“These are not my hands!”: Effect of Gender on the Perception of Avatar Hands in Virtual Reality

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ABSTRACT
Rendering the user’s body in virtual reality increases immersion and presence – the illusion of ‘being there’. Recent technology enables determining the pose and position of the hands to render them accordingly while interacting within the virtual environment. Virtual reality applications often use realistic male or female hands, mimic robotic hands, or cartoon hands. However, it is unclear how users perceive different hand styles. We conducted a study with 14 male and 14 female participants in virtual reality to investigate the effect of gender on the perception of six different hands. Quantitative and qualitative results show that women perceive lower levels of presence while using male avatar hands and male perceive lower levels of presence using non-human avatar hands. While women dislike male hands, men accept and feel presence with avatar hands of both genders. Our results highlight the importance of considering the users’ diversity when designing virtual reality experiences.

ACM Classification Keywords
H.1.2 User/Machine Systems: Human factors; I.3.0 Computer Graphics: General

Author Keywords
virtual reality; presence; uncanny valley; immersion; avatars

INTRODUCTION AND BACKGROUND
A core challenge of virtual reality (VR) is transporting people to another place and inducing the illusion of ‘being there’. The subjective experience of ‘being there’ as well as the ability to ‘act there’, even when one is physically situated in another place, is known as *presence* [5, 21]. Relating to the perception of VR, authors define presence as “the sense of being in an environment” [3] or “the outcome or a direct function of immersion” [17]. VR systems and applications are usually designed to maximize the experience of presence and often make use of virtual body representations of users, also known as their *avatars*, to provide a realistic and familiar interface between the own body and the virtual environment.

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Previous work shows that realism and appearance of avatars have an effect on experiencing presence in VR. The effect on presence using different levels of realism was examined by Vinayagamoorthy et al. [20]. While in a VR cave, participants reported that the lowest degree of presence was caused by more realistic characters. Similarly, Lugrin et al. measured a lower degree of body ownership using more realistic avatars in VR [10]. Authors of both works assume that their results might be the outcome of the *Uncanny Valley* phenomenon coined by Mori [12]. Mori’s hypothesis predicts that imperfections of appearance and motion of very human-like characters (e.g. robots [11] or animated CGI characters [7]) lead to an uncanny sensation by human observers.

Experiencing presence in VR depends on individual factors that should be considered when creating very immersive applications (cf. Lombard and Ditton [9]). It has been shown that there can be gender-related differences between men and women: For example, Felnhofer et al. suggest that regardless of age, men generally experience higher levels of presence than women in VR [4]. Schmidt et al., however, conclude that women feel higher levels of technology-related immersion and anxiety in VR [16]. Changes in interpersonal attitudes caused by using VR were found by Peck et al. [13]. The authors conclude that embodying light-skinned people in a dark-skinned virtual body can decrease participants’ implicit racial bias.

Displaying the user’s hand as the primary body part for interaction enables natural user interactions with the virtual world and has different effects on interaction (cf. [14, 2]). For example, Argelaguet et al. found that hand realism has an influence on the sense of agency, which is stronger for less realistic virtual hands [1]. The sense of ownership is increased for human virtual hands, which was confirmed by Lin and Jörg [8]. However, it is unclear whether and how the human-likeness of user controlled virtual hands influence the perceived sensation of presence in VR. Furthermore, it is unknown if virtual hands are perceived differently by men and women, especially when avatar hands from another gender are used.

In this exploratory study, we investigate the effect of different hands and gender on presence experienced by men and women in immersive virtual environments through a first-person VR experiment. Gender-related differences caused by violated expectations of how the own avatar have to look like would have consequences for designers and developers of immersive VR applications and games. We contribute with design implications for human avatar hands in immersive VR applications.

METHOD

The aim of our study is to investigate the effect of human and non-human virtual hands on presence perceived by men and women in VR. We use a mixed factorial design with the within-subjects variable *virtual hand* and the between-subjects variable *gender*. Participants answered quantitative questionnaires in VR and provided further feedback by thinking-aloud while performing three different tasks.

