

Temporal and Spatial Variations in Presence: A Qualitative Analysis

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Abstract

This paper presents the qualitative findings from an experiment designed to investigate breaks in presence. Participants spent approximately 5 minutes in an immersive CAVE™-like system depicting a virtual bar with five virtual characters. On four occasions the projections were made to go white to trigger clearly identifiable “anomalies” in the audiovisual experience. Participants’ autonomic responses were measured throughout to investigate possible physiological correlates of these experienced anomalies.

Our analysis of the interviews with participants suggests that these anomalies were subjectively experienced as breaks in presence. The findings also reveal that breaks in presence have multiple causes and can range in intensity, resulting in varying recovery times. In addition, presence can vary in intensity within the same space, suggesting that presence in an immersive VE can fluctuate both temporally and spatially.

1. Introduction

In this paper we present a qualitative analysis of interviews from a 30-person experiment designed to investigate breaks in presence (BIPs). During the course of a highly immersive experience in a virtual environment (VE), participants experienced four deliberately triggered “anomalies” designed to remind them that they were not in the virtual scene depicted in the Cave¹, but in a laboratory conducting an experiment. The purpose of triggering these anomalies was to investigate whether these clear interruptions in the mediated experience could be associated with an identifiable physiological signature. A method for using GSR data to successfully predict when these anomalies occur will be described elsewhere.

Presence is of interest to practitioners in a number of fields including engineering, computer science, psychology, cognitive science, communication and philosophy [5, 10], as well as telecommunication and teleoperation [8]. Research has been driven both by theoretical and practical concerns [10], since a heightened sense of presence is considered essential for effective psychotherapy [7], for performance in training simulations [2], and for a wide variety of other VE applications.

¹ CAVE™ is a trademark of the University of Illinois at Chicago. In this paper we use the term ‘Cave’ to describe the generic technology as described in [4] rather than to the specific commercial product.

The debate concerning the definition and determinants of presence is accompanied by open questions concerning its measurement. A number of measurement approaches have been proposed. These can be classified according to when the measurement is taken (whether during or after the experience), and the type of data collected (whether subjective or objective). Increasingly, researchers are investigating ways of combining multiple measures.

The overarching goal of the experiment was to investigate presence as a multi-level construct ranging from lower-level involuntary responses to higher-level subjective responses. The purpose of the qualitative analysis presented in this paper was to shed light on how participants subjectively characterized these anomalies, and specifically whether they experienced them as BIPs. If so, our findings could inform further explorations of non-intrusive ways of identifying BIPs during the mediated experience.

In the following section we introduce related work on presence measurement, referring specifically to the rationale for studying BIPs. Next we describe our experimental procedure and the agenda for the semi-structured interviews. We then discuss the qualitative method used for our analysis, and present our findings. We conclude with a discussion of our results and propose directions for future research.

2. Related work

Presence research has relied extensively on subjective reporting, using post-experience questionnaires such as the SUS [16] and PQ [20] to assess participants’ sense of “being there” in a mediated environment. However, questionnaires present a number of drawbacks in that inaccurate recall and demand characteristics can distort results. They also capture post-hoc rationalisations, as opposed to the experience itself.

It has been argued that rather than being a stable constant throughout the mediated experience, presence may vary over time [3, 8, 13]. Slater and Steed explored a “breaks in presence” (BIPs) approach, asking participants to signal each time their sense of presence in the VE was interrupted by a sudden awareness of their physical surroundings [15]. They report a strong positive correlation between questionnaire-based presence and presence as estimated by the number of reported BIPs.

Alternative approaches have been explored to study temporal variations without requiring participants’ conscious attention. Freeman et al. investigated the use of behavioural measures, studying postural shifts in response

to motion stimuli [6]. Meehan et al. investigated the use of physiological measures including skin temperature, heart rate and GSR to measure objective responses to a virtual “pit” room containing a steep drop-off to the floor below [11]. The advantage of both these approaches is that they potentially offer a graded measure of the objective response. However, they both require specific stimuli to capture the responses, and are therefore limited by content-dependency.

Slater, Brogni and Steed sought to address this limitation by exploring the hypothesis that breaks in presence are associated with an observable physiological signature [14]. Their findings reveal a close association between reported BIPs and increases in GSR and heart rate and therefore have implications for the non-intrusive observation of responses to a wide variety of VEs. However, they caution that the physiological changes may be at least partially caused by the act of signalling the BIP.

