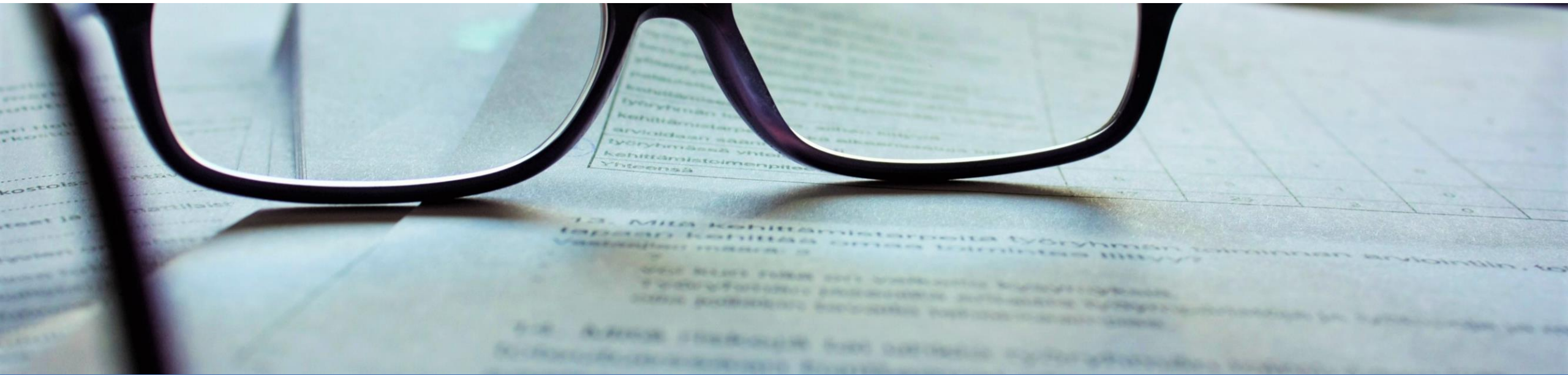




How to Read a Paper

Human-Computer Interaction Exercise

Preperation

- **Be in the university's subnet**
 - › If not: goto <https://www.frankfurt-university.de/de/hochschule/bibliothek/fernzugriff/>
 - › Install VPN (Forticlient)
- Later you will need and use **a literature management system**
 - › You can use Zitavi or Zotero: <https://www.frankfurt-university.de/de/hochschule/bibliothek/citavi-zotero/>
 - › Both are free (for you)
- **A ChatGPT Account** is helpful
 - › ChatGPT Plus is even more helpful

Find your Keywords

- **Use your keywords from your research question** to start searching for literature
- **Make a list** of other **keywords/annotations**
 - › Include each of the key concepts or variables you're interested
 - › Find synonyms and related terms
- How to find keywords? Identify your **research fields, theoretical frameworks, device categories, and measures (or methods)**
 - › **Research field(s):** "human-computer interaction" (rarely required),...
 - › **Theoretical frameworks:** "social acceptability", „accessibility“, „ergonomics“, ...
 - › **Device categories:** "virtual reality", „augmented reality“, „wearables“, „mobile devices“, ...
 - › **Measures/Tasks:** "target selection", „Fitts' law“, "EMG", "electromyography", ...
 - › **Be more specific, if required:** "heart rate", „privacy“, „face detection“, ...

Databases

- Some useful databases to **search for journals and conferences articles**:
 - › Google Scholar <https://scholar.google.de/>
 - › ACM <https://dl.acm.org/>
 - › IEEE <https://ieeexplore.ieee.org/>
 - › Web of Science <https://www.webofscience.com/>
 - › Scopus <https://www.scopus.com/>
 - › The university's library <https://idp.hebis.de/>
 - › JSTOR (history) <https://www.jstor.org/>
 - › Project Muse (humanities and social sciences) <https://muse.jhu.edu>
 - › PubMed (life sciences and biomedicine) <https://pubmed.ncbi.nlm.nih.gov/>

Google Scholar



☒ Articles ☐ Case law

Refine your Query

The image shows a Google Scholar interface with a red box highlighting the 'Advanced search' option in the left sidebar. An arrow points from this box to a larger 'Advanced search' panel. This panel contains several search criteria: 'Find articles with all of the words' (input: 'target selection AND reality'), 'with the exact phrase' (empty), 'with at least one of the words' (input: 'virtual augmented mixed extended'), 'without the words' (empty), 'where my words occur' (radio buttons for 'anywhere in the article' and 'in the title of the article', with 'in the title of the article' selected), 'Return articles authored by' (empty), 'Return articles published in' (empty), and 'Return articles dated between' (empty range). Another arrow points from the bottom of the 'Advanced search' panel to a search results box. This box shows the query 'allintitle: target selection AND reality virtual OR augmented OR mixed OR ext' and 8 results. The top result is 'Pinpointing: Precise head-and eye-based target selection for augmented reality' by M Kytö, B Ens, T Piumsomboon, and GA Lee, published in 2018. The abstract mentions 'target size for robust selection' and 'augmented reality'.

Google Scholar

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Metrics

Advanced search

Settings

Advanced search

Find articles

with **all** of the words

with the **exact phrase**

with **at least one** of the words

without the words

where my words occur

Return articles **authored by**

Return articles **published in**

Return articles **dated** between

target selection AND reality

virtual augmented mixed extended

anywhere in the article

in the title of the article

e.g., "PJ Hayes" or McCarthy

e.g., J Biol Chem or Nature

e.g., 1996

allintitle: target selection AND reality virtual OR augmented OR mixed OR ext

8 results (0,18 sec)

Pinpointing: Precise head-and eye-based **target selection** for **augmented reality** [PDF] acm.org

M Kytö, B Ens, T Piumsomboon, GA Lee... - Proceedings of the ..., 2018 - dl.acm.org

... **target** size for robust **selection**. We demonstrate **and** discuss example applications for **augmented reality**, including compact menus with deep structure, **and** a proof-of-concept method ...

☆ Save 📄 Cite Cited by 175 Related articles All 6 versions

Enter your keywords

Google Scholar

The image shows a Google Scholar search interface. The search bar contains the query: `("target selection" OR "target acquisition") AND ((virtual OR augmented OR r`. A red box labeled "Click" points to the search button. Below the search bar, it says "About 17,100 results (0,03 sec)".

On the left sidebar, there are filters for "Highly cited. We love that" (highlighted with a red box), "Since 2022", "Since 2021", "Since 2018", "Custom range...", "Sort by relevance", "Sort by date", "Any type", "Review articles", "include patents", "include citations", and "Create alert".

The search results list several papers. The first paper is "Pinpointing: Precise head-and eye-based **target selection** for **augmented reality**" by M Kytö, B Ens, J Piumsomboon, GA Lee... (2018). A red arrow points from the "Highly cited" box to this paper. An orange arrow points from the "Click Later" box to the PDF link. The second paper is "Fully-occluded **target selection** in **virtual reality**" by D Yu, Q Zhou, J Newn, T Dingler... (2020). An orange arrow points from the "Click Later" box to the PDF link. The third paper is "Investigating bubble mechanism for ray-casting to improve 3D **target acquisition** in **virtual reality**" by Y Lu, C Yu, Y Shi... (2020). An orange arrow points from the "Click Later" box to the PDF link. The fourth paper is "NotiBike: Assessing **Target Selection** Techniques for Cyclist Notifications in **Augmented Reality**" by T Kosch, A Matvienko, F Müller, J Bersch... (2022). An orange arrow points from the "Click Later" box to the PDF link. The fifth paper is "Eyes-free **target acquisition** in interaction space around the body for **virtual**".

Annotations include:

- Click**: A red box pointing to the search button.
- Click Later**: An orange box with arrows pointing to the PDF links of the first four papers.
- Highly cited. We love that**: A red box pointing to the first paper.