Stimuli

We used three realistic and three artificial hand models (see Figure 2). Male and female hand models were taken from the Leap Motion SDK. The male model has a haired skin texture and a muscular appearance. The female hands model has glossy nail textures and dainty fingers. An androgynous hand was created through an equal blending of meshes and textures from the male and female hands. We selected an abstract, cartoon, and robot hand as artificial hand models. The abstract hand model was extracted from the Leap Motion SDK and was equipped with white cylinders as bones and gray spheres as joints. For the cartoon model we smoothed the mesh topology of the androgynous hand and replaced the texture by a skin-colored toon shader with a black outline. Model and textures of the robot hands were extracted from the Genesis Bot model for the DAZ3D software application using a rigid skinning for the hand skeleton.

Apparatus and Tasks

Our apparatus consists of an Oculus Rift DK2 head-mounted display (HMD), a Leap Motion sensor, and an application developed in Unity3D. Our application uses the hand tracking of the Orion beta SDK provided by Leap Motion for VR support on HMDs. The Leap Motion sensor is mounted on the front of the Oculus Rift using a 3D-prined frame. Our experiment was running on a Windows PC with an Intel i7-6700, 16GB RAM, and a Nvidia GTX980. According to the refresh rate of the Oculus DK2 HMD, we set the target frame rate in Unity3D to 60 frames per second (fps). To ensure that the fps remains constant we designed a simple scene in Unity3D. To ensure that the tracking quality was throughout the same for all hands, we used throughout the same tracking system provided by Leap and the same configuration of bones.

We developed three different tasks which were used to ensure that the hands are present in the field of view of the participant and facilitate an immersive VR-experience: (1) in the *keyboard task* participants operate with a virtual keyboard to enter "I love VR" into a text display. (2) In the *draw task* participants paint curves and lines into the virtual space while moving their hands and performing a pinch gesture. Their task was to draw "Hello World" in 3D space. (3) In the *pyramid building task*, participants generate blocks on a virtual table by pressing a virtual button and built a small pyramid of at least 6 blocks. All scenes were blended using black fading. The application provides auditory feedback to confirm button presses through loudspeakers.

Measures

Post-test questionnaires are the most frequently used measures of presence in previous work. One disadvantage of post-test questionnaires is that they rely on subjects' memories, which reflect an inconsistent and incomplete picture of the VR-experience. We, therefore, developed a *VR questionnaire* which appears in front of the participant within the virtual environment. Thus, participants filled the virtual questionnaire using the virtual hands whose influence we measured (cf. suggestions by Frommel et al. [6] to avoid interruptions in immersive games). We decided to use the 32-item presence questionnaire by Witmer & Singer [21] due to following reasons: (1) it addresses related factors as involvement, naturalness, and interface (avatar) quality, (2) the presence questionnaire does not include any question that can not meaningfully be answered within the VR, and (3) the questionnaire has been used in a large number of studies (cf. [15, 19, 23]). In line with Schwind et al. [18] and according to our assumption that there are avatar-related factors that influence presence in VR, we asked for the perceived likeability, attractiveness, naturalness, and eerieness of the virtual hands on a 7-point Likert scale. We would like to remark that the direct measure of perceived naturalness could be a potential confound of the naturalness subscale in the presence questionnaire. Due to inconsistent or inconclusive outcomes of previous work, psychophysiological measures for presence as heart-rate, skin conductance, or electromyography (EMG) were not used.

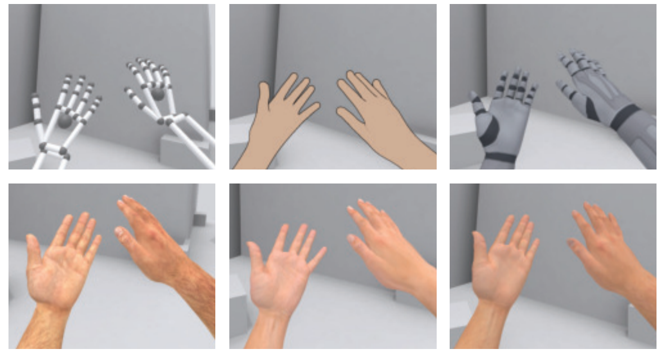

Figure 2. 1st row: screenshots of non-human hands: abstract, cartoon, robot; 2nd row: human hands: male, female, androgynous

Participants

Our sample was drawn from students and employees of our university. 14 male and 14 female participants from Central Europe with light skin tones took part in our experiment. The mean age was 26.07 years ($SD = 7.99$). Students received a compensation of 10€. Seventeen participants stated to have no VR experience at all, 11 had limited VR experiences.