The experiment reported in this paper expands on previous BIP studies by disambiguating the physiological responses from the signalling of BIPs; participants in the main condition were not briefed on “transitions to real” and were not asked to report them. By inducing “whiteout” anomalies in the experience, we also sought to match physiological findings with clearly identifiable anchor points in participants’ experience. Our goal was to compare any physiological findings with participants’ subjective accounts of the whiteouts, and thus to investigate whether lower-level autonomic responses and higher-level cognitive responses presented a coherent or contradictory message.

Spagnoli and Gamberini [18] describe a study exploring participants’ responses to technical breakdowns in the course of immersive interaction in a virtual library. Findings from their interaction analysis suggest that technical anomalies do not automatically translate into a state of “emersion”, but rather lead users to logically and actively incorporate the anomaly within the immersive experience. In our analysis we sought to further extend their research by comparing the effect of the brutal whiteouts with content- and apparatus-related anomalies, with a view to exploring the complex ways in which presence is enhanced and undermined by a variety of factors.

3. Experimental procedure

Upon arrival, participants were given an instruction sheet describing the experimental procedure and the possible risks associated with using virtual reality equipment (including simulator sickness). They were asked to fill out a consent form and a pre-questionnaire covering their age, gender, occupation, and previous experience with VEs and computer games.

They were then led though to the Cave, where they were shown how to connect the electrocardiogram (EKG) and respiration sensors. Galvanic skin response (GSR) sensors were attached to their non-dominant hand, and they were asked to stand still in the Cave for a baseline reading. During this time, no images were displayed on the Cave walls.

Next, participants were asked to complete a brief exercise in a virtual “training” room designed to make them comfortable moving around the Cave. Once they felt comfortable, they were told that in a few moments they would find themselves in a bar, where they were asked to spend a few minutes until we told them it was time to come out. It was explained that they were free to explore the bar as they wished, and that afterwards we would be asking them questions about the experience.

They remained in the virtual bar for the duration of two songs, approximately five minutes. The bar contained five virtual characters: one barman, one couple standing near the bar on the right, and another couple seated on the left of the room. When approached by the participant, the characters would utter phrases suggesting that a celebrity was about to arrive.

At four points during the experience, the walls of the Cave were blanked out, leaving participants in a completely white room for approximately 2 seconds. Two experimental minders observed them throughout, noting their bodily and verbal responses to the whiteouts. Participants’ autonomic responses were also monitored throughout. Figure 1 shows a participant in the bar environment, wearing the physiological monitoring equipment.



Figure 1: Participant in the Cave

Immediately after the experience, and before taking off the equipment or leaving the Cave, participants were asked to answer two questions concerning their immediate impressions regarding their overall sense of “being in” and “responding to” the bar.

Next, they were shown the video of themselves in the bar, and were asked to comment on anything that they remembered while watching the video. A semi-structured interview was conducted afterwards.

The experiments were carried out in a four-sided CAVE™-like system [4], which is driven by an Onyx IR2 with 4 graphics pipes. Users were wearing wireless trackers. The application was written on top of DIVE².

4. Semi-structured interview

One of the reasons for gathering physiological data is to shed light on participants’ involuntary responses during

² www.sics.se/dive

the experience itself. However, in this research we were also interested in understanding how participants themselves viewed their experience of interacting in the VE. For this reason, at the end of each experimental session we conducted an in-depth semi-structured interview on various aspects of the experience, in particular the causes and extent of any anomalies experienced, as well as responses to the virtual characters. A total of 30 participants were interviewed, but 27 were kept in the data pool because the audio quality on three interviews made them unsuitable for transcription.

Each interview was conducted using a semi-structured interview agenda, to ensure that it did not stray from the research questions in which we were interested. Interview agendas are designed in advance to identify logically ordered themes [17]. The interview agenda contained “open” questions designed to avoid “yes/no” answers. We also avoided asking leading questions or using jargon. We deliberately avoided using the word “presence”, referring to BIPs as “transitions to real”, and to the deliberately induced anomalies as “whiteouts”.

We began with general questions, asking participants to describe the overall experience in the bar, and to highlight any factors that were surprising or that violated their prior expectations. We then asked them about their sense of being in the bar, and whether (and how) this might have changed over time. After this, we focused specifically on “transitions to real”.

