tracked and applied to an avatar, it will be perceived as more appealing [Bailenson et al. 2005; Kokkinara and McDonnell 2015] than if it is perceived to be generated by an algorithm.

The use of the behavioral measure in our study is motivated by the finding, that when interacting directly with a virtual character, people often show behavior that is similar to human interaction, e.g., by keeping personal distance to them in the virtual environment [Bailenson et al. 2003] or responding emotionally to the character's behavior [Zucker et al. 2011]. For this reason, a variety of methods based on studies in social psychology, include physiological data (e.g., skin conductance), as well as subjective (e.g., co-presence questionnaire) and behavioural measures, such as the use of personal space around the virtual character: proximity [Bailenson et al. 2003]. Previous research on proximity in the physical world indicates that individuals leave differential amounts of personal space between themselves and others [Hall 1966]. Therefore, those people that are familiar with one another or wish to convey a friendly impression or a positive attitude, choose smaller interpersonal distances than neutral or unfriendly communicators [Evans and Howard 1973]. Similarly, studies in virtual environments have validated the use of distance cues to measure co-presence behaviours in virtual environments [Bailenson et al. 2004, 2003; Blascovich 2002; Llobera et al. 2010]. In our experiments, we exploited proximity as a method of investigating affinity to virtual characters.

Several studies in virtual reality have also examined the effect of virtual characters' appearance and behavioural realism on the viewers, mainly focusing on the feeling of co-presence when interacting with those characters, i.e., the sense that one is present and engaged in an interpersonal space with them [Biocca 1997; Garau et al. 2003]. While some evidence confirms the importance of realistic appearance [Nowak 2001], others put less importance to it [Garau et al. 2003; Slater and Steed 2002]. However, a common result suggests that a mismatch between the realism of behaviour and appearance lowers the feeling of co-presence [Bailenson et al. 2005], while other effects, such as involvement and positive evaluation are also affected [Garau et al. 2003]. We included the question of appearance realism to reveal possible relations between perceived co-presence, affinity and agency.

3 SCREEN–BASED EXPERIMENT

For this experiment, we developed a screen-based game-like environment, where participants could explore and interact with virtual characters observed on the TV screen.

Figure 1: Render styles used for the Agency Experiment 1: 0. Training, 1. Realistic, 2. Toon CG, 3. Toon Shaded. Characters were created in 3ds Max 2015 and exported to UE4 where additional changes to the materials were made. Toon Shaded character is rendered using the Cel Shade plugin for UE4.

3.1 Stimuli Creation

The characters we used for this experiment were animated using motion capture of one actor, who we instructed to do a set of exercising motions. Facial motion was not used, apart from the blinking which was present in the idle condition. The actor was instructed to do a range of eight different gym exercises on the spot (push-up, squat, left and right leg lunges, forward back-bend, jump, jog on spot and arm stretching), as well as one standing (idle) posture (shifting the weight from one foot to the other, blinking, etc.). We judged gym exercises to be a reasonable set of motions that a person can do on the spot without acknowledging the presence of the viewer, since we wanted to avoid the characters to move in space. This way, the distance from the viewer could be kept constant and controlled.

The motions were exported to Unreal Engine 4.9.2 and were assigned to the characters. Animations would trigger in random order during the experiment through an algorithm for the observing group, or be triggered through button presses of the participants in the controlling group. All animation would smoothly blend in and out with the idle animation. Jogging and arm stretching animation would play by holding the trigger buttons of the controller and loop until the triggers were released.

The virtual scene was realised using Unreal Engine. The virtual environment consisted of a simplistic space with one virtual room for the training session and three virtual rooms for the experiment session. Each room contained one of the virtual characters, rendered in a particular style: training character with no textures, *Realistic*, *Toon CG* or *Toon Shaded* (see Figure 1), and a red spot on the floor, which was placed $4m$ meters away from the virtual character. This position was chosen as an optimal observation distance, that would give some personal space to the viewer, but at the same time details of the character could still be visible on the TV screen due to the large screen size (55" Ultra HD screen). We chose a simplistic environment setup with no decoration, in order to avoid distraction of participants view from the virtual characters.

We created a first person camera view which tracked the movement of the participant. Participants were able to navigate (translation and rotation of the camera) using the Xbox controller. In the virtual room, we placed a red spot which served as the observation distance. Access closer than ~4 meters to the character was initially restricted with an invisible sphere collider that was placed around the character. Once the first person camera was navigated to the red spot, the camera translation was locked for 100s. This amount of time was necessary for playing each exercise animation two times, which we assumed to be enough exposure to the stimuli. During the exercises session, feedback of the character's progress would appear on the screen. This element was added to the framework to decrease boredom and give feedback to the participants on which exercises their character had or had not already executed.

3.2 Experiment Design

We recruited 41 participants (24 males and 17 females, average age 24.1). Participants were students from different disciplinary backgrounds as well as employed individuals from various fields, recruited mainly via university mailing list and advertisement in the university campus. Most participants played games occasionally or were passionate gamers, only 3 participants never played games before. All participants were naïve to the purpose of the experiment. University ethics approval was granted for the experiment, and participants received a 5 EUR book voucher to compensate for their time.