Procedure

After signing the consent form, the participant was asked to take a seat in the middle of our VR-laboratory. We presented all devices and explained the procedure of the study. The direction of the virtual space was aligned according to the speakers placed in front of the participant. After setting up the HMD, a participant was familiarized with the first virtual hand and the first task. The participant could finish the task by pressing a button or showing a thumbs-up gesture. After each task, participants had to rate how they liked the task using a 7-point Likert item on a virtual panel presented in VR. Since not all questions could be displayed at once, a virtual wall containing four questions per page was presented. The

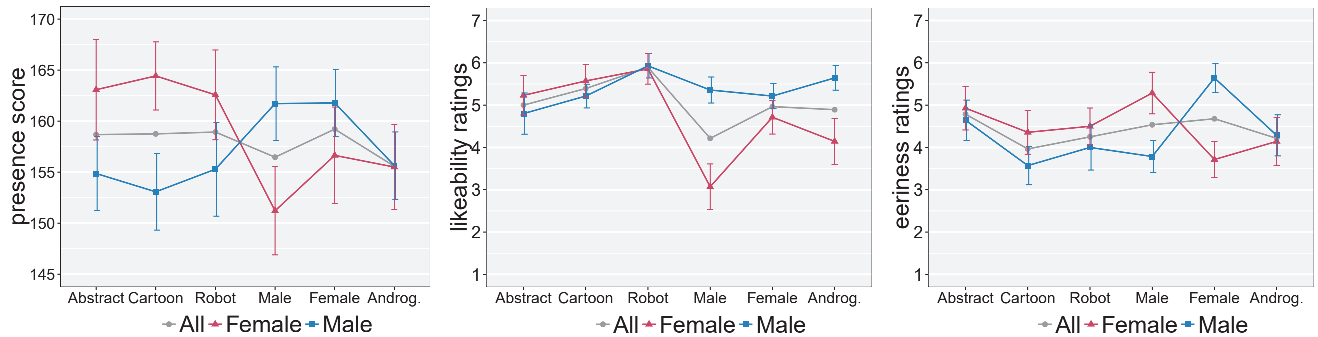

Figure 1. Gender related differences of presence (l.), likeability (c.), and eerieness (r.) between the avatar hand models. Virtual hands are sorted by mean naturalness ratings of all participants (not depicted). Presence scale ranges from 145 to 170. All error bars show standard error of the mean (SE).

participant could navigate through the questionnaire by pressing "next" and "back" buttons. As long as participants asked for no break, they remained in VR for all hands, tasks, and questions. Using thinking-aloud, we asked the participants to describe their thoughts, issues, and concerns. After finishing all questions the participant repeated the procedure using the next virtual hands. After leaving the VR, we handed out a questionnaire on a sheet of paper. We asked for comments about their concerns, what they would like to improve, and which hand they finally prefer.

RESULTS

On average, participants spent 58.6 minutes ($SD = 18.1$ min) in VR. Thus, the average time each participant used a virtual hand pair was 9.76 minutes.

Quantitative Results

Virtual hand style and gender of the participants were used as factors in a multi-factorial analysis of variance of aligned rank transformed data as introduced by Wobbrock et al. [22]. All pairwise cross-factor comparisons are Bonferroni corrected. Level of the significance level α is at .05.