In addition, we experimented with the use of visual graphs to help participants describe their presence experience. They were asked to draw a line representing the extent to which they felt they were in the bar versus in the laboratory over time. The use of these graphs helped to focus the discussion of why and how their sense of presence may have fluctuated during the experience.

5. Data analysis

The interviews were taped and then transcribed verbatim. The transcripts were analysed by combining two methods of qualitative analysis: *content analysis* [19], and *thematic analysis* [9].

First, content analysis was used to locate themes in the transcripts that related to our research questions; as mentioned, themes of interest included responses to the avatars, and the subjective experience of BIPs. As a “system of observation and empirical verification” [12], content analysis provides a research method that attempts to assess texts objectively. Its value is that it moves beyond subjective interpretation because the analyst develops categories before searching for them in the data [9]. The text is then ordered into manageable content categories by coding words or phrases related to the research questions. Next, each content category is quantified by counting the number of times it appears in the data.

Next, thematic analysis was used to provide a more in-depth view of the data. Where content analysis looks for preconceived themes in the data, thematic analysis searches for additional ideas that are not linked to the initial research questions [9]. The combination of these two methods

allowed us to classify preconceived themes, as well as themes that emerged from the data itself. Throughout the analysis, an additional researcher checked the results against the data to provide credibility checks [1].

6. Findings

This section describes our analytical findings. First, we address the overall sense of presence, beginning with participants' response to the immediate questions. Next, we focus on the theme of temporal variations in presence, relating it directly to our research questions concerning the subjective experience of BIPs. Finally, we discuss a theme that emerged from the thematic analysis of the interview transcripts, concerning spatial fluctuations in presence. The findings are illustrated by direct quotes from the interviews with participants; participants are identified by number and gender.

6.1 Overall sense of presence

Analysis of the immediate questions showed that the majority of participants experienced a sense of being in, and responding to, the bar more than fifty percent of the time. The results are illustrated in Figure 2:

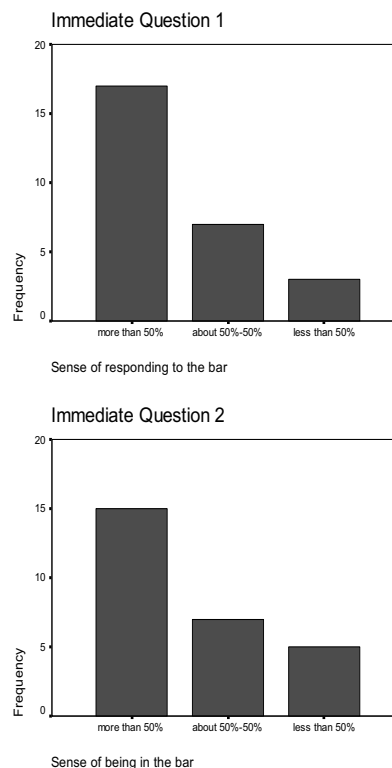


Figure 2: Responses to the immediate questions

The purpose of these two questions was to capture participants' immediate subjective response to the experience in a way that was as far as possible unclouded by post-hoc rationalisations. Afterwards, they were able to expand on their answers in the semi-structured interviews.

6.1.1 The sense of "being in" the bar

In terms of the sense of "being there", some participants expressed a sense of feeling drawn into the bar environment and forgetting about the spatial limitations of the Cave: *"I did get the impression of being in a bar. I was quite surprised to the extent the bar extended out into the space beyond the wall. It felt like I should have been able to touch the bar"* (P4 male). This expectation of being able to touch the objects resulted in a sense of surprise at feeling the physical boundaries of the Cave wall: *"I was going to see... where, um, where I could put my hands, but then, obviously, it was on the wall and I realised I was just about to walk into it and I thought 'woop'"* (P12 female). This experience of touching the wall while expecting to reach out for virtual objects in the VE leads, in this instance, to a sudden awareness of the physical reality of being in the Cave, as opposed to the virtual bar.