To measure participants responses to virtual characters, we used behavioural and subjective measures. For the behavioural response, we used proximity [Bailenson et al. 2003; Blascovich 2002]. We used a label reading task that was presented in the study of Bailenson et al. [2003], that was administered in order to ensure that the participant approached the character, for close inspection. Unlike the mentioned study, we used two labels instead of one to prompt the participant to move around the character. This was implemented since our participants were using gamepad navigation instead of walking, therefore we speculated that minimum distance would not be an accurate representation of proximity due to various experience of participants with gamepad controls and could lead to "mistakes" of moving towards the character too close without the intention to do so. Therefore, we decided to use an average of the trajectory distances while the participant was moving around the character to find a label at the front and one at the back. For the subjective response, the questionnaire was administered, consisting of three question groups: Agency, Realism, Affinity, and Co-presence (see Table 1).

The participants were divided in two groups - Observing and Controlling, where each group saw characters in three render styles with an additional training example. The three render styles were placed in the rooms for participants in a counter-balanced order.

3.2.1 Procedure. All participants first signed a consent form and read instructions and then filled a form with demographics information. Participants were seated $1.6m$ away from the TV screen (recommended minimum distance for a 55" Ultra HD screen) and were given the Xbox controller for the interaction with the experiment. The experimenter repeated the instructions verbally. Participants then started with a training session in order to familiarize with the controls, the tasks of the experiment and the questionnaire, with the help of the experimenter. Participants used the controller to navigate (translation and rotation of the camera) the game environment. They were instructed to move inside the virtual room and place themselves (the camera) on top of the red spot. Once the participant reached the red spot, the camera translation locked and the participant was instructed to observe or use the gamepad (depending on which condition they were in). In the observing condition, each exercise animation was shown two times, while in the controlling condition the participant was instructed to explore the buttons on the controller and observe what will happen to the character. During the exercises session, feedback of the character's progress would appear on the screen.

When the observation period was over, the proximity task started. An instruction to look for the text labels around the character appeared on the scene as a 3D text (see Figure 2). We used two word labels – one at the front and one at the back of the character, so participants would have to walk around the character. The words were simple and short (chalk, table, pencil, black, red, green). Participants were instructed to read and remember the labels and then move outside the virtual room. As the participant was moving around the character, trajectory data of the camera movement was saved, i.e., starting from the moment that the camera control was unlocked, until the moment that the participant exited the virtual room. Participants were free to move as close to the character as they wanted, however, intersecting the character was restricted using colliders around the character and the camera. The 1*m* radius sphere collider was chosen because we wanted to prevent participant's camera view to intersect with the character. The text itself was already visible from ~3.5 meters distance.

On exiting the room, a screen with instructions appeared and participants wrote down the two words on a piece of paper. This task was designed in a way that would minimise additional attentional load of a memory task, hence the words chosen for the labels were very simple. All participant correctly reported all the words. After writing down the two words, we administered a questionnaire regarding the virtual character which was presented on the screen in order to additionally collect the participant's direct opinions. We created an 12-item questionnaire, where the items were taken from groups Agency, Realism, Affinity and Co-presence (see Table 1). The questionnaire appeared on the screen and participants were asked to move a virtual slider and select their answer by using the controller. When participants had visited all three rooms and completed all the tasks they were allowed to leave comments in an open text form.

3.3 Results

Each questionnaire item was analyzed separately. We performed a two-way repeated measure ANalysis Of VAriance (ANOVA) with between factors *Condition* (Controlling and Observing) and *Participant Sex* and within factor *Render Style*. Due to a high amount of scales, we present them grouped in four categories, outlined in Table 1: *Agency, Realism, Affinity* and *Co-presence*. Where violations of sphericity occurred, Greenhouse-Geisser corrections were used (marked next to the F-value with *), and for the violation of homogeneity of variances we analyzed the data with an appropriate non–parametric test. Tukey Honestly Significant Difference (HSD) test was used as a post-hoc test to analyse significant interactions and correct for multiple comparisons. The results are visually summarised in Appendix 7.

Table 1: Likert-scale subjective responses to explore the effect of render style on the perception of virtual characters. The Affinity questions are based on measures previously used by McDonnell et al. [2012], Co-presence questions are taken from Bailenson et al. [2003] and Agency questions are partially based on Kokkinara and McDonnell [2015].