We found no significant effect of hands $[F(5,130) = .345, p = .884]$ or gender $[F(1,26) = .272, p = .606]$ on perceived presence. However, the hands×gender interaction was significant $[F(5,130) = 3.898, p < .001]$. Pairwise cross-factor comparisons of gender and virtual hand revealed significant differences between the abstract and male hand ($p = .047$), male and robot hand ($p = .034$), as well as male and cartoon hand ($p = .003$). Other pairwise comparisons of presence showed not significant differences (all $p > .05$).

Hands had a significant effect on likeability $[F(5,130) = 5.903, p < .001]$ but we found no significant effect for gender $[F(1,26) = 3.549, p = .071]$. We found an interaction effect of hands×gender on likeability $[F(5,130) = 5.951, p < .001]$. Pairwise cross-factor comparisons revealed significant differences between the following hands: abstract and male ($p < .001$), abstract and androgynous ($p = .044$), male and robot ($p = .008$), male and cartoon($p < .001$), and cartoon and androgynous ($p = .043$) hands. Other pairwise comparisons of likeability ratings were not significant (all $p \geq .178$).

We found no significant effect of hands $[F(5,130) = 1.181, p = .322]$ or gender $[F(1,26) = .472, p = .498]$ on ratings of eeriness. However, the hands×gender interaction was significant $[F(5,130) = 4.157, p < .001]$ again. Pairwise cross-factor comparisons of gender and virtual hand revealed significant differences between male and female hands ($p < .001$) and female and cartoon hands ($p = .011$) hands for the eeriness ratings. Other pairwise comparisons of eeriness ratings showed no significant differences (all $p > .05$).

To understand which avatar-related factors influence presence, we conducted a multiple linear regression using the enter method. Ratings of likeability, eeriness, naturalness, and attractiveness were used as independent variables. The regression equation was significant $[R^2 = .441$, $R^2_{Adj.} = .195$, $SE = 19.138$, $F(4,163) = 9.854$, $p < .001$, $d = .784]$ for β-coefficients of naturalness ($\beta = -.159, p = .047$) and eerieness ($\beta = -.336, p < .001$). We found no significant effects on presence for likeability ($\beta = -.154, p = .171$) and attractiveness ($\beta = -.036, p = .755$). The scatterplot (not illustrated) of standardized residuals indicated that the data met the assumptions of homogeneity of variance, linearity, and homoscedasticity of the regression analysis. Assuming that the factors are independent, eeriness would explain 11% of the variance of the mean presence.

In the final questionnaire, presented after a participant had left the VR, we asked for demographics and which virtual hand they would like to use again in VR: 8 (5 male/3 female) participants would use the robot hand again, 7 participants (1 m./6 f.) the female hand, 5 (3 m./2 f.) the cartoon hand, 4 (3 m./1 f.) the androgynous hand, and 3 (1 m./2 f.) the abstract hand. One male would use the male hand again. Participants were also asked which hand they never would like to use again: 10 (3 m./7 f.) never would like to use the male hand again, 6 male the abstract hand, 6 (3 m./3 f.) the female hand, 3 female the cartoon hand, and 3 (2 m./1 f.) the androgynous hand.

Qualitative Results

Qualitative feedback was collected through think-aloud protocols to gain deeper insights into participants' perception. Participants' comments were transcribed, annotated, and analyzed. Through open coding, we analyzed why the avatar hands affect the experience of presence. Two researchers went through all transcribed notes to check each other's coding and to establish consistency in the assignment of codes to the same phenomena. A list of categories from the raw data was identified through underlining the key concepts. We found that participants' presence in VR was affected by three different deviations from their own hands:

(1) Deviations from human appearance were mostly mentioned using the non-human hands. Participants emphasized that too abstract styles are not uncanny but not familiar enough to feel present. Participants mentioned, for example, that they feel very uncomfortable using the abstract hands: "It's a completely unnatural arm – like a prosthesis. It distracts" (P8, m.); and "[...] too much abstraction feels unnatural and that abstraction is not really acceptable" (P6, m.). One participant was confused due to the shading of the cartoon hands. "I don't see how I should hold my hand correctly" (P25, f.). We found that female participants accept non-human hands when they consider them as "gloves" (P25, f.) or "a costume" (P20, f.).