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Frankfurt University of Applied Sciences

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Affiliations

Award Winners

Home > Conferences > CHI > Proceedings > CHI '18 > Pinpointing: Precise Head- and Eye-Based Target Selection for Augmented Reality

RESEARCH-ARTICLE • Best paper award

The title

Pinpointing: Precise Head- and Eye-Based Target Selection for Augmented Reality

The authors

Authors: Mikko Kytö, Barrett Ens, Thammathip Plumsomboon, Gun A. Lee, Mark Billinghurst [Authors Info & Claims](#)

The conference or journal

CHI '18: Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems • April 2018 • Paper No.: 81 • Pages 1–14 • <https://doi.org/10.1145/3173574.3173655>

Highly cited

Online: 19 April 2018 [Publication History](#)

107 3,617

eReader PDF

Read this

CHI '18: Proceedings of the 2018 CHI...

Pinpointing: Precise Head- and Eye-Based Target Selection for Augmented Reality

Pages 1–14

[Previous](#) [Next](#)

ABSTRACT

Supplemental Materials

ABSTRACT

Head and eye movement can be leveraged to improve the user's interaction repertoire for wearable displays. Head movements are deliberate and accurate, and can be used as a state-of-the-art pointing technique. Eye gaze can potentially be faster and more accurate than hand-based pointing from low accuracy due to calibration errors and drift of wearable eye-tracking sensors. This work investigates precise, multimodal selection techniques using head motion and eye gaze. A comparison of speed and pointing accuracy reveals the relative merits of each method, including

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SCROLL DOWN!!!

How to Read a Paper

Prof. Dr. Valentin Schwind

8

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Pages 1–14

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ABSTRACT

[Supplemental Material](#)

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the achievable target size for robust selection. We demonstrate and discuss example applications for augmented reality, including compact menus with deep structure, and a proof-of-concept method for on-line correction of calibration drift.



Video for people who don't want to read the abstract

Supplemental Material

Pointing modes

suppl.mov

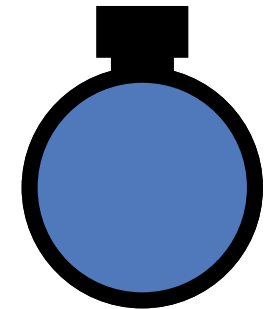
 

☒ Articles ☐ Case law

Exercise: Find and describe a paper that measuring user experience in video games

1. Go to <https://scholar.google.com> ...
2. Enter the related keywords
3. Click on results that seems to be relevant...
4. Find and open a paper (if not possible open the next one)...
5. Find and describe what they measured...

You have 5 minutes...



Issues in Understanding Scientific Reports in HCI

- What could you find?
- How did you select the paper?
- How did you ensure that you found a good paper?
- Do you understand it?
- What was your problem?
- Why was it difficult to understand?

Research Paper in HCI

- **Empirical Papers:** Describes material and data used for an empirical user study, the methodologies applied to answer the research questions and the results obtained.
- **Case Study Papers:** Used to describe the study of a certain person, group, location, event, or situation.
- **Methodology Papers:** Describe a novel method which may be intended for use in research or practical settings (or both).
- **System/Data Papers:** Describes material and design process of set. They contain no empirical user study. **Original Research / Primary Research**
- **Literature Reviews/Survey Papers:** Provide insights and an overview about the field and have their own contribution **Secondary Research**
- **Theory/Position/White/Ontology Papers:** Describe definitions, principles, concepts or models on which work in the field (empirical, experience, met) **Popular science**

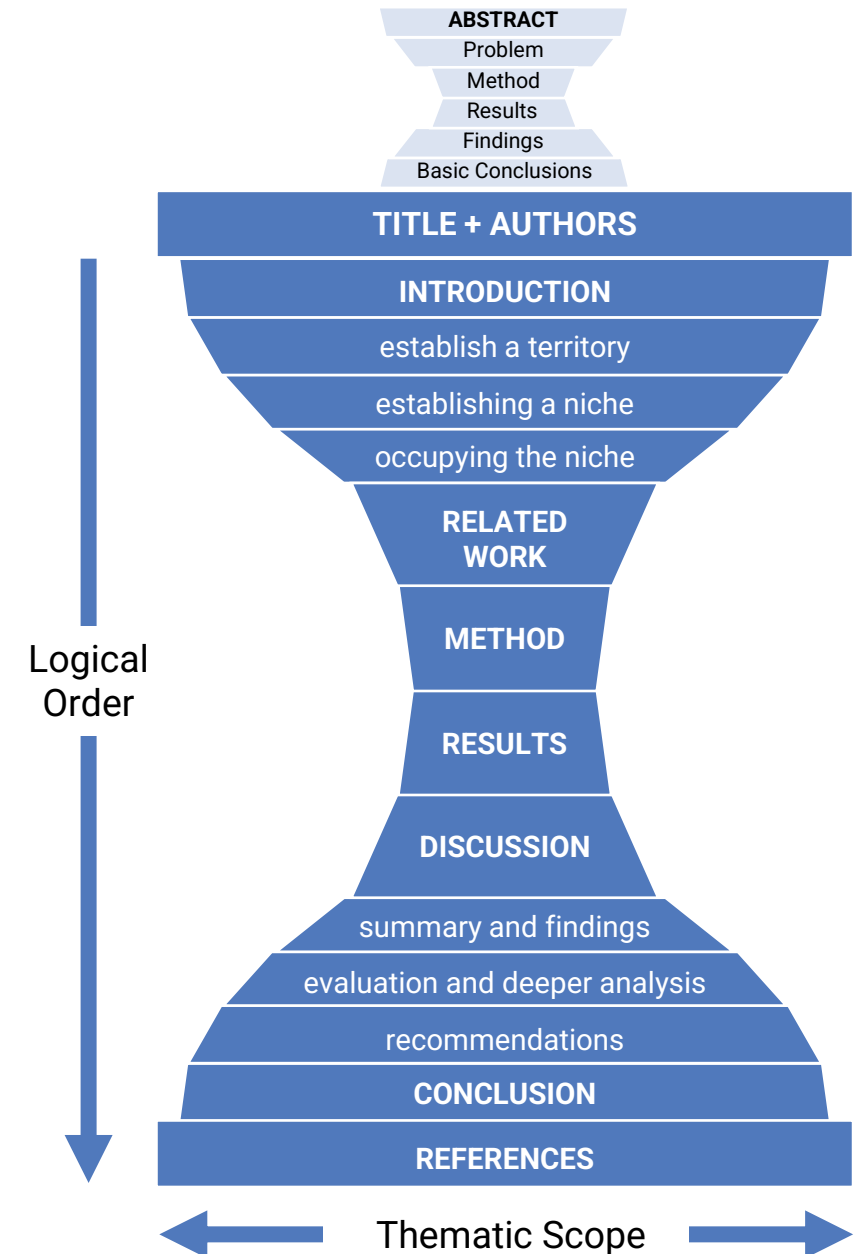
The IMRAD Structure

- **IMRAD**: Introduction, **M**ethods, **R**esults, **a**nd **D**iscussion
- All research articles (and yours) are typically structured in this order
 - › **Introduction** – Why was the study undertaken? What was the research question, the tested hypothesis or the purpose of the research?
 - › **Related Work** – What are findings of previous work before the study was undertaken?
 - › **Methods** – When, where, and how was the study done? What materials were used or who was included in the study groups (patients, etc.)?
 - › **Results** – What answer was found to the research question; what did the study find? Was the tested hypothesis true?
 - › **Discussion** – What might the answer imply and why does it matter? How does it fit in with what other researchers have found? What are the perspectives for future research?

[1] <https://en.wikipedia.org/wiki/IMRAD>

The Paper as an Hourglass

- **ABSTRACT**
- **INTRODUCTION**
 - › Motivation & Problem Statement
 - › Theoretical Background
 - › Research Question
 - › Hypothesis
- **RELATED WORK**
- **METHOD**
 - › Study Design
 - › Independent Variables
 - › Dependent Variables
 - › Apparatus
 - › Tasks
 - › Procedure
 - › Participants
- **RESULTS**
 - › Descriptive statistics
 - › Inferential statistics (No interpretation!)
- **DISCUSSION**
 - › Brief summary of findings
 - › Discussion/Interpretation of findings
 - › Relation to previous/related work
 - › Limitation of the study
- **CONCLUSION**
- **(CONTRIBUTION)**
- **(ACKNOWLEDGEMENTS)**



Example:

- Valentin Schwind, Pascal Knierim, Lewis Chuang, and Niels Henze. 2017. "Where's Pinky?": The Effects of a Reduced Number of Fingers in Virtual Reality. In Proceedings of the Annual Symposium on Computer-Human Interaction in Play (CHI PLAY '17). Association for Computing Machinery, New York, NY, USA, 507–515.