Participants were asked whether they considered the virtual bar a place they visited, or images that they saw. The majority reported a sense of being in a place: *"It's like a place I went to because I won't think of, 'Oh, you remember that hologram' or whatever he was. I'll be like, 'remember the barman?' instead of 'remember that image'... Definitely a place. Also, because it was so different from the space and it was definitely somewhere I went"* (P21 female). The sense of being in a surrounding space populated by people contributed to the sense of being in a place: *"Yeah, I felt more in a bar. Very much. Because the whole scene was, it was 3D, so I really felt that I was inside the bar and watching all those people speak and behave"* (P9 female).

In addition to the visuals, many also said that the audio aspect of the experience added to their sense of being in the bar. In particular, they mentioned the music and the characters' chatter as contributing factors: *"I think I felt like being in a real bar. I think perhaps the music helps. And the fact that the people were talking. I felt that it was the environment of a real bar"* (P2 male). This sense of being in the bar was not described as stable or constant, but was buoyed up by moments when the audio made the space come to life, for example when characters spoke: *"The music helped a lot. It was moments I felt I was in a bar: like when people were talking"* (P8 female).

6.1.2 The sense of "responding to" the bar

The combined audio and visual experience offered some participants a spatial sense of being in a virtual bar. This led them, in some instances, to *respond* to the bar as if it were real, for instance by instinctively trying to reach out and touch virtual objects. In addition to inanimate objects, some participants reported automatically responding to the virtual characters in social ways. One example was the attempt to engage in verbal interaction: *"Rationally of course you know that it's unreal because it's an experiment, but it's more of instinct, because once you are in a 3D thing, the music is there, and the people are there, they're talking, and I said 'hello'"* (P3 male).

Participants often expressed surprise at their own social responses to the characters: *"The man that was in the right*

side.... They smile to me. I smiled back. It was like my reaction to a real situation. I am surprised because my response was as if they were real people. At the beginning, I didn't expect to treat them as real people" (P2 male).

In addition to verbal interaction, some participants said they had tried to engage with the characters by waving at them: *"I talked to them... I said 'hello' and I moved my hand in a queer way"* (P20 male). Some also attempted to make physical contact: *"The one in the shorts, the blue one in front of me. I touched him like this, on the shoulder. I wouldn't pat him on the shoulder, I would just go like this, Just like a real person"* (P27 male). Interestingly, this touch is qualified as a socially acceptable form of touch, rather than an invasive or overly familiar gesture.

The virtual characters in the bar had fairly limited behaviours; for example, they did not drink out of their glasses, dance or move around the room, rather they stood in the same spot and made relatively muted gestures while speaking. In spite of this, many participants reacted emotionally to their body language and behaviour. Particular characters were often singled out for mention, such as the barman: *"This barman that I would keep turning to look at...that look was very real. So I wanted to look at him...with him I could actually feel like 'Oh my God, there's somebody staring at me.' The barman did not talk to me. I felt uncomfortable, like in real life, like when you know someone is staring at you and somebody doesn't say anything to you"* (P1 female). In this case, the relatively limited animation produced a realistic and powerful social response. Despite the fact that the barman did not look or behave in a highly realistic way, he was able to produce a sense of social discomfort simply by engaging in eye contact.

This sense of mutual gaze, combined with a purely accidental coincidence in animation, produced in some participants the sense of postural congruence, and made them wonder whether the characters were watching and imitating them: *"I was trying to find out if the guy that was standing up was trying to maybe mimic me or not because he was, like, I was crossing my hands and he was doing the same at some point. And then I had the feeling he was looking at me, so then I tried to move from one side to the other to see if he was following me and he wasn't, he wasn't really following me"* (P20 male). This example illustrates the fluctuating nature of the experience: at certain times, specific behaviours would coincide with expectations, causing participants to engage with the characters. However, lack of consistency ultimately undermined the illusion, making for a fluctuating sense of belief in the characters as sentient social entities.

There is some evidence that responses were partially shaped by participants' individual characteristics. For example, one shy participant reported a significant sense of discomfort in the virtual bar, explaining that his response was comparable to what it would have been in an equivalent real-world situation: *"I behaved reasonably as I'd behave in a real bar. Usually I do nothing really. I don't particularly like bars. I think bars are, like, nervous social situations, because it is a situation where you are supposed to bond, impress other people, so I don't*

particularly like those situations. I think I felt nervous before I entered the space. It had nothing to do with the virtual reality. It had something to do with the subject choice, or the object choice for the bar. Whereas I probably would have felt less nervous if it was like... I don't know... some less social situation" (P6 male).