(2) Deviations from one's gender were perceived while using virtual human hands. Especially women reacted negatively when interacting with male hands. One female participant nearly wanted to end the VR when starting to use the male hands: "I can't do that. This is so creepy!" (P23, f.). In particular hair on the male arms evoke very uncomfortable feelings: "This is so disgusting, greasy, chunky, hairy – I just want to have a shaver and wash my hands" (P20, f.). In contrast to male participants who regarded female hands as "very realistic" (P13, f.) or "unusual, but very attractive" (P10, m.).

(3) Deviations from the own body were noticed when participants used virtual human hands. For example, female participants draw direct comparisons with themselves when using female hands: "Where are my freckles?" (P19, f.), "I hadn't French manicure! These are not my hands!" (P22, f). "Proportions of these hands make it clear that these are not my own." (P8, m.). Deviations from the movement of their own hands were especially criticized by male participants. The quality of the tracking was criticized using virtual human hands, although the same tracking was used for all virtual hands: "The tracking of this [male] hand is significantly worse. [...] The abstract hand has the best tracking" (P2, m.).

We identified **habituation** and **excitement** (of being in VR) as factors with a positive effect on feeling presence while using virtual hands. Especially participants that had no VR experience were strongly involved as soon as they started a task. We observed, for example, a female participant starting with female hands and without VR experience who was immediately highly involved in the task. She naturally interacted fast and without any comments. On request, she explained that she did not even notice the hands because it "is self-explanatory to interact with them in this way". Furthermore, just being in another body was often considered positively and as exciting: "I love it! It's fun. It's so different to be another character, another type of sense and appearance" (P26, f.).

DISCUSSION AND CONCLUSION

In this paper, we investigated how virtual hands influence the perception of presence in VR. Using questionnaires integrated into VR we found that presence is perceived by men and women differently. Our results show that there are significant interaction effects of gender and hands on presence. Women, in particular, feel less presence and perceive more eeriness using virtual male hands. Women feel higher levels of presence using non-human hands. In contrast to men, who feel a higher level of presence using human hands including virtual female hands. We measured lower ratings and a significant difference between ratings of female's likeability for male hands in contrast to the male's likeability for female hands. Using regression analyzes we found that the perceived eeriness and naturalness of virtual hands have a significant effect on perceived presence.

Qualitative feedback provided by think-aloud protocols reveals potential reasons for the quantitative results. We found three levels of deviation from real hands which affect the feeling of presence: Deviations from common human appearance, the own gender, or the own body. We found that deviations from the own gender were perceived negatively by female participants. Women were averse to the hair on virtual male arms and feel disgusted and were distracted. They feel comfortable when they used non-human hands and regarded them as gloves or costumes. Men highlighted the perceived realism and the hand tracking quality and feel more present with human hands.

We conclude that women have increased expectations for their representation. However, eeriness ratings show that both women and men feel discomfort, when using hands of the other gender. An overall decrease of presence or likeability as predicted by the Uncanny Valley was not found. Lacking coherence between the perception and actual projection of the own presence as well as violations of a gender-specific appearance are potentially caused by an induced gender dysphoria – a negatively perceived mismatch of the actual (biological) sex and the perceived gender. We suggest that deviations from the own gender and the own self in VR should be investigated by further research.

Our findings have wide implications for designers: We suggest to avoid gender-swapping in very immersive VR applications and to provide male and female hands if human avatars are desired. An androgynous model without noticeable characteristics is a compromise while using human hands model. Suits, costumes, gender-neutral styles, or abstract avatar hands are rather preferred by women. The robot style seems the best trade-off between men and women for non-human avatars.

Effects of age, ethnicity, or the own skin tone were not investigated in our study and we can not draw conclusions about populations with other skin melanation, which should be investigated in further research. For example, previous work indicates that there are ethnicity-related changes in VR [13], which could also be investigated using different avatar styles. We also want to highlight that being accustomed to the VR experience probably means that the avatar is faded out by the user. Due to our positive experiences with questionnaires in VR, which do not only rely on a participant's memories, we suggest to use this measuring to collect subjective data in VR for future research. Source code and assets used in this experiment are available at github[1].