<https://doi.org/10.1145/3116595.3116596>



Example: Title and Authors

Sometimes papers have catchy titles or acronyms..

Obviously it's about missing fingers in VR

It's a conference paper and obviously from 2017

Authors

The affiliations

I still have a redirection on that mail

Section 9: VR and Other Novel IO Technology

CHI PLAY 2017, October 15–18, 2017, Amsterdam, NL

“Where’s Pinky?”: The Effects of a Reduced Number of Fingers in Virtual Reality

Valentin Schwind^a, Pascal Knierim^a, Lewis Chuang^b, Niels Henze^a

^aVIS, University of Stuttgart
Stuttgart, Germany
{firstname.lastname}@vis.uni-stuttgart.de

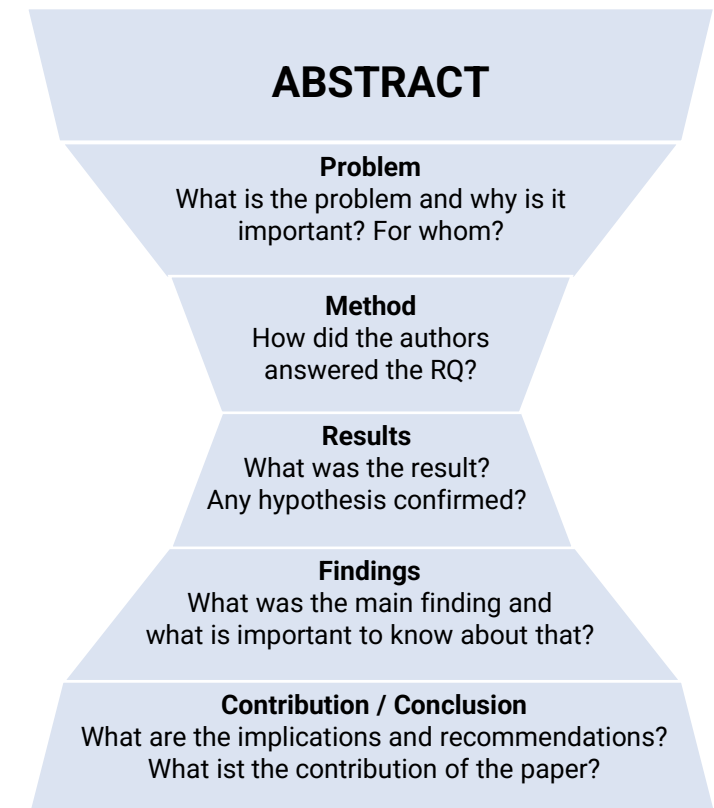
^bMax Planck Institute for Biological Cybernetics
Tübingen, Germany
{firstname.lastname}@tuebingen.mpg.de

ABSTRACT
The hands of one’s avatar are possibly the most visible aspect when interacting in virtual reality (VR). As video games in VR

concept of ‘being’ or ‘acting’ in a virtual environment while physically situated in another place. Avatars in VR also provide a natural and intuitive interface for the user to interact

Abstract

- Typically, 150 - 250 words
- **Briefly introduces the reader** to
 - › motivation, problem, and relevance
 - › the aims of the study and which methods were used
 - › results and findings
 - › conclusion & contribution
- Ideally, each sentence deals about one section in your paper
- The abstract **always answers** these four questions:
 - › Why did you do this?
 - › What did you do?
 - › What did you find?
 - › What do your findings mean?



Abstract: Tips for reading

- **Reflect the structure** of the paper
 - › Bear in mind that there is a match between abstract and paper
 - › Ideally, each section of your paper belongs to one sentence in the paper
- **Search for what they did and why**
 - › What did they developed?
 - › How many participants were tested?
 - › What happened during the study?
- **Find the contribution**
 - › What is the key benefit for readers?
 - › For whom it is interesting?
 - › How is the contribution articulated? (Which words are used, are there any 'modulators', e.g. 'Perhaps ... suggests ... might ... could ...?')

The Abstract

ABSTRACT

The hands of one's avatar are possibly the most visible aspect when interacting in virtual reality (VR). As video games in VR proliferate, it is important to understand how the appearance of avatar hands influence the user experience. Designers of video games often stylize hands and reduce the number of fingers of game characters. Previous work shows that the appearance of avatar hands has significant effects on the user's presence—the feeling of 'being' and 'acting' in VR. However, little is known about the effects of missing fingers of an avatar in VR. In this paper, we present a study ($N = 24$) that investigated the effect of hand representations by parametrically varying the number of fingers of abstract and realistically rendered hands. We show that decreasing the number of fingers of realistic hands leads to significantly lower levels of presence, which is not the case for abstract hands. Qualitative feedback collected through think-aloud and video revealed potential reasons for the different assessment of realistic and abstract hands with fewer fingers in VR. We contribute design implications and recommend considering the human-likeness when a reduction of the number of fingers of avatar hands is desired.

“Where’s Pinky?”: The Effects of a Reduced Number of Fingers in Virtual Reality

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^aVIS, University of Stuttgart

Stuttgart, Germany

{firstname.lastname}@vis.uni-stuttgart.de

^bMax Planck Institute for Biological Cybernetics

Tuebingen, Germany

{firstname.lastname}@tuebingen.mpg.de

ABSTRACT

The hands of one's avatar are possibly the most visible aspect when interacting in virtual reality (VR). As video games in VR proliferate, it is important to understand how the appearance of avatar hands influence the user experience. Designers of video games often stylize hands and reduce the number of fingers of game characters. Previous work shows that the appearance of avatar hands has significant effects on the user's presence—the feeling of 'being' and 'acting' in VR. However, little is known about the effects of missing fingers of an avatar in VR. In this paper, we present a study ($N = 24$) that investigated the effect of hand representations by parametrically varying the number of fingers of abstract and realistically rendered hands. We show that decreasing the number of fingers of realistic hands leads to significantly lower levels of presence, which is not the case for abstract hands. Qualitative feedback collected through think-aloud and video revealed potential reasons for the different assessment of realistic and abstract hands with fewer fingers in VR. We contribute design implications and recommend considering the human-likeness when a reduction of the number of fingers of avatar hands is desired.

ACM Classification Keywords

H.1.2 User/Machine Systems: Human factors; I.2.7 Three-Dimensional Graphics and Realism: Virtual reality

Author Keywords

Virtual reality; presence; lacking fingers; immersion; avatars.

INTRODUCTION

With the rise of virtual reality (VR) and head-mounted displays (HMDs), the need for understanding how and why the human brain perceives and accepts the virtual world is becoming more and more important. This is particularly relevant for researchers and designers of immersive VR games and applications. A key feature of upcoming VR technologies and games is rendering the user's body in the virtual world using avatars. Avatars in VR significantly increase the user's immersion and the feeling of presence [11]—one of the key

concepts of 'being' or 'acting' in a virtual environment while physically situated in another place. Avatars in VR also provide a natural and intuitive interface for the user to interact with the surrounding virtual world. The most important body parts for interaction through avatars in VR are one's hands and fingers. Using current game controllers, virtual hands can be displayed in VR. Today's technologies even allow motion tracking of hands and fingers without wearing additional motion controllers or markers. Thus, arms, hands, and fingers can be rendered in VR according to their real pose and location.

For video games, however, it is not only important to provide hands for interaction but also to understand how their appearance influences the experience of the user. Designers of video games have unlimited freedom to vary the appearance of an avatar. Cartoonists, for example, simplify their drawings due to the thickness of black outlines. Thus, to avoid too big hands or overlapping of the black outlines, they reduce the number of fingers of their characters. This kind of stylization was adopted and preserved by many video games such as in *Earthworm Jim*, the *Rayman* series, *The Smurfs*, or *Simpsons – The Game*.