Group	*Question*	*Statement*
Agency	Agency	*"Overall, I felt I was causing the movements of the virtual character in the room to happen."*
	Own Will	*"Overall, I felt as if the character in the room was moving according to his own will."*
	External Force	*"Overall, I felt as if the character was moved by an external force."*
Realism	Appearance Realism	*"I found the character's appearance realistic ("Not at all" = the character's appearance is highly stylised like in cartoons, "Extremely" = it could almost be mistaken for a photograph)."*
	Movement Realism	*"I found the character's movements realistic."*
	Overall Realism	*"I found the character realistic overall."*
Affinity	Appeal	*"I found the character appealing ("Extremely" = the character is one that you would like to watch more of and would be captivated by a game with that character as the lead").*
	Eerie	*"I found the character eerie ("Not at all" = character restores a sense of security, confidence, calm in me. "Extremely" = character is gloomy and leaves me with a sense of fear)."*
	Familiar	*"I found the character familiar ("Extremely" = I have seen something similar to it before)."*
Co-presence	Co-presence	*"I perceived that I was in the presence of another person in the virtual room with me."*
	Alive	*"The character appeared to be sentient, conscious, and alive to me."*
	Computerised	*"I perceived the character as being only a computerised image, not as a real person."*

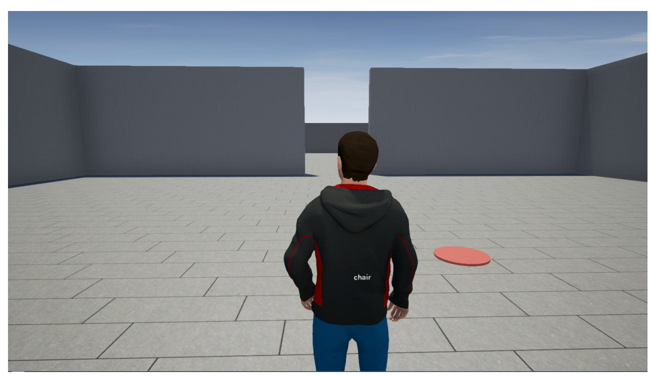

Figure 2: The virtual room. Character is shown from the back view where the second label was presented for the proximity task. Participants were instructed to navigate around the character, find both labels and exit the room (opening in the wall in front of the character).

3.3.1 Agency. As expected, participants reported high levels of Agency towards all virtual characters only in the Controlling group, as shown by the significant main effect of Condition ($F(1, 37) = 257.27, p \approx 0$). We see that *our two groups, Observing and Controlling,* *differed in the level of perceived agency towards the character, as expected.*

3.3.2 Realism. We found a significant main effect of Render Style on Appearance Realism ($F(2, 74) = 31.25, p \approx 0$), with all styles significantly different from each other and higher scores in the order Realistic (post–hoc: $p \approx 0$ for all), Toon CG, Toon Shaded (post–hoc: $p < 0.003$ between both non-realistic styles). Interestingly, a main effect for Render Style was found for Movement Realism ($F(2, 74) = 3.79, p = 0.027$), where Realistic render style was judged to have the most realistic motion, but post-hoc showed this was only true in comparison with Toon Shaded render style and the same was found for Overall Realism ($F(2, 74) = 25.43, p \approx 0$). Overall, *Realistic render style was recognised as most realistic in appearance, as expected. It even changed the perception of movement to be perceived as more realistic.*

3.3.3 Affinity. We found no main effects for the Appeal or Eeriness scales. There was a main effect of Render Style, which made a difference on Familiarity ratings (Friedman test: $\chi^2(2) = 22.33, p \approx 0$). Post–hoc revealed that the Realistic render style was considered significantly more familiar than the other render styles (Wilcoxon test: $p < 0.005$, for both). There was also a main effect of Participant Sex on Familiarity, where females gave lower Familiarity scores overall ($F(1, 37) = 4.37, p = 0.044$) and a further interaction with the Condition ($F(1, 37) = 8.52, p = 0.006$) showed that this was particularly the case when they were in the Observing group ($p < 0.009$). We conclude *that the Realistic render style is more familiar than the other two styles.*

3.3.4 Co-presence. Again, the Render Style had an effect on the Co-presence ratings. Participants perceived the characters to be more Alive and felt more Co-presence and less like a Computerised image in the case of the Realistic render style (Alive: $F(2, 74) = 7.23, p = 0.001$, post–hoc: $p < 0.005$; Co-presence: $F(2, 74) = 8.29, p = 0.001$, post-hoc: $p < 0.002$ for all; Computerised: $F(2, 74) = 17.42, p \approx 0$, post–hoc: $p < 0.001$). There was also an interaction between Render Style and Participant Sex for the Computerised ($F(2, 74) = 3.24, p = 0.045$), where male participants judged the Realistic render style to be less like a computerised image even in comparison to both styles ($p < 0.008$ for all), whereas female participants judged only the Toon Shaded render style to be more like a computerised image in comparison to Realistic render style ($p < 0.02$). We conclude that *the Realistic render style raised the level of perceived co-presence, a tendency which was slightly more pronounced when rated by male participants.*

3.3.5 Proximity. During the proximity task, the Euclidian distance of the current camera (user) position and the virtual character position in the virtual space was calculated for each moment. In order to calculate a representative value for the proximity task, the trajectory data needed to be cleaned. First, we discarded the part of the trajectory where the participant remains static at the beginning of the proximity task. We also discarded the part of the trajectory where the participant departs from the 5–meter circle ($4m$ from the $1m$ character collider) that surrounds the virtual character, heading towards the exit of the current virtual room. Some participants moved outside the circle but returned close to the character before heading towards the exit. We only discarded the data from the last time that they exited the circle.