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[1] https://github.com/valentin-schwind/selfpresence

REFERENCES

1. Ferran Argelaguet, Ludovic Hoyet, Michaël Trico, and Anatole Lécuyer. 2016. The role of interaction in virtual embodiment: Effects of the virtual hand representation. *Proceedings - IEEE Virtual Reality* 2016-July (2016), 3–10. DOI:http://dx.doi.org/10.1109/VR.2016.7504682
2. Mahdi Azmandian, Mark Hancock, Hrvoje Benko, Eyal Ofek, and Andrew D. Wilson. 2016. Haptic Retargeting: Dynamic Repurposing of Passive Haptics for Enhanced Virtual Reality Experiences. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems (CHI '16)*. ACM Press. DOI: http://dx.doi.org/10.1145/2858036.2858226
3. Frank Biocca and Mark R. Levy. 2013. *Communication in the Age of Virtual Reality*. L. Erlbaum Associates Inc., Hillsdale, NJ, USA. 416 pages.
4. Anna Felnhofer, Oswald D Kothgassner, Nathalie Hauk, Leon Beutl, Helmut Hlavacs, and Ilse Kryspin-Exner. 2013. Physical and social presence in collaborative virtual environments: Exploring age and gender differences with respect to empathy. *Computers in Human Behavior* 31 (2013), 272–279. DOI: http://dx.doi.org/10.1016/j.chb.2013.10.045
5. Gary Fontaine. 1992. The Experience of a Sense of Presence in Intercultural and International Encounters. *Presence: Teleoperators and Virtual Environments* 1, 4 (1992), 482–490. DOI: http://dx.doi.org/10.1162/pres.1992.1.4.482
6. Julian Frommel, Michael Weber, Katja Rogers, Julia Brich, Daniel Besserer, Leonard Bradatsch, Isabel Ortinau, Ramona Schabenberger, Valentin Riemer, and Claudia Schrader. 2015. Integrated Questionnaires: Maintaining Presence in Game Environments for Self-Reported Data Acquisition. In *Proceedings of the 2015 Annual Symposium on Computer-Human Interaction in Play (CHI PLAY '15)*. ACM Press, 359–368. DOI: http://dx.doi.org/10.1145/2793107.2793130
7. Jari Kätsyri, Meeri Mäkäräinen, and Tapio Takala. 2016. Testing the âĂŸuncanny valley' hypothesis in semirealistic computer-animated film characters: An empirical evaluation of natural film stimuli. *International Journal of Human-Computer Studies* (sep 2016). DOI: http://dx.doi.org/10.1016/j.ijhcs.2016.09.010
8. Lorraine Lin and Sophie Jörg. 2016. Need a Hand?: How Appearance Affects the Virtual Hand Illusion. In *Proceedings of the ACM Symposium on Applied Perception (SAP '16)*. ACM, New York, NY, USA, 69–76. DOI:http://dx.doi.org/10.1145/2931002.2931006
9. Matthew Lombard and Theresa Ditton. 1997. At the Heart of It All: The Concept of Presence. *Journal of Computer-Mediated Communication* 3, 2 (1997). DOI: http://dx.doi.org/10.1111/j.1083-6101.1997.tb00072.x
10. Jean-Luc Lugrin, Johanna Latt, and Marc Erich Latoschik. 2015. Anthropomorphism and Illusion of Virtual Body Ownership. In *Proceedings of the 25th International Conference on Artificial Reality and Telexistence and 20th Eurographics Symposium on Virtual Environments (ICAT - EGVE '15)*. Eurographics Association, 1–8. DOI: http://dx.doi.org/10.2312/egve.20151303
11. Karl F. MacDorman, Robert D. Green, Chin Chang Ho, and Clinton T. Koch. 2009. Too real for comfort? Uncanny responses to computer generated faces. *Computers in Human Behavior* 25, 3 (may 2009), 695–710. DOI: http://dx.doi.org/10.1016/j.chb.2008.12.026
12. Masahiro Mori, Karl F MacDorman, and Norri Kageki. 1970/2012. The Uncanny Valley [From the Field]. *Robotics & Automation Magazine, IEEE* 19, 2 (1970/2012), 98–100. DOI: http://dx.doi.org/10.1109/MRA.2012.2192811
13. Tabitha C. Peck, Sofia Seinfeld, Salvatore M. Aglioti, and Mel Slater. 2013. Putting yourself in the skin of a black avatar reduces implicit racial bias. *Consciousness and Cognition* 22, 3 (sep 2013), 779–787. DOI: http://dx.doi.org/10.1016/j.concog.2013.04.016
14. Mamy Pouliquen, Alain Bernard, Jacques Marsot, and Laurent Chodorge. 2007. Virtual hands and virtual reality multimodal platform to design safer industrial systems. *Computers in Industry* 58, 1 (2007), 46–56. DOI: http://dx.doi.org/10.1016/j.compind.2006.04.001
15. Patrice Renaud, Joanne L Rouleau, Luc Granger, Ian Barsetti, and Stéphane Bouchard. 2002. Measuring sexual preferences in virtual reality: A pilot study. *CyberPsychology & Behavior* 5, 1 (2002), 1–9. DOI: http://dx.doi.org/10.1089/109493102753685836
16. Mareike Schmidt, Johanna Xenia Kafka, Oswald D. Kothgassner, Helmut Hlavacs, Leon Beutl, and Anna Felnhofer. 2013. *Why Does It Always Rain on Me? Influence of Gender and Environmental Factors on Usability, Technology Related Anxiety and Immersion in Virtual Environments*. Springer International Publishing, Cham, 392–402. DOI: http://dx.doi.org/10.1007/978-3-319-03161-3_29
17. Thomas Schubert, Frank Friedmann, and Holger Regenbrecht. 2001. The Experience of Presence: Factor Analytic Insights. *Presence: Teleoperators and Virtual Environments* 10, 3 (2001), 266–281. DOI: http://dx.doi.org/10.1162/105474601300343603
18. Valentin Schwind, Katrin Wolf, Niels Henze, and Oliver Korn. 2015. Determining the Characteristics of Preferred Virtual Faces Using an Avatar Generator. In *Proceedings of the 2015 Annual Symposium on Computer-Human Interaction in Play (CHI PLAY '15)*. ACM Press, 221–230. DOI: http://dx.doi.org/10.1145/2793107.2793116
19. Kay M. Stanney, Kelly S. Kingdon, David Graeber, and Robert S. Kennedy. 2002. Human Performance in Immersive Virtual Environments: Effects of Exposure Duration, User Control, and Scene Complexity. *Human*