However, several people behaved in a more open and 'daring' way compared to how they would usually behave in real life: "I was behaving like in a real bar, with maybe a little bit more staring, and a little bit more daring" (P1 female). Some usually shy people reported interacting with the avatars in a way that they would not ordinarily interact with real people: "I don't usually talk to a lot of people in the... in normal bars, but this time I felt like replying to them" (P26 male).

This section focused on participants' overall sense of presence in the virtual bar, expressed as their sense of "being in" the bar and thinking of it as a place visited rather than as images seen. It also discussed some automatic behaviours reported by participants, that shed light on their spontaneous responses to the space and to the characters in the bar. The following section addresses factors that contributed to fluctuations in presence throughout the experience.

6.2 Temporal variations in presence

This section begins by summarising the presence graphs participants drew, depicting their sense of presence over time. It then describes various causes for BIPs, beginning with the induced whiteouts and continuing with factors relating to the apparatus and the virtual characters. It concludes by discussing how varying recovery times shed light on the varying intensity of experienced BIPs.

6.2.1 Graphs

Participants were asked to draw a graph describing the extent to which they felt they were in the bar versus being in the laboratory throughout the experience. A sample graph is shown in Figure 3:

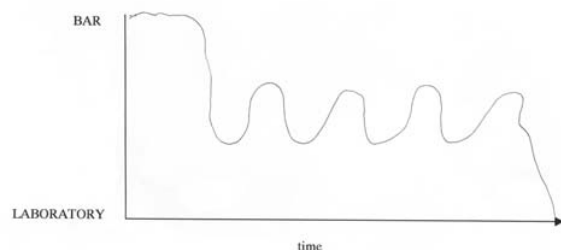


Figure 3: Presence graph illustrating BIPs (P8 female)

The graphs took one of four main patterns:

1. **High initial presence:** a strong sense of being in the bar in the beginning, decreasing over the course of the experience;
2. **Fluctuation:** a fairly high sense of presence throughout, punctuated by slopes caused by BIPs;

3. **Strong in the middle:** an initially low sense of presence, increasing towards the middle, and decreasing towards the end;
4. **Strong in the end:** a low initial sense of presence, steadily increasing until the end of the experience.

The graphs illustrate that the subjective experience of presence in the bar varied significantly between participants. For some, a high initial sense of presence gradually diminished due to insufficient stimuli in the VE. Others reported the opposite, explaining that it took them some time to habituate to the experience and become involved in it. Overwhelmingly, regardless of the overall shape of their presence graph, participants described an experience interspersed with interruptions (see Figure 3). The most obvious of these were the induced whiteouts.

6.2.2 Whiteout anomalies as BIPs

In the semi-structured interview, participants were asked about the induced anomalies. Specifically, they were asked to describe how many times the walls of the Cave had gone blank, what their response had been, and whether their reaction had been the same each time, or whether it had changed. Although there were four whiteouts, not all participants were accurate in their recall: "It happened three times. I think... The first time, it was like 'Oh'... You know, it was like waking up, and the second time, it was like 'Oh, it's happened again'" (P1 female). This statement illustrates the fact that the first whiteout appears to have had the strongest effect for the majority of participants. The first occurrence represented a sudden and surprising event in the experience, which participants sometimes attempted to explain to themselves in terms of a technical malfunction: "The first time I thought, like, a wire had gone loose" (P3 male).

However, after additional whiteouts, they often sought a plausible explanation for their repeated occurrence: "I didn't know if the whiteouts were triggered or anything. I assumed that it was loading the next bit of the program, or something like that, or, just, like, a blip in the, I don't know... As it stopped it was just like a temporary jolt from your surroundings" (P10 male).

The sensation was described as similar to waking up from a dream. Although unclear in their cause and meaning, these induced anomalies had the effect of breaking participants' sense of presence in the bar by reminding them of the apparatus and the laboratory. This was particularly the case after two or more whiteouts: "The second time I was like, 'Oh no, they were doing it deliberately, to make me feel that this is artificial. That you're still in the lab'" (P3 male).

The purpose of inducing the whiteouts was to generate clearly identifiable anomalies in the experience, in order to link any patterns in the physiological data with precise anchor points in the experience that participants could subjectively describe. The interviews reveal clearly that the induced anomalies were experienced as breaks in presence. However, additional causes of BIPs were also reported, including environmental factors relating to the technical apparatus.