Table 2: Descriptive statistics for medians of distances in Proximity task (Screen-based Experiment): Means, standard deviations (SD) and standard error (SE).

Observing

	N	Mean (cm)	SD	SE
Realistic	20	185.58	34.99	7.82
Toon CG	20	193.24	24.18	5.41
Toon Shaded	20	194.8	35	7.83

Controlling

	N	Mean (cm)	SD	SE
Realistic	21	182.31	36.76	8.02
Toon CG	21	180.77	34.62	7.55
Toon Shaded	21	173.91	31.39	6.85

Cleaned trajectory data was not found to be normally distributed. Hence, we chose to use the median of the distances for each participant as the response variable for the proximity task.

Table 2 shows the mean and standard errors of the median distance for participants on each controlling group and rendering style. Median distances from the characters were smaller for participants in Controlling condition, especially for the Toon Shaded style. However, variations were especially large.

To formally test for possible effects of our factors, we conducted a two-way repeated measure ANOVA. Data was tested for normality. No main effect or interactions of Render Style or any of the Condition groups (Controlling and Observing) were found. However, we found some interesting correlations with the questionnaire scales (see below).

3.3.6 Correlations. We analyzed the possible relationships between behavioural measures of Proximity and the subjective responses to the questionnaire to assess if people's perception of the character is reflected in their behaviour. Non-parametric Spearman's rank correlation tests were conducted on the results of both groups (Condition) of participants separately to analyze the data.

For the Observing group, a correlation between Proximity and Appeal was found. Participants from this group came slightly closer when they perceived the character to be more appealing ($r_s = -0.27, p = 0.048$). Even though the participants from this group did not have control over the character, they reported various levels of control and we found that Agency was related to Proximity ($r_s = -0.32, p = 0.014$). Participants also came closer when they perceived the character as more Alive ($r_s = -0.26, p = 0.044$).

For the Controlling group, similar patterns were not observed. We found no correlations between Proximity for perceived Agency or Appeal. However, participants came closer to characters, which they rated higher on the Eerie scale ($r_s = -0.33, p = 0.008$).

Overall, we conclude that *perceived (not actual) control will make people move closer to the virtual character. Other results seem to indicate participants approached them according to interest of observing details.*

4 VIRTUAL REALITY: EXPERIMENT 1

To determine if higher immersion and sense of co-presence with virtual characters would alter our results on proximity and affinity from the Screen–based Experiment, we implemented the same environment in the virtual reality setting.

The experiment framework was similar to Experiment 1. However, some modifications were made to maximise the performance on the current Oculus Rift system and to minimize the risk of simulation sickness. Specifically, light intensity in the scene was reduced, while we also removed one of the three lights on the characters' scenes (spot light behind the character). This permitted a frame rate above 75 fps, which is recommenced for Oculus Rift DK2. Although the added value of the third light would be an enhanced perception of depth on a flat TV-screen, we assumed that this would have minimal impact on a immersive VR setup, where stereoscopic view and motion parallax ensure perception of depth.

Moreover, using the same observation point as in the Screen-based Experiment, many details on the virtual character were inevitably lost in the VR setup, due to the screen resolution (1080x1200 per eye). We decided to move the observation point closer to the virtual character (3.5m), in order to allow a similar view of the rendered details (the recommended distance for objects in focus in DK2 is 0.7-3.5m).

Navigation was different in VR, since we used head tracking for camera rotations, and the Xbox controller for translation. We adjusted the speed of the camera and restricted side movements and camera rotations using the controller, in order to prevent simulation sickness. These changes significantly differentiated the way the proximity text was performed, hence, we avoided direct comparison of results from the Screen-based Experiment. Additionally, underestimation of distance has often been shown in VR (e.g., [Loomis et al. 1992]) so a direct comparison would not be appropriate.

Finally, the questionnaires were created as flat billboards inside the environment in order to allow stereoscopic view and to avoid interrupting the immersion.

We recruited 38 participants (28 males and 10 females, average age: 27.9) with the university department ethical approval and compensation of 5 EUR for their time. Participants were recruited, as before, with similar demographics. One participant was deaf, but did not show any difference on the task performance from the rest of the sample, so his data was not excluded. Participants were informed about the risks of VR and signed a consent form. They also had to initially adjust and calibrate the HMD. All other methods and procedures were kept the same as in the Screen-based Experiment.

4.1 Results

The same methods of statistical analysis were used as in the previous experiment: two-way repeated measure ANOVA, *Condition* and *Participant Sex* as between factors, *Render Style* as within factor; Tukey HSD for multiple comparisons. The data was tested for sphericity and homogeneity of variance. The results per individual scales are presented, as before, grouped in 4 categories (Table 1). Summary of results is presented in the Appendix 7.