Performance 15, 4 (2002), 339–366. DOI: http://dx.doi.org/10.1207/S15327043HUP1504_03

20. Vinoba Vinayagamoorthy, Andrea Brogni, Marco Gillies, Mel Slater, and Anthony Steed. 2004. An investigation of presence response across variations in visual realism. In *The 7th Annual International Presence Workshop*. 148–155.
21. Bob G. Witmer and Michael J. Singer. 1998. Measuring Presence in Virtual Environments: A Presence Questionnaire. *Presence: Teleoperators and Virtual Environments* 7, 3 (1998), 225–240. DOI: http://dx.doi.org/10.1162/105474698565686
22. Jacob O. Wobbrock, Leah Findlater, Darren Gergle, and James J. Higgins. 2011. The Aligned Rank Transform for Nonparametric Factorial Analyses Using Only Anova Procedures. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '11)*. ACM Press, 143–146. DOI: http://dx.doi.org/10.1145/1978942.1978963
23. Christine Youngblut and Odette Huie. 2003. The relationship between presence and performance in virtual environments: results of a VERTS study. In *IEEE Virtual Reality, 2003. Proceedings.*, Vol. 2003-Janua. IEEE Comput. Soc, 277–278. DOI: http://dx.doi.org/10.1109/VR.2003.1191158