6.2.3 Environmental factors as BIPs

Several “environmental factors” relating to the apparatus used in the experiment contributed to breaks in presence. Participants found the 3D stereoscopic glasses uncomfortable, and were aware of not wanting to damage what they suspected was fragile equipment: *“Maybe the sensation of this thing on the glasses, because I’m not very comfortable. The worry that I would step on the cable and break your equipment”* (P25 female).

The VE was deliberately designed to be approximately the same size as the Cave, leaving participants free to walk around the bar without needing to use a 3D mouse. The objects and characters in the environment were also spatially arranged such that all elements of interest were located along the back and side walls of the Cave. However, participants sometimes turned to face the back open wall, seeing the laboratory: *“So when I turned back then I saw the curtain and all, I saw you guys on the computer, again, and then it was back to the lab feeling again”* (P17 male). In addition to seeing the laboratory and the experimenters, other participants looked up and reported feeling shocked at seeing the projectors on the ceiling.

Certain aspects of the VE itself also undermined the sense of presence. One participant cited the inability to touch the virtual objects in the Cave: *“Trying to touch something. If I try and touch the beer, I just think, ‘Yeah, this is virtual reality.’ It’s just when you’re looking that everything seems real”* (P14 male). In addition to the lack of haptic interaction, certain visual elements also detracted from participants’ sense of presence, in particular the fact that not all visual objects appeared to be equally convincing in the bar: *“The door behind both the barman... It was just, like, kind of standing out. It seemed out of place to me. Like it wasn’t flowing with the rest of the bar. It’s like a stage door. ‘Okay, that’s where you go out from,’ kind of thing. I felt that it was a door out of the experience”* (P1 female).

In addition to these environmental factors relating both to the apparatus and the VE, a number of BIPs were caused by the appearance and behaviour of the virtual characters, as discussed below.

6.2.4 Virtual characters as BIPs

Just as the door stood out as an object in the environment that did not “flow” with the rest of the space, often specific virtual characters were singled out as less convincing than others. In one case, the female character on the left was described as undermining presence: *“The girl in the corner because she, I think where she was in the corner it was kind of shadowed, so she didn’t look as real as the others, they didn’t look real, but, how do you explain? She kind of didn’t look convincing, I suppose. So, when she said things and I looked at her, that, well, kind of reminded me that I was back in the experiment again”* (P12 female).

In addition to appearance, the behaviour of the avatars sometimes had a significant impact: *“Whenever I would look at the two who were just standing there, they seemed a*

little unreal... Because there wasn’t any movement and their movements, as opposed to the others, were a little more jerky, if you will. They were not very smooth. Their body language was unreal, it was inhuman. It was like, a reminder, ‘okay, you’re not in the bar’” (P1 female).

Both the characters’ appearance and behaviour served to undermine their role as social entities. Once belief in the bar as a social space was broken, it appears to have been irreparable: *“When I realised that I can’t interact with the people, I think that I was in an experiment and that I want just to look around, I want just to grab, or feel the things, the objects”* (P2 male). What is interesting is that once the belief in the characters was undermined, participants stopped treating the bar as a social environment and began exploring it as if they were alone, uninhibited by the presence of others.

6.2.5 Recovering from BIPs

Participants were able to recover their sense of presence after some BIPs. In many cases, recovery was apparently rapid: *“I experienced a change very briefly when there was a break in the signal. There I did get that feeling, but it passed quickly. As soon as the signal came back on, I felt that I was back in the bar. It was pretty much complete and immediate”* (P4 male). However, recovery became more difficult with the each successive whiteout: *“It just got longer after the second and third break. You were just sort of, like, ‘Oh, okay, it’s back again’ then, you know, back again, back again, let’s try to get back (laughs) again. Yeah, so it sort of lengthens after the second and third time”* (P27 male).

In some cases, recovery was significantly longer: *“About ten or twenty seconds. It wasn’t immediate. I turned back to look at you all”* (P26 male). The act of turning back to look at the laboratory served to reinforce the BIPs. Also, more intense BIPs required active effort on the part of participants in order to recover a sense of presence in the bar: *“Well to get back into it, that was almost like a positive... like an effort. Like, ‘Oh, okay. Now it’s back. Now what are they saying.’ It was kind of like that now. So it was like, it went off, and then I was like, ‘Okay’...and then came back on so I had to focus on something in the bar to bring it back to life. It was an effort”* (P1 female).

