"What a Mess!": Traces of Use to Increase Asynchronous Social Presence in Shared Virtual Environments

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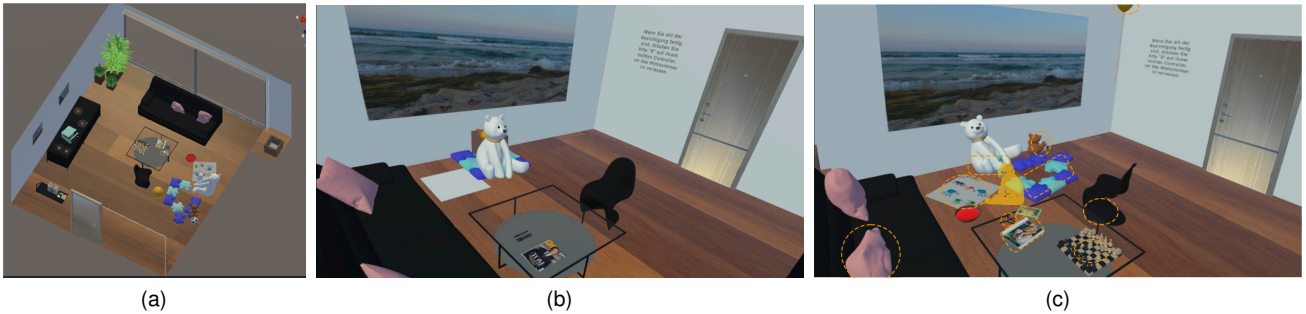
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Figure 1: The same virtual living room: a) from a bird-eye perspective with traces b) without traces, c) with exemplary traces of use, e.g., the magazine opened at a particular article, including a toddler to convey objects' size.

ABSTRACT

Shared virtual environments (VEs) are challenged conveying and triggering users' feelings of social presence. Traces of use are implicit evidence of prior interactions that support social awareness in the real environment (RE). However, they have not been explored in VEs so far. We investigate the traces' effect on users' perception of asynchronous social presences in a within-subject study (N=26) by comparing the users' experience with and without traces. The traces significantly increased the feeling of social presence. We contribute an initial exploration of the *traces of use* concept in VE to design shared social spaces for long-term use.

Index Terms: Human-centered computing—Collaborative and social computing design and evaluation methods—Design and evaluation methods—;

1 INTRODUCTION

In the real environment (RE), traces of use are evidences of prior interactions that represent relationships between the user, a material and an interaction [7]. As such they are also perceptible changes to shared environments fostering asynchronous social awareness of other humans and living-beings [5]. Traces of use are often physical and unavoidable. Yet, in the virtual environment (VE), spaces can always be reset by the system or users. At the same time, shared VEs are challenged to convey and trigger the feeling of social presence [4]. Yet, work on asynchronous interactions and social presence is still limited, although such settings are gaining popularity among VE users. We want to explore whether *traces of use* in a permanent, shared VE can increase the feeling of asynchronous social presence.

In a within-subject study (N=26), we found that users' social presence in the VE with traces was significantly higher than in the same VE without. Users also rated that it was easier to empathize with

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other users, and they considered the VE more "natural", "authentic" and "realistic" in the room with traces. However, the perceived untidiness of the VE with traces also reminded users of annoying real-world duties (e.g., cleaning up after the children).

2 RELATED WORK: DESIGNING WITH TRACES OF USE

In RE, designing with *traces of use* includes designing with the dimensions: time, material changes, and the relations between people, environment, and materials [7]. In real environments, the concept is used to increase users' feelings of connectedness to and awareness of their surroundings, other users, and the content provided by the interface [5]. Baxter et al. [2] identified four indication types of use that we considered in our design: a) object characteristics, b) object state, c) object setting and d) object context. Object characteristics are non-reversible like a cracked mug. The object state describes reversible conditions, such as a crumpled pillow. Object settings describe (user-specific) configurations and the object context includes changes to the object's location or surroundings.

3 STUDY DESIGN

We conducted a within-subject study (N=26, 15 self-identified as female, 11 as male) comparing a virtual living room in two versions: one with traces and one without traces (see Fig. 1). We chose the living room scenario because it is a personal, yet shared space where traces of personality are natural and expected depending on the context (e.g., private household versus staged interior design). Participants' age ranged from 15 to 63 years, M=41; SD=16,9.

We included at least two examples of each trace type according to Baxter et al. [2] on a total of 13 objects and considered the traces of use embedded into the virtual living room our primary independent variable with two dimensions: with and without traces. As dependent variables, we tracked participants' viewing time and behavior per room, their feeling of social presence, and general presence. Additionally, we used five questions from Bailenson et al. [1]'s questionnaire for interpersonal distance in immersive VEs to measure the social presence. Lastly, we measured the general presence using Slater et al.'s [8] questionnaire, and open-ended questions about their room experiences.