Designers can also reduce the number of fingers in realistic ways. In 2009, the cover art of the game *Left4Dead 2* showed a hand with a severed little finger, ring finger, and thumb. To appease the Entertainment Software Rating Board (ESRB) game developer Valve changed the cover in a way that the index and middle fingers remained [19]. In video games, designers reduce the number of fingers in a realistic way as for the aliens in *Avatar – The Game* or Elizabeth's character in *BioShock Infinite*. Thus, the body structure of game avatars in VR does not necessarily match the structure of the user's body. However, little is known about the effects of a reduced number of fingers on the user experience and perception of presence in VR.

To investigate the effect of varying an avatar's number of fingers we conducted a study in VR. We tested five-, four-, three-, and two-fingered hands rendered with a realistic and an abstract style. We collected quantitative and qualitative data. We not only show that reducing the number of fingers significantly affect the perceived presence but also show that this effect depends on the realism of the avatar. This has consequences for VR users and, thus, is relevant for researchers and designers of immersive VR games and applications. We discuss further effects and potential factors that influence the user experience of being in VR with fewer fingers. We contribute implications for game and VR designers.

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CHI PLAY '17, October 15–18, 2017, Amsterdam, Netherlands

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DOI: <https://doi.org/10.1145/3116595.3116596>

The Keywords

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H.1.2 User/Machine Systems: Human factors; I.3.7 Three-Dimensional Graphics and Realism: Virtual reality

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Valentin Schwind^a, Pascal Knierim^a, Lewis Chuang^b, Niels Henze^a

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Dissecting the Abstract

- **RELEVANCE:** The hands of one's avatar are possibly the most visible aspect when interacting in virtual reality (VR). As video games in VR proliferate, it is important to understand how the appearance of avatar hands influence the user experience. Designers of video games often stylize hands and reduce the number of fingers of game characters.
- **PREVIOUS WORK:** Previous work shows that the appearance of avatar hands has significant effects on the user's presence—the feeling of 'being' and 'acting' in VR.
- **THE PROBLEM:** However, little is known about the effects of missing fingers of an avatar in VR
- **THE STUDY:** In this paper, we present a study (N = 24) that investigated the effect of hand representations by parametrically varying the number of fingers of abstract and realistically rendered hands.
- **RESULTS + FINDINGS:** We show that decreasing the number of fingers of realistic hands leads to significantly lower levels of presence, which is not the case for abstract hands. Qualitative feedback collected through think-aloud and video revealed potential reasons for the different assessment of realistic and abstract hands with fewer fingers in VR.
- **INTERPRETATION, CONCLUSION, CONTRIBUTION:** We contribute design implications and recommend considering the human-likeness when a reduction of the number of fingers of avatar hands is desired.

Introduction

ABSTRACT

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concepts of 'being' or 'acting' in a virtual environment while physically situated in another place. Avatars in VR also provide a natural and intuitive interface for the user to interact with the surrounding virtual world. The most important body parts for interaction through avatars in VR are one's hands and fingers. Using current VR technologies, virtual hands can be displayed in VR. Today's technologies even allow motion tracking of hands and fingers without wearing additional motion controllers or markers. Thus, arms, hands, and fingers can be rendered in VR according to their real pose and location.

For video games, however, it is not only important to provide hands for interaction but also to understand how their appearance influences the experience of the user. Designers of video games have unlimited freedom to vary the appearance of an avatar. Game artists often simplify their drawings due to the thickness of black outlines. Thus, to avoid too big hands or overlapping of the black outlines, they reduce the number of fingers. This kind of stylization was adopted and preserved by many video games such as in *Earthworm Jim*, the *Rayman* series, *The Smurfs*, or *Simpsons – The Game*.

Designers can also reduce the number of fingers in realistic ways. In 2009, the cover art of the game *Left4Dead 2* showed a hand with a severed little finger, ring finger, and thumb. To appease the Entertainment Software Rating Board (ESRB) game developer Valve changed the cover in a way that the index and middle fingers were missing. In video games, designers reduce the number of fingers in a realistic way as for the aliens in *Avatar: The Game* or Elizabeth's character in *BioShock Infinite*. The appearance of game avatars in VR does not necessarily match the structure of the user's body. However, little is known about the effects of a reduced number of fingers on the user experience and perception of presence in VR.

To investigate the effect of varying an avatar's number of fingers we conducted a study in VR. We tested five-, four-, three-, and two-fingered hands rendered with a realistic and an abstract style. We collected quantitative and qualitative data. We not only show that reducing the number of fingers significantly affect the perceived presence but also show that this effect depends on the style of the avatar. These findings are relevant for VR users and, thus, is relevant for researchers and designers of immersive VR games and applications. We discuss further effects and potential implications on the user experience of being in VR with fewer fingers. We contribute implications for game and VR designers.

- The big picture
- The statement problem
- The audience
- Brief background or relevant theory
- Practices for the topic
- Overall purpose, motivation
- The research question and hypotheses
- Overview about the rest of the paper
- Findings and contribution

Related Work

RELATED WORK

In the following, we provide an overview of the previous work that is related to the perception of the virtual self and hands in VR. This includes research on the rubber hand illusion, which has consequences for the perception of the virtual self, as well as the condition of phantom pain, which is experienced by some amputees in their removed limbs. Both phenomena, established in the real world, have implications for how one's body avatar ought to be represented in VR. Finally, we discuss how the appearance of virtual avatars affects the illusion of body ownership and the feeling of presence in VR.

The rubber hand illusion experiment by Botvinick and Cohen [4] demonstrated that humans can incorporate prosthetic limbs into their body representation when congruent visual and tactile feedback is provided. Further research of the rubber hand illusion (originally not situated in VR) showed how our body registers the interaction space using self-location [7], self-agency [3], and body ownership [13]. VR allows to further explore the rubber hand illusion from a first person view and for animated false limbs as well as full bodies [23]. The acceptance of structural changes of hands in VR was investigated by [10]. They used a rubber hand illusion in a virtual environment. They found that participants experienced relatively high levels of body ownership (90%) when they were asked to interact with a five-fingered hand. Consequently, the authors recommend investigating hands with fewer fingers.

Our work differs from previous work in that it examines existing body parts in the rubber hand illusion. The removal of limbs is particularly related to work that investigates phantom pain and its treatment in VR. However, it has not yet been investigated how fewer limbs affect acceptance in VR. Murray et al. [16] showed that VR can be used to treat the phantom pain of amputees. Not situated in VR, but also related to our work is the research by Giummarra et al. [9] which compared sensations of amputees and non-amputees. Their findings indicated that both phantom pain and an illusory embodiment, do not necessarily require amputation.

Previous work also shows that the appearance of an avatar affects the VR experience. Lin and Jörg [12] found that more human-like hand models increased the illusion of body ownership. Using a first-person computer-game Christou et al. [5] found that visual characteristics of the avatar influenced the user's experience. In a similar study, Magniet et al. [13] found that the avatar's appearance in VR influences the user's behavior as well. Their results indicate that the more human-like the avatar's appearance, the more virtual hands, however, the more body ownership increases for virtual human hands. Peck et al. [17] showed that the manipulation of skin tones caused changes in interpersonal attitudes and decreased participants' implicit racial bias. Not only skin color but also the virtual body size lead to biases in estimating the own weight, which was shown by Prybykova et al. [18].

Research in *presence* is vital, especially as games and virtual environments strive towards becoming more and more immersive. Presence is defined as the “sense of being in another environment” [2] or as “the outcome or a direct function of

immersion" [20]. Vinayagamoorthy et al. [25] and Lugrin et

al. [14] found that higher degrees of presence were caused by less realistic VR game characters. In both works, the authors assumed that the gender of the avatar was a significant phenomenon by itself [15], who also hypothesized that imperfections of virtual human-like characters cause uncomfortable sensations. In addition, the authors found gender-related differences when using different virtual hands in VR [21]. Their results indicate that women dislike to use hands and men perceive lower levels of presence when using non-human avatar hands. The authors suggest avoiding gender swapping in VR by using non-realistic bodies or – if necessary – by using androgynous avatars.