4.1.1 Agency. Condition, as expected, had a main effect on the perceived Agency ($F(1, 34) = 106.94, p \approx 0$), where controlling the character would induce a higher level of agency. There was only one more main effect in this category of questions – regardless of which character participants saw or if they were controlling him or not, Participant Sex had an effect on Own Will ($F(1, 34) = 4.58, p = 0.040$), where males would perceive to a greater extent that the characters possessed their own will. There was no main effect of Render Style or Condition for the External Force question. As in Experiment 1, *agency was detected in the way it was intended by the experiment design, and we also observe some gender differences in the level of perceived control.*

4.1.2 Realism. Appearance Realism was judged with higher scores in the expected direction for all types of Render Style (Friedman test: $\chi^2(2) = 29.70, p \approx 0$; Wilcoxon post–hoc tests: $p < 0.02$, for all). Movement Realism was not affected by Condition, while Overall Realism was again influenced by Render Style (Friedman test: $\chi^2(2) = 13.41, p = 0.001$). Post–hoc revealed that Toon Shaded had a significantly lower realism overall than the other render style ($p < 0.02$ for all). Similarly as Experiment 1, *the realism of the Realistic render style was perceived to be higher than other styles while Toon Shaded was least realistic overall.*

4.1.3 Affinity. The Realistic render style was judged higher on Appeal overall ($F(2, 68) = 4.19, p = 0.019$; post-hoc: $p < 0.03$, for all). Similarly, Familiarity ratings were significantly higher for a Realistic render style as well ($F(2, 68) = 3.48, p = 0.036$), post–hoc, however, did not find significant differences for the Realistic render style in comparison to Toon Shaded and Toon CG. No effects were found for Eerie. We conclude that *the Realistic style in virtual reality was found to be more appealing and slightly more familiar than less realistic styles.*

4.1.4 Co-presence. Opposite to our expectations and regardless of the fact that the experiment was conducted in an immersive environment, Co-presence was rated low for all conditions. There was an effect of Render Style in the case of Alive, where Toon Shaded render style was perceived significantly less alive than other two styles ($F^*(1.71, 58.12) = 4.08, p = 0.027$; $p < 0.016$ for all) and the same style was considered significantly more as a Computerised image ($F(2, 68) = 4.64, p = 0.013$; post–hoc: $p < 0.015$ for all). Therefore, *even though this experiment was designed to be more immersive, the co-presence was low, especially with the Toon Shaded render style.*

4.1.5 Proximity. Table 3 reports the mean and standard errors of the median distances (trajectories were not normally distributed) for participants in each Condition. Average median distances from the characters were smaller for participants in the Controlling group, especially for the Toon CG style. However, as with Experiment 1, variations were especially large. The ANOVA results did not show any main effects of the factors.

4.1.6 Correlations. We computed Sperman's rank correlation test between behavioural measures Proximity and questions about perceived agency, co-presence and affinity and realism towards the character, for reasons already described in section 3.3.6, paragraph Correlations. This was done for both groups of participants separately.

Table 3: Descriptive statistics for medians of distances in Proximity task (VR Experiment) according to the Render Style: Means, standard deviations (SD), standard error (SE) corrected for within variability.

Observing

	N	Mean (cm)	SD	SE
Realistic	19	175.66	27.05	6.21
Toon CG	19	192.90	30.62	7.02
Toon Shaded	19	184.34	35.91	8.24

Controlling

	N	Mean (cm)	SD	SE
Realistic	19	181.37	20.16	4.62
Toon CG	19	182.61	21.4	4.91
Toon Shaded	19	186.31	27.37	6.28

In the Observing group, only one significant correlation was found, where participants kept more distance between them and the character when the perceived aliveness (Alive) was higher ($r_s = 0.30, p = 0.024$).

In the Controlling group, participants got closer to the characters when they perceived to have a higher level of control (Agency) over the character ($r_s = -0.29, p = 0.024$), as we predicted. Participants also got closer if they rated Movement Realism higher ($r_s = -0.27, p = 0.044$) and when they perceived the character to be highly Computerised ($r_s = -0.43, p = 0.001$).

Again, we see that *control over the character reduces the proximity distance, possibly indicating comfort when approaching the character. The observing condition made the character seem more alive, which increased the distance between the observer and the character.*

5 VIRTUAL REALITY: EXPERIMENT 2

In the previous virtual reality experiment, results on the proximity measure did not reveal differences in how participants approached the different render styles. This could have been due to the absence of an effect of the render style on people's personal distance towards the character or due to some other uncontrolled variable. For example, the motion of the participant in the previous experiment was restricted to gamepad controls, making the personal distance less likely to reflect an actual behavioral response to the characters. To rule out the possibility that participants' locomotion using a gamepad was the reason for the absence of a significant effect of render style on proximity, we conducted an experiment on a smaller sample using the HTC Vive system, where participants could approach the character more naturally – by walking through the tracking area (a feature not supported by our Oculus Rift system). We predicted that this change would significantly improve the reliability of the proximity measure by making it more ecologically valid. Related to that is the change from the previous measure of medians for proximity using two labels, to minimum distance by using only one label for the task and thus better representing the actual value of proximity as proposed by Bailenson et al. [2003]. While Vive and Oculus systems differ in screen resolution, this is consistent across render styles and should not affect our measures.

We recruited 18 participants (5 female and 13 male, average age 23.5), 9 for controlling and 9 for observing condition. They were recruited in the same fashion as in the previous experiments.