Technical Setup: We developed the VE scenes in Unity version 2020.2.7fl and prepared individual objects, such as the pillows, in

Blender version 2.91.2, or used available objects from the asset store. Users experienced the scenes through an Oculus Quest [6] HMD.

Procedure and Tasks: Every participant gave their consent according to GDPR and familiarized themselves with VE completing four tasks (turn left and right, pick up an object, move around with the object, and place it in a pre-defined spot). Afterwards, they received a background story to the living room scenario. Participants were asked to imagine they were Alex, a student who uses the VE to connect to other people in times of increasing remote work and study. Alex doesn't know the other room users yet but knows that they should share common interests. Then, participants experienced the first virtual living room followed by a social presence questionnaire before entering the second room. The room order was counter-balanced with 50% entering the room with traces first followed by the room without traces and vice versa. After experiencing both virtual rooms, participants completed a post-questionnaire comparing both rooms and their general feeling of presence.

4 RESULTS

We tested the data for normal distribution with the Shapiro-Wilk normality test. Additionally, we decided to evaluate users' performance and opinions by summarizing all traces of use types because there was no significant difference in the individual type of trace level. Overall, participants felt moderately present in our VEs (M=4.06 on a scale of 1 to 7; SD=0.68).

Tracked Times and Objects: The head-tracking data showed that participants looked more often and longer at objects in the room with traces of use. Comparing the total numbers of looks (see Table 1), the Wilcoxon-Signed-Rank-Test showed a significant difference (W=132, p=.015) between rooms. Similarly, the average duration of looking at the objects was significantly longer for the room with traces (W=140.5, p=0.004405). On average, participants looked 10.1 seconds longer at the objects while also staying about 30 sec. longer in the room (with traces: M=321.2 sec., SD=120.1 sec.; without traces: M=291.1 sec., SD=75.2 sec.).

Table 1: Head-tracking results. Participants looked more often and longer at the different objects in the room with traces.

Room	M Views	SD	M Duration (sec)	SD
With	9.2	3.7	17.67	12.8
Without	5.7	3.1	7.58	4

Social Presence: We applied the Mann-Whitney-U-Test showing that the room with traces of use triggered a significantly higher feeling of social presence than the one without (U = 502, p= .003). The data were normally distributed. In the room with traces, the distribution ranged from -5 to 14 with M=3.23, SD=3.71. The room without traces ranged from -15 to 8 with M=-1.46, SD = 5.59.

Qualitative Feedback: Participants stated what they liked or disliked about the rooms and revealed diverse opinions about them. Twelve liked the room with traces of use for being "homely", "inviting", "vivid", and "authentic". In contrast, however, six people preferred the room without traces of use because of its clean, well-structured, and tidy characteristics. In comparison, these six people felt rather disturbed by the traces of useor reminded of real-world duties:"*One would have to clean up here. This is what my child leaves behind and then I have to clean up afterward*", P21.

5 DISCUSSION

Our results show that the traces of use significantly increased the feeling of social presence of asynchronous users. Below, we discuss our findings in comparison to RE findings and give an outlook for potential future research projects and open research questions.

Traces of Use Increase Social Presence in Asynchronous VE
Social presence is influenced by how realistic the context is, including the socio-spatial setup [3]. Our participants perceived the room with traces as more "natural", "authentic" and "realistic", which is one explanation for the higher social presence. Participants also spent more time trying to make sense of the spatial conditions, which further reflected in their increased feeling of social presence. The findings align with RE projects [5] where the traces were created or discussed to increase social awareness. It shows that our VE was experienced as a shared social space including unique spatial identifiers that also derived by the sensual characteristics of traces of use. Considering all these aspects, we can clearly answer our research question and state that *traces of use* increase the feeling of social presence with asynchronous users in VE.

Research Questions and Opportunities Objects and environments in RE have a "natural" aging effect, showing their transience also without any human interaction. Thus, it extends the design requirements to age a VE by default and makes explicit which changes derive from other users and which from increasingly realistic, natural conditions. This also questions whether we want to design temporal and transient VEs or if it undermines the potential and intentions of using VEs altogether. For example, six of our users would have preferred the room without traces because they felt more comfortable in tidy environments and could forget real-world duties and responsibilities. It questions to what extend the application of the traces of use concept makes sense in VE and how the concept can be extended about VE-specific traces?

5.1 Limitations

Our study considered a passive user-VE interaction only. However, we aimed at initially exploring the concept considering Baxter et al.'s [2] traces of use classifications. We neither had a built-in eye tracker but inferred the results from the head tracking data. Yet, head tracking data can also provide close accuracy.

6 CONCLUSION

Our work explored the effect of an RE design concept, traces of use, in VE, showing that it significantly increases the feeling of asynchronous social presence and makes the VE more unique and "authentic". Yet, our study is an initial contribution only. We want to introduce this concept to practitioners and designers aiming to design social virtual spaces for long-term use triggering high social presence for also asynchronous use.

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