Investigations of the rubber hand illusion [4, 23, 10] and illusion of body ownership [12, 1, 24] are related, but different from the kind of body changes investigated in this paper. They highlight the importance of visual and haptic cues for registering the interaction in space of the own body using additional limbs. How the illusion of body ownership affects the user experience in VR is currently unknown. For this reason, and especially in context of games, which reduce the number of fingers (e.g. for stylized hands), we decided to explore the effects on presence (cf. [25, 14, 21]) using avatar hands in VR.

METHOD

Fingers are an integral part of daily interaction and are often removed, for example, for stylization reasons. However, previous work did not in-clude removing limbs of VR avatars, how degree of realism of the own body has users perceive presence. Therefore, we effect of fewer fingers with realistic as we hands in a user study in VR. We used a design with the two independent variables (*realistic*) and FINGERS PER HAND (8 resulting in eight conditions. Data was col-lected through questionnaires in VR and qual-ity think-aloud method and video observation.

Stimuli

We compared *five*-fingered hands with *h*cessively removed little finger, ring finger of each hand (see Figure 1). We use trigger events in our apparatus and kept *t* index fingers. Previous work found *t* show different levels of presence while us hands. As suggested [21], we used a *h* hand model consisting of a mesh blending female hand models provided by the *Lea* remove an effect of the finger movement *t* adjacent parts of the palm, we remove fingers. Thus, the hands look more natural off or torn, which was achieved by smooth the palm of the hand. A professional 3D artist removed the fingers and the influence of their virtual bones on the hand skin using Autodesk 3ds Max. The abstract hand models are based on the white abstract hands used by Argelaguet et al. [1]. They consist of rigid oval shapes for the fingers and arms as well as a circle-shaped palm.

Last paragraph summarizes the RW and definitions!
You can contrast your work: How is it related to the previous work?

- **Summarizes and presents the state of knowledge** using a simple narrative
- Mostly structured by related fields
- Conclusions that have been reached until today
 - › Do all writers agree with each other?
 - › Are the experiments comparable?
 - › What is the quality of the studies?
 - › Main issue and controversies around the problem
- Summary at the end of the section

Method: Study Description

■ „How the authors answered the research question“

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Stimuli

We compared *five*-fingered hands with hands where we successively removed little finger, ring finger, and the middle finger of each hand (see Figure 1). We used a pinch gesture to trigger events in our apparatus and kept both thumbs as well as index fingers. Previous work found that men and women show different levels of presence while using male and female hands. As suggested [21], we used a human androgynous hand model consisting of a mesh blending between male and female hand models provided by the Leap Motion SDK. To remove an effect of the finger movement on the animated skin at adjacent parts of the palm, we removed the stumps of the fingers. Thus, the hands look more natural and not as being cut off or torn, which was achieved by smooth transitions towards the palm of the hand. A professional 3D artist removed the fingers and the influence of their virtual bones on the hand skin using Autodesk 3ds Max. The abstract hand models are based on the white abstract hands used by Argelaguet et al. [1]. They consist of rigid oval shapes for the fingers and arms as well as a circle-shaped palm.

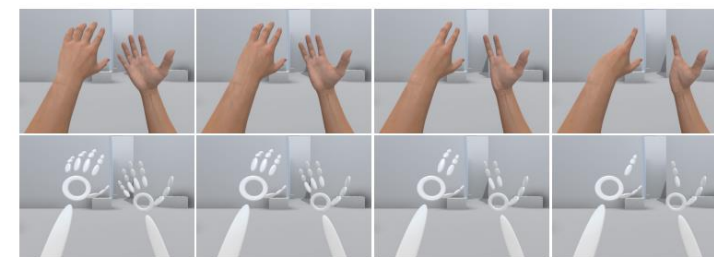


Figure 1. Screenshots of the avatar hand models of the four realistic (1st row) and four abstract (2nd row) hands with five, four, three, and two fingers.

Apparatus

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Tasks

Three immersive tasks were used to ensure that the virtual hands are in the field of view of each user. Furthermore, they enabled a versatile and immersive VR experience. We used the tasks proposed and provided by the software by Schwind et al. [21]. In the *typing task*, participants operated with a virtual keyboard to enter "I love VR" into a text display. The *draw task* enabled users to perform free hand painting in the surrounding virtual space using the pinch gesture. The *pyramid task* is a physical simulation where participants were advised to staple at least six blocks on a table to build a small pyramid. Black fading was used for transitions between all tasks as well as between the tasks and the final questionnaire.

Measures

We used questionnaires in VR to facilitate a continuously user experience (*cf.* integrated questionnaires in gaming environments by Frommel et al. [8]) as suggested by Schwind et al. [21]. Thus, every participant filled in the questionnaire using the virtual hands whose effect we actually measured. We decided to use the presence questionnaire (PQ) by Witmer and Singer [26]. The questionnaire has been used in a large

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number of studies, includes items that address related factors such as naturalness or involvement, and all questions can be meaningfully answered in VR. As suggested by previous work [21, 22], we additionally asked for likability, human-likeness, attractiveness, and eeriness on 7-point Likert scales. Participants' feedback and their actions were recorded through think-aloud protocols and video cameras.

Procedure

After signing the consent form, every participant was asked to take a seat in the middle of our VR laboratory. We explained the experimental procedure and introduced the functionality of the HMD as well as the hand tracking sensor. Furthermore, all participants were instructed to "think aloud", which means to verbally articulate all their concerns and thoughts especially considering their virtual embodiments. We pointed out that participants could pause or abort the experiment at any time. The order of the eight virtual hands was given by a balanced Latin square design. The order of tasks was randomized by software. Every task could either be finished by pressing a button or showing a thumbs-up gesture. After completing all tasks a panel with the questionnaire appeared in front of the participant's view. Since all questions could not be displayed at once, panels containing four questions were presented. The participant navigated through these panels of the questionnaire by pressing two buttons labeled "back" and "next". After leaving the VR we handed out a questionnaire where we asked for feedback, general concerns, suggestions. Finally, we also asked for both the hand they prefer and definitely not prefer.



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Participants

We recruited 24 participants (11 males, 13 females) from our campus via mailing lists and social networks. All participants had light skin tones matching the visual appearance of the realistic virtual hand. None of the volunteers was excluded from participation in the study. The average age of the participants was 21.8 years ($SD = 6.41$). Only four participants mentioned having previous VR experience, 20 of our participants stated that they had no VR experience at all.

Method: Stimuli

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METHOD

Fingers are an integral part of daily interaction and are often removed, for example, for stylization reasons in today's video games. However, previous work did not investigate the effects of removing limbs of VR avatars, however, shows that the degree of realism of the own body has an impact on how users perceive presence. Therefore, we decided to test the effect of fewer fingers with realistic as well as abstract avatar hands in a user study in VR. We used a within-subject study design with the two independent variables *REALISM* (*abstract* and *realistic*) and *FINGERS PER HAND* (*two*, *three*, *four*, *five*) resulting in eight conditions. Data was collected quantitatively through questionnaires in VR and qualitatively through the think-aloud method and video observations.