5.1 Stimuli Creation

To enable the tracking of the participants' position in virtual reality, we created a first person camera view by using the Steam VR plugin supported by Unreal Engine. The environment and characters used for the task were exactly the same as in previous experiment with a few modifications. Due to the restrictions of the size of the tracking area, the participants were no longer able to travel long distances in the environment, therefore the camera was placed near the observation spot, which also served as a teleportation target, which transported the participant to the next virtual room after the completion of all tasks. Participants were able to navigate through the virtual room by walking in the actual experiment room, which was calibrated for the system to capture ($3.0m \times 2.8m$). The observation distance was therefore placed closer to the character, at the edge of the capture area, while the character's position was at the opposite edge, giving $3.0m$ distance between the two. Also, participants only read one label at the front of the character, which is task design, commonly used in proximity research [Bailenson et al. 2001, 2005].

5.2 Results

The same methods of statistical analysis were used as in the previous experiment: two-way repeated measure ANOVA, *Condition* and *Participant Sex* as between factors, *Render Style* as within factor; for post–hoc tests, Tukey HSD was used. The data was tested for sphericity and homogeneity of variance. The results per individual scales are presented, as before, grouped in 4 categories (Table 1). Summary of the results is presented in Figure 3 and in Section 7. We briefly talk about subjective responses first and then present the results for proximity.

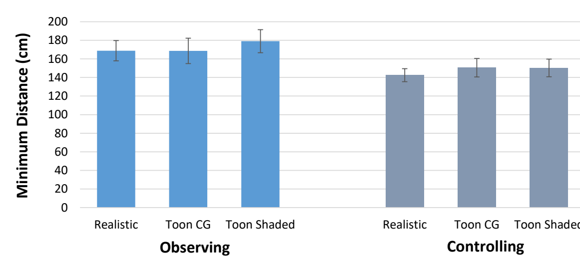

Figure 3: Virtual reality Experiment 2: minimum distance from the character per Condition and Render Style. Error bars show standard errors of means.

5.2.1 Subjective Responses. Similarly to the previous experiments, we got a main effect of Condition on Agency ($F(1, 14) = 98.87$, $p \approx 0$) and Render Style on Appearance ($F(2, 28) = 15.94$, $p \approx 0$) and Overall Realism ($F(2, 28) = 13.71, p \approx 0$) in the expected way, where Realistic was more real than other two styles in appearance ($p < 0.02$) and overall ($p < 0.03$). Similar result as in previous experiment was observed also for Computerised and Alive, but Co-presence was higher for the Realistic Render Style in comparison to the Toon Shaded in the present experiment ($F(2, 28) = 6.62$, $p = 0.004$; post-hoc: $p < 0.001$). We can conclude that *the ability to walk to the character did not change the experience significantly in comparison to the previous virtual reality experiment but it did slightly improve Co-presence for the Realistic character.*

5.2.2 Proximity. Proximity for this experiment was calculated based on the minimum distance as opposed to median of the trajectory, which is a more common measure used in proximity research [Bailenson et al. 2001]. Contrary to our expectations, we did not get any significant difference of Proximity for any of the variables. We did notice that participants approached characters closer when they were in the Controlling Condition but the difference was not significant (see Figure 3). *Enabling the participants to walk towards the character as opposed to using a gamepad to move through the environment did not significantly affect the proximity behavior.*

5.3 Discussion

Our results indicate that manipulating the appearance of the character mainly affected the subjective ratings of realism, affinity and co-presence. An important finding is, that realistic characters were preferred over more stylised representations, even though none of the styles were rated to be particularly unappealing and eerie. Preference for realism has been reported in previous studies which manipulated realism by changing the render style [Hyde et al. 2013; McDonnell et al. 2012]. In addition, our results showed this to be especially true for virtual reality environments.

Since the realistic character was not found to be particularly eerie, it is not surprising, based on our hypothesis, that render style did not affect the measure of proximity. We proposed the behavioral measure would show possible implicit effects of the realistic character on perception by increasing the proximity distance towards it. This was not supported by our results.

Contrary to our expectation, the experiment condition (controlling vs. observing) did not affect affinity ratings, only perceived agency was rated in the intended way. Proximity was also not affected, even though there was a tendency to stay further away from observed characters in the last experiment but this effect was not strong enough to be detected by the chosen analysis. Even though the analysis showed significantly lower levels of perceived control in the observing group as expected, some people still reported to have certain level of control (Participant's comment: *"The character started moving when I was correctly positioned on the red spot."*) and some participants in the controlling group did not feel completely in control of the character's motions. Indeed, when analyzing proximity results based on the perceived agency, we found that higher rated agency of the character decreased the size of the minimum distance. This indicates that agency, but only perceived one, affects proximity. In game design, proximity could therefore be used to assess the level of perceived agency towards a character.

In the observing group, proximity was associated with perceived aliveness (a component of co-presence), which increased the observing distance. This is an important result, since participants did not differ in their reports for co-presence according to the condition they were experiencing, but only participants in the observing group exhibited behavior which indicated higher co-presence. It could relate to the finding of Bailenson et al. [2004] where proximity was found to be a more sensitive measure than subjective reports. This result is even more interesting specifically because realistic render style increased the perceived aliveness and could potentially represent a link between realistic appearance and proximity. In summary, proximity seems to be related to subjective perception of agency over the character, but realism could serve as a mediator which increases the co-presence and could influence the proximity as well.