The analysis points to a range of intensity of BIPs, and a resulting range of recovery times. The BIPs caused by the characters resulted in relatively rapid recoveries: *“A few seconds, maybe like two, three seconds. It wasn’t like immediately that ‘Okay, I’m involved in the conversation again’”* (P1 female). In comparison, the BIPs caused by the whiteouts were generally more intense: *“It’s possible to compare but at different levels. The lights going off were stronger feeling”* (P1 female).

The whiteouts also had a stronger effect than environmental factors: *“And my hand going straight through the bar. Or trying to touch something. Halfway down, maybe. It’s the light that takes you all the way down, like the complete switching off”* (P14 male).

Participants experienced a longer recovery after whiteouts than character-related BIPs. The act of suddenly hitting the physical Cave boundaries had a similar effect to

the whiteouts and resulted, for some, in an even stronger BIP: *"When comparing the flash versus the hitting the wall, I guess, probably bumping into the wall was more, sort of, a sharp reminder"* (P18 male).

This section has addressed various causes of BIPs, and has presented evidence suggesting that BIPs range in intensity and recovery time. This supports the notion that rather than being a stable response, presence may vary through the course of the mediated experience. In the following section we present findings suggesting that presence also varies spatially within the same VE.

6.3 Spatial variations in presence

As discussed above, participants sought to maintain a sense of presence in the VE. This desire to avoid disruptions in presence also expressed itself in terms of where they chose to go in the environment. They tended to avoid spending time on the left side of the room, near the seated couple: *"I didn't seem to spend that much time on the left of the bar. Those people were further away. I couldn't see them as well and I was a bit confused about that and the bar just kept getting me. The guys sitting down, I almost didn't notice them because they were away, because there was that distance"* (P21 female).

The couple on the left was located just beyond the boundaries of the Cave wall, so it was not possible to physically approach them as closely as the couple standing by the bar. For some, the seated couple also appeared more socially distant: *"The sitting couple were very into their own conversation, and did not want me to join. Standing couple.... they tried to interact, smiled, tried to get me into the conversation"* (P2 male).

Similarly, the barman was often singled out as a more sympathetic and engaging character: *"The bartender, he didn't say much until the last part when he said you should order something (laughs), but he was smiling so I found that I was actually looking at him a little bit more than I looked at the rest.... He doesn't speak, I think that's something that's quite (laughs)... It's just something you remember because everyone is always talking, talking, talking and he doesn't speak, but he always looks at you. He smiles sometimes so when he spoke at the last part, it was a nice change, I was like, 'Whoaaaa, he actually speaks.' So I sort of, like, retained the best memory of him"* (P27 male).

Participants generally gravitated towards the right side of the room partly for social reasons, because the characters seemed more approachable. However, another reason was that the left corner of the room appeared darker, making the Cave edges more obvious: *"I saw the walls, the corner. The left one is a little obvious because I think it's in a dark area. Whereas this one is right in the cut of the woman"* (P27 male).

A combination of factors including avatar placement and behaviour, and ambient lighting, meant that many participants spent the bulk of their time towards the bar on the right side of the VE. They actively avoided the area where they felt socially excluded and where the Cave boundaries were more evident, suggesting that participants' subjective sense of presence varied not only temporally in

the course of the experience, but also spatially according to where they stood in the VE.

7. Discussion

The primary goal of the qualitative analysis presented in this paper was to establish how participants subjectively experienced the whiteout anomalies. The analysis revealed that they did indeed perceive them as breaks in presence, likening the experience to a feeling of "waking up" or a "shock". Experimental minders observing the participants' behaviour in the Cave noted that the first whiteout was often accompanied by "startle" behaviours, with participants suddenly standing still and sometimes expressing verbal surprise. In many cases, physical responses to successive whiteouts were less pronounced. This observation tallies with our preliminary physiological findings indicating that the first whiteout resulted in a more pronounced increase in GSR. It is also consistent with participants' explanation that they experienced a strong reaction to the first whiteout, but less of a surprise after subsequent whiteouts. With regard to the whiteout-related BIPs, the physiological and subjective data therefore appear to present a cohesive picture.

An additional goal of the analysis was to learn more about how the whiteouts, and other possible