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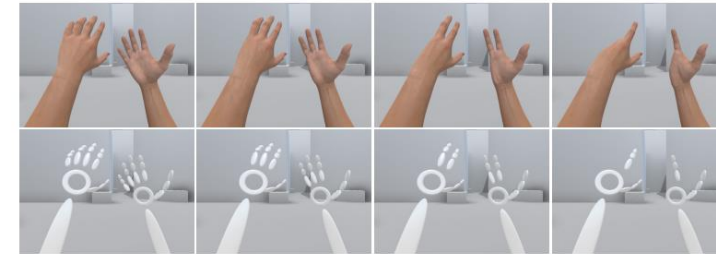


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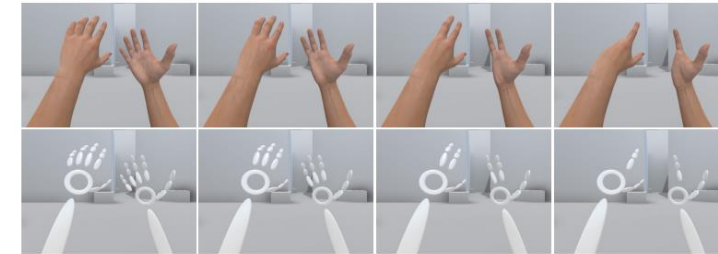


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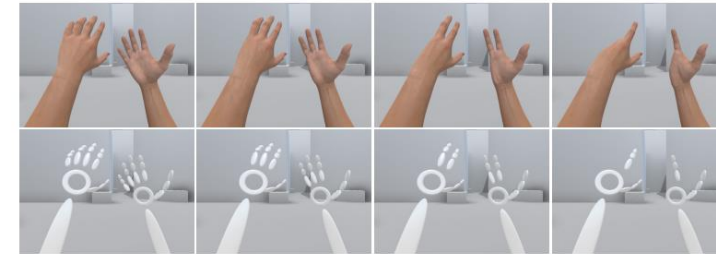


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Method: Tasks

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Stimuli

We compared *five*-fingered hands with hands where successively removed little finger, ring finger, and the middle finger of each hand (see Figure 1). We used a pinch gesture trigger events in our apparatus and kept both thumbs as well as index fingers. Previous work found that men and women show different levels of presence while using male and female hands. As suggested [21], we used a human androgynous hand model consisting of a mesh blending between male and female hand models provided by the Leap Motion SDK. To remove an effect of the finger movement on the animated skin at adjacent parts of the palm, we removed the stumps of the fingers. Thus, the hands look more natural and not as being cut off or torn, which was achieved by smooth transitions towards the palm of the hand. A professional 3D artist removed the fingers and the influence of their virtual bones on the hand skin using Autodesk 3ds Max. The abstract hand models are based on the white abstract hands used by Argelaguet et al. [1]. They consist of rigid oval shapes for the fingers and arms as well as a circle-shaped palm.

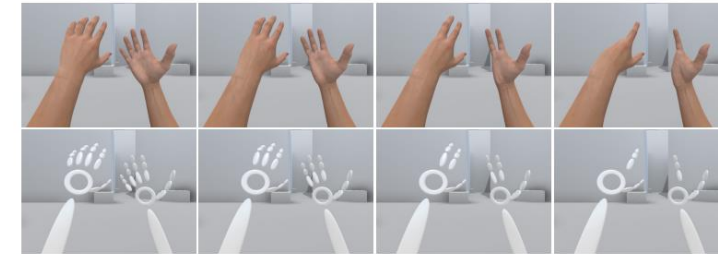


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Apparatus

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Tasks

Three immersive tasks were used to ensure that the virtual hands are in the field of view of each user. Furthermore, they enabled a versatile and immersive VR experience. We used the tasks proposed and provided by the software by Schwind et al. [21]. In the *typing task*, participants operated with a virtual keyboard to enter "I love VR" into a text display. The *draw task* enabled users to perform free hand painting in the surrounding virtual space using the pinch gesture. The *pyramid task* is a physical simulation where participants were advised to staple at least six blocks on a table to build a small pyramid. Black fading was used for transitions between all tasks as well as between the tasks and the final questionnaire.

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We used questionnaires in VR to facilitate a continuously user experience (*cf.* integrated questionnaires in gaming environments by Frommel et al. [8]) as suggested by Schwind et al. [21]. Thus, every participant filled in the questionnaire using the virtual hands whose effect we actually measured. We decided to use the presence questionnaire (PQ) by Witmer and Singer [26]. The questionnaire has been used in a large

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Method: Measures / Dependent Variables

■ „How the authors answered the research question“

■ Typical Sections:

- › What the authors do?
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Stimuli

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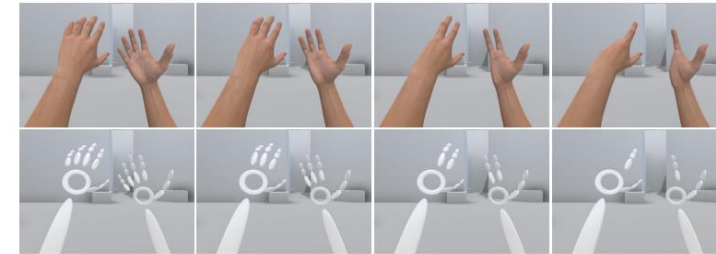


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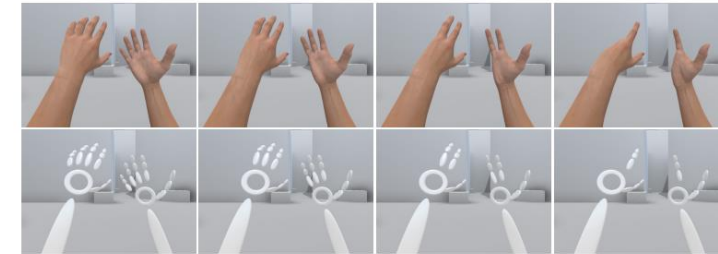


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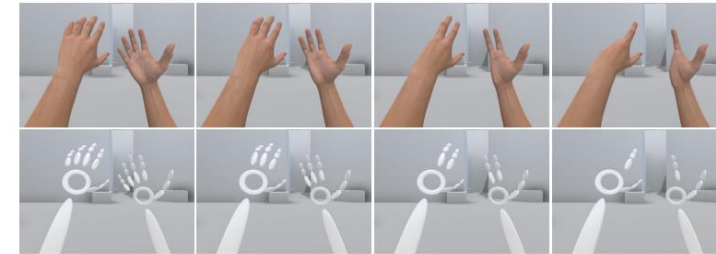


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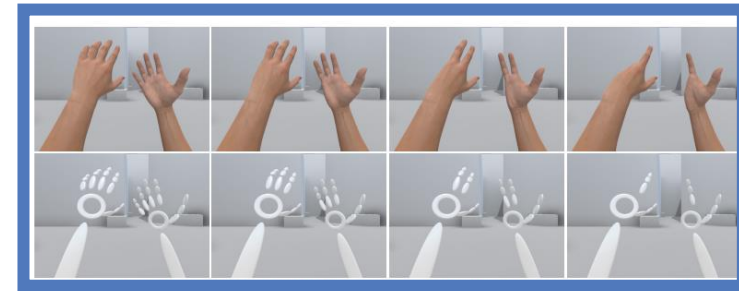
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We compared *five*-fingered hands with hands where we successively removed little finger, ring finger, and the middle finger of each hand (see Figure 1). We used a pinch gesture to trigger events in our apparatus and kept both thumbs as well as index fingers. Previous work found that men and women show different levels of presence while using male and female hands. As suggested [21], we used a human androgynous hand model consisting of a mesh blending between male and female hand models provided by the Leap Motion SDK. To remove an effect of the finger movement on the animated skin at adjacent parts of the palm, we removed the stumps of the fingers. Thus, the hands look more natural and not as being cut off or torn, which was achieved by smooth transitions towards the palm of the hand. A professional 3D artist removed the fingers and the influence of their virtual bones on the hand skin using Autodesk 3ds Max. The abstract hand models are based on the white abstract hands used by Argelaguet et al. [1]. They consist of rigid oval shapes for the fingers and arms as well as a circle-shaped palm.

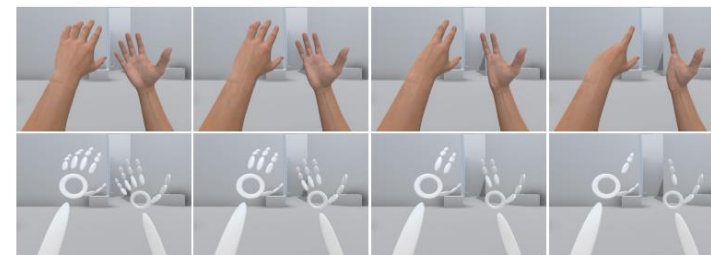


Figure 1. Screenshots of the avatar hand models of the four realistic (1st row) and four abstract (2nd row) hands with five, four, three, and two fingers.

Apparatus

Our system consisted of an HTC Vive HMD and a Leap Motion sensor mounted onto the front of the display using a 3D printed frame. We used a PC with Windows 10, an Intel i7-6700, 16GB RAM, and a Nvidia GTX980 graphics card. Our Unity3D application used hand tracking provided by the Orion SDK of Leap Motion optimized for hand tracking on HMDs. The target frame rate of the application was 60 frames per second. To ensure that the frame rate and the tracking quality was the same for all hands, we used the same tracking system provided by Leap and the same configuration of bones. The surrounding scene was the same for all condition and designed with a neutral white style and a standard sun- and skylight. Real-time global illumination, anti-aliasing, and ambient occlusion were enabled for rendering.

Tasks

Three immersive tasks were used to ensure that the virtual hands are in the field of view of each user. Furthermore, they enabled a versatile and immersive VR experience. We used the tasks purposed and provided by the software by Schwind et al. [21]. In the *typing task*, participants operated with a virtual keyboard to enter "I love VR" into a text display. The *draw task* enabled users to perform free hand painting in the surrounding virtual space using the pinch gesture. The *pyramid task* is a physical simulation where participants were advised to staple at least six blocks on a table to build a small pyramid. Black fading was used for transitions between all tasks as well as between the tasks and the final questionnaire.

Measures

We used questionnaires in VR to facilitate a continuously user experience (cf. integrated questionnaires in gaming environments by Frommel et al. [8]) as suggested by Schwind et al. [21]. We used the presence questionnaire (PQ) by Witmer and Singer [26]. The questionnaire has been used in a large

¹<https://github.com/valentin-schwind/selfpresence>

number of studies, includes items that address related factors such as naturalness or involvement, and all questions can be meaningfully answered in VR. As suggested by previous work [21, 22], we additionally asked for likability, human-likeness, attractiveness, and eeriness on 7-point Likert scales. Participants' feedback and their actions were recorded through think-aloud protocols and video cameras.

Procedure

After signing the consent form, every participant was asked to take a seat in the middle of our VR laboratory. We explained the experimental procedure and introduced the functionality of the HMD as well as the hand tracking sensor. Furthermore, all participants were instructed to "think aloud", which means to verbally articulate all their concerns and thoughts especially considering their virtual embodiments. We pointed out that participants could pause or abort the experiment at any time. The order of the eight virtual hands was given by a balanced Latin square design. The order of tasks was randomized by software. Every task could either be finished by pressing a button or showing a thumbs-up gesture. After completing all tasks a panel with the questionnaire appeared in front of the participant's view. Since all questions could not be displayed at once, panels containing four questions were presented. The participant navigated through these panels of the questionnaire by pressing two buttons labeled "back" and "next". After leaving the VR we handed out a questionnaire where we asked for feedback, general concerns, suggestions. Finally, we also asked for both the hand they prefer and definitely not prefer.



Figure 2. Images of the participants situated and observed in our VR laboratory.

Participants

We recruited 24 participants (11 males, 13 females) from our campus via mailing lists and social networks. All participants had light skin tones matching the visual appearance of the realistic virtual hand. None of the volunteers was excluded from participation in the study. The average age of the participants was 21.8 years ($SD = 6.41$). Only four participants mentioned having previous VR experience, 20 of our participants stated that they had no VR experience at all.

Study Design

- **What is the hypothesis** and **how do the authors want to answer it?**
 - › “[...] previous work did not investigate the effects of removing limbs of VR avatars, however, shows that the degree of realism of the own body has an impact on how users perceive presence. Therefore, we decided to **test the effect of fewer fingers with realistic as well as abstract avatar hands in a user study in VR.**”
- What is **the study design**? What are **the IVs**?
 - › We used a **within-subject study design with the two independent variables REALISM (abstract and realistic) and FINGERS PER HAND (two, three, four, five)** resulting in eight conditions.
- Which **data** was **collected**? And **how**?
 - › “Data was collected **quantitatively through questionnaires** in VR and **qualitatively through the think-aloud method and video observations.**”

Method

■ Apparatus

- › There must be a picture → if not, search for the source code
- › What did they build ?
- › How did participants use it?
- › Often contain condensed: „To prevent motion sickness, we used an HMD with 90 FPS“

■ Tasks

- › What did the participants do?
- › Why/How did they do the tasks? And why?

■ Procedure

- › Describes what happened to every participant
 - › e.g., How were stimuli ordered in the procedure („The order of the conditions was randomized for each participant.”)?

The Results

- Objective findings of the research (not the interpretation!)
- Main results are always plotted

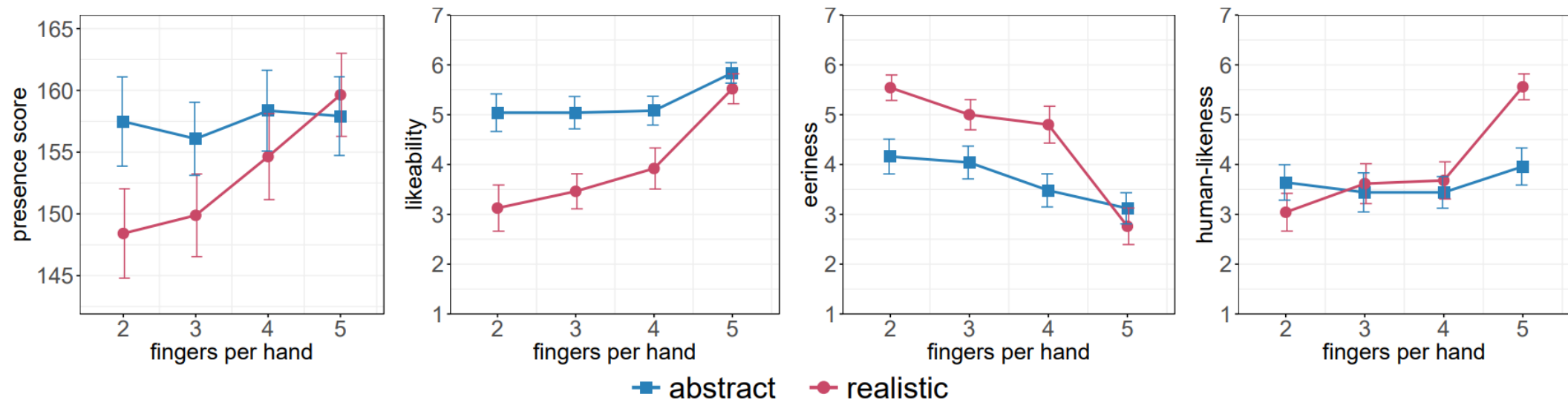


Figure 3. Average presence scores, perceived likeability, eeriness, and human-likeness of abstract and realistic virtual hands with number of fingers per hand. All error bars show standard error of the mean (SE).

Discussion

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a missing finger, no problem.”(P3, R4). And short-term habituation such as with one participant after getting an abstract hand with five fingers: “[...] and now it’s freaky to have all fingers again.” (P12, A5).

(3) The **Uncanny Valley** by Mori [15] describes a non-linear relationship of familiarity and human-likeness. It predicts a sudden dip of familiarity in relation to the human-likeness (or realism) of a robot or virtual avatar. Since we have only used two different styles (*abstract* and *realistic*), our quantitative data does not allow to infer the shape of a potential Uncanny Valley with virtual avatars and reduced number of fingers. However, qualitative data provided while participants used five-fingered hands indicate that there is a potential relation to this phenomenon: “Looks strange. I don’t know. I liked the other one [hand, A5] more because of the design. Perhaps it’s because these hands look more human than the others.” (P2, R5), “I don’t know, it’s confusing because the hand is too real!” (P14, R5).

(4) A **visually induced identity dysphoria** potentially causes discomfort through lacking coherence between the known appearance of one’s own body and the virtually projected self. “I feel it’s supposed to be my hand. But I know it’s not my hand, so I think it is creepy.” (P6, R5). The incongruence of the real and virtual body was recognized and lead to a negative sensation. “Hand is too orange.” (P22, R5), and using structural changes such as missing fingers in particular: “What is this? I’m not a pinky!” (P17, R4). “I feel it’s a finger, unfamiliar because you’re missing a finger, but it’s not a finger, then you’re thinking: Where’s pinky?” (P17, R4).