There were differences in ratings according to platforms. In a screen-based setup, people went closer to characters which they found appealing, especially when they were in the observing group, which might mean they felt more comfortable with them, found them more interesting to look at, etc. We also found differences between the Oculus and Vive displayed environments. With HTC Vive system, the realistic character induced higher co-presence. While this was unexpected, it is an interesting finding which probes further investigation.

It is important to note that co-presence was still relatively low for all setups. Previous studies linked co-presence with character's interaction with the user, even with minimal cues, such as eye-gaze [Bailenson et al. 2003], which we didn't include. An important feature was also missing from our study due to the specifics of the experiment design: self-avatar. This absence could have an important effect on behavioral [Bodenheimer and Fu 2015], size [Banakou et al. 2013] and distance judgments [Mohler et al. 2010]. We also included only minimal, neutral facial cues, but previous work has found differences in brain activation for approaches to menacing or friendly appearances [Carter et al. 2013], so the addition of detailed facial animation could change the perception of the realistic character. For the experiments, we used just one male character model. It is possible that different effects would occur with different render styles, or with more stylised geometry. Finally, we also used only one environment – creating more diverse environments in the same render style could change the viewer's experience.

In conclusion, we believe proximity could give a valuable insight for the design of agents and avatars during the creative process of a game since it could indicate the level of agency (VR and screen–based) and appeal (screen–based platforms). Realism also should not be avoided, as it helps inducing higher levels of co-presence and agency in immersive environments. Further tests are needed to investigate these relationships.