(5) A **mismatch of visual and haptic cues** can lead to a lack of proprioception and to a feeling of losing control. “I don’t feel the feedback from fingers that were not displayed was considered as a strange and peculiar feeling. “It is totally creepy when I touch my fingers which are not displayed.” (P12, R2). The concept is related to the rubber hand illusion [4] when visual cues are in conflict with tactile sensations. This is also related to findings by Costantini and Haggard [6] who interpret that sensory evidence about “me” is related to a prior mental representation of one’s own body.

DISCUSSION AND CONCLUSION

In this paper, we investigate how reducing the number of fingers affects the perception of virtual hands in VR. We decreased the number of fingers from little to the middle finger and tested the hands at two different levels of realism (*abstract* and *realistic*).

We collected quantitative data using questionnaires integrated in VR. Our quantitative results indicate that the number of fingers significantly affects presence and shows interaction effects with the level of realism. The reduction of fingers does not significantly influence presence using abstract hands. However, when using realistic hands, the feeling of presence significantly decreased with the number of fingers. The diverging effect of reducing fingers for abstract and realistic hands is confirmed by significant interaction effects for all questionnaire measures except for attractiveness. Furthermore, through reducing the number of fingers, we found significant

effects on likeability, eeriness, human-likeness, and attractiveness. Except for the perceived human-likeness, all measures show that the reduction of fingers lead to stronger effects while participants interacted with realistic hands. Ratings of human-likeness were constantly low for all hands, except for the five-fingered human hand, which indicates that the participants had a clear concept of how human avatar hands should look like.

Through the qualitative analysis of think-aloud protocols and videos, we identified factors and effects that were not captured by the quantitative measures. We derived associations, habituation, aesthetic aspects, sensitivity to display/tracking errors, and the individual performance (e.g. while completing the tasks) as additional factors that influence the experience while using avatar hands with fewer fingers. We also found additional effects including emotional reactions and changes of hand interaction. In the second iteration of the qualitative analysis, we discussed five potential underlying cognitive mechanisms: visually induced phantom pains, familiarity based on prior experiences, the Uncanny Valley, a visually induced identity dysphoria, and the mismatch of visual and haptic feedback.

In context of previous research, our paper presents the first investigation of a VR experience with a reduced number of fingers. We examined the effect on presence, thus, our work contributes to a better understanding of the perception of user’s avatars in VR games and applications. Embodiment and ownership in VR and haptic cues are related to findings of investigations about the rubber hand illusion; however, adding limbs conceptually differs from reducing fingers. The illusion we created is the opposite of the rubber hand illusion and lead to mainly negative feedback in VR. This is supported by findings of Hoyet et al. [10] who observed relatively high levels of the illusion of body ownership after adding a sixth finger. We assume that self-perception in VR using structural changes that do not match the structure of the user’s body depends on whether limbs are added or removed.

Our observations indicate that the reduction of fingers induced phantom pains. The phantom pain of non-amputees could include pain due to the fear of amputation or “real” phantom pains as observed with people with missing limbs, which are also treated in VR [16]. Interestingly our participants responded emotionally, which indicated that they were highly immersed with their appearance in VR and not with the outer world anymore. Nevertheless, the feeling of presence was negatively influenced by reducing realistic fingers. Some shock moments, however, indicate that the participants still had an immersive VR experience. Source code and assets of our project are available on github³.

Limitations and Future Work

To keep the length of our study reasonable, we only used two different hand styles (realistic and abstract). Cartoon or comic styles, which often make use of four finger hands for stylized characters, should be considered in further studies to examine

³<https://github.com/valentin-schwind/lessfingers>

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e.g. also a hypothetical effect of the Uncanny Valley of the own avatar. We symmetrically reduced the number of fingers on both hands. Thus, we could not analyze potential effects of hand or finger asymmetries. Furthermore, we removed little fingers, ring fingers, and middle fingers. Future studies could additionally take thumb and index finger into account. Further research could also investigate the effects of other combinations of removed fingers. For example, it is possible, that the loss of the little finger is easier to handle than the loss of the index finger.

With emotional reactions and effects on the hands interaction, we identified two factors in our qualitative analysis that could be quantified by future studies. Future studies could derive five potential cognitive mechanisms that influence self-perception in VR with a reduced amount of fingers. To develop a robust and reliable model of virtual self-perception, which also illustrates interrelations and influences the themes, more empirical research is needed. We, therefore, suggest quantifying data of the derived themes to predict potential dependencies and correlations. In line with Schwind et al. [21], we assume that deviations from the own self (e.g. by using altered body scans) should be considered by future research.

VR Game Design Implications

For designers of immersive VR games and applications, we recommend considering the level of realism of an avatar when a reduction of fingers is desired. Using an *abstract* hand style, our VR users felt high levels of presence even with only two fingers left. This was not the case for *realistic* avatar hands. The level of presence decreased according to the number of fingers that were left. For designers of VR games and applications or games with avatars with less fingers in an abstract way, they profit not only from higher acceptance as opposed to real avatars, but also from less design time they have to spend on implementing highly realistic hand representations. Emotional reactions of our participants indicate that a reduction of fingers of realistic hands should only be considered for shocking and horror experiences. In case of less fingers, we observed to even accept hands with a reduced number of *abstract* and *realistic* fingers. However, our participants responded sensitively to any structural changes of the avatar hands. Therefore, we recommend that the number of fingers should be kept consistent during the VR experience or gameplay.

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- The findings
- The reason for those findings
- The implications
- Illustrate the limitations
- Future Research
- Often provides clear design guidelines

Discussion

- A presentation of **background information** as well as recapitulation of the research aims of the study.
- A brief **summary of the results**, whereas the focus lies on discussing and not recapitulating the results.
- Explanation of the **results for normal humans**
- A **comparison of results with previously published studies**
- **Conclusions or hypotheses drawn from the results**, with summary of evidence for each conclusion
- **Proposed follow-up research questions** and outlook on further work
- **Weaknesses? Non-significant results? Unexpected data?**
- If you are a non-scientist, **where to find the interesting stuff?**

How I do read research papers...

Demonstration

Future Work

- **What are the recommendations now?**
 - › Logical extension of the study: What comes next?
 - › Replication of the study: Different setting?
 - › Correction of limitations: Sample, apparatus, variable control, method
- **It is a great motivation for you, when someone recommends to do your study**
 - › Happens sometimes
 - › That is a great template

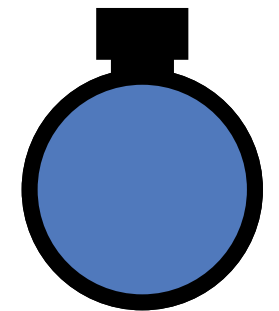


☒ Articles ☐ Case law

Exercise: Find and describe a paper that is related to your research question

1. Go to <https://scholar.google.com> ...
2. Enter the related keywords
3. Click on a result that seems to be relevant...
4. Try to open the paper (if not possible open the next one)...
5. Find and describe the technique...

You have 5 minutes...



Questions

- What is the paper about?
- What did the authors do?
- Why did they do it?
- What are the independent variables?
- What are the dependent variables?
- What did they find out?
- What did you learn?

Using ChatGPT to summarize a paper...

Demonstration

Plugins: AI PDF

Summarize the paper, the findings, and method. Write one paragraph. Be concise. Do not hallucinate. Do not invent facts.

Using ChatGPT to summarize multiple papers...

Demonstration

Plugins: ScholarAI, Consensus Research, MixerBox Scholar

“What is the effect of latency on games? I want to conduct a study with artificial latency to simulate the effect. List and summarize in one paragraph about 3 related research papers that motivate the research around that topic. List and summarize in 3 papers that are related to that research question. List and summarize 3 research papers that use a similar method. Use all plugins. Ignore duplicates. Only use papers that have a DOI. Only summarize the main findings and method of the papers.”

Task Next Time

- Each person in your group searches and reads at least 3 papers
 - › Person 1: papers that motivate your research (can be from other disciplines!)
 - › Person 2: papers closely related to your research question
 - › Person 3: papers in your field using a similar method as you



Research Motivation



Closely Related



Similar Method

No duplicates!