6 ACKNOWLEDGEMENTS

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7 APPENDIX

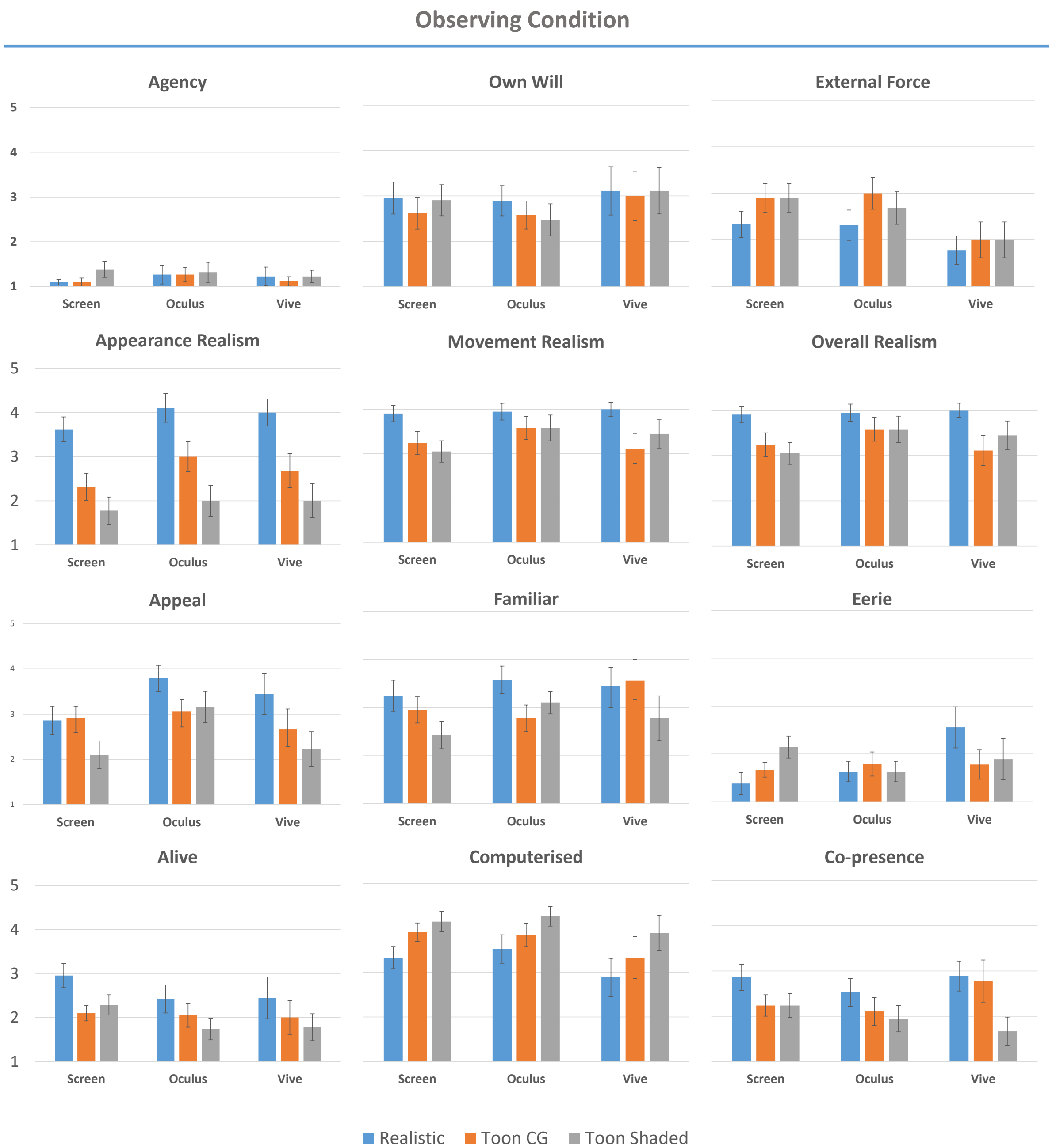

Figure 4: Subjective responses of participants in the observing group per scale. The bars represent means for each render style in the screen–based experiment (*Screen*), first virtual reality experiment (*Oculus*) and second virtual reality experiment (*Vive*). Error bars show standard errors of the means.

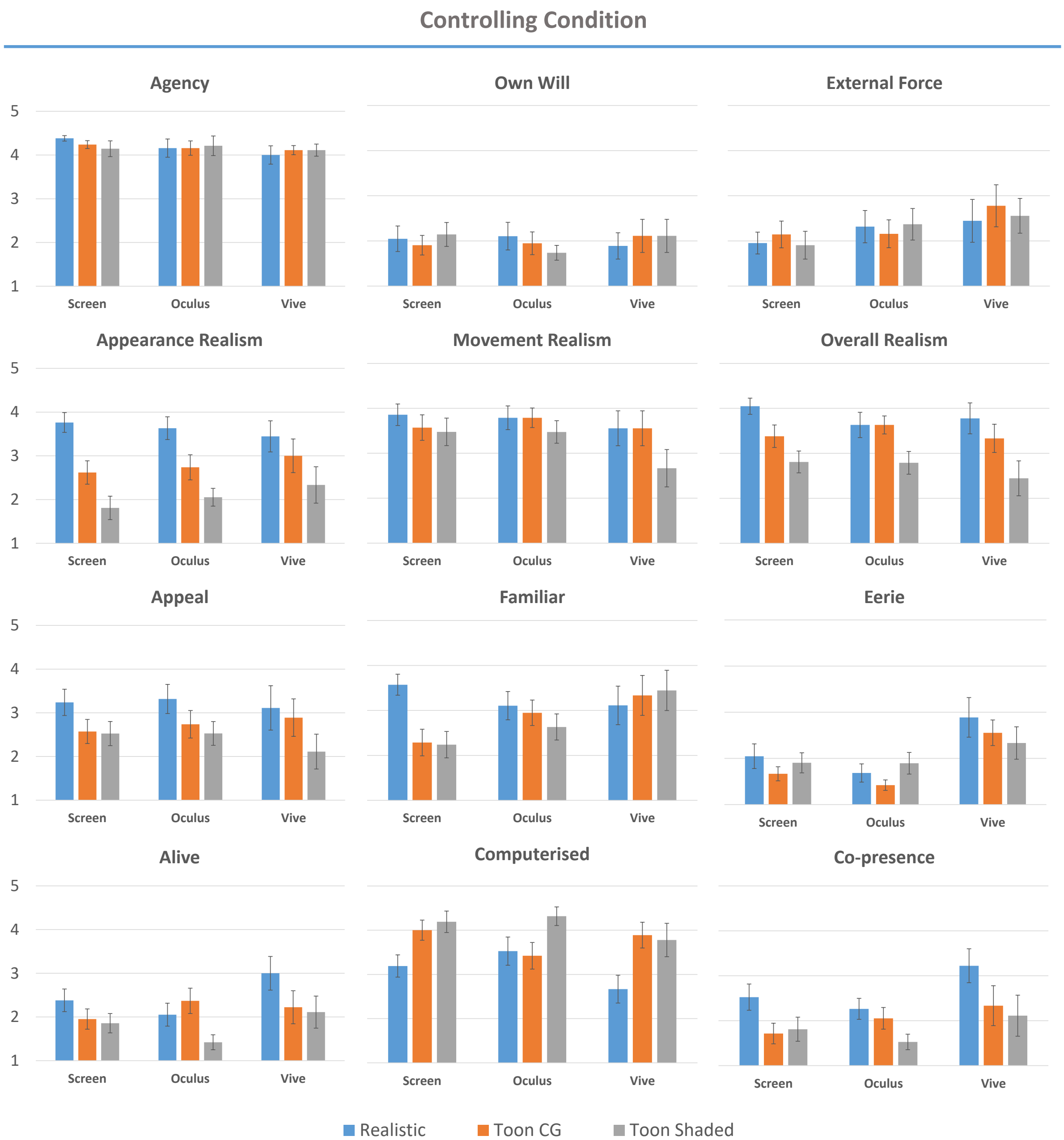

Figure 5: Subjective responses of participants in the controlling group per scale. The bars represent means for each render style in the screen–based experiment (*Screen*), first virtual reality experiment (*Oculus*) and second virtual reality experiment (*Vive*). Error bars show standard errors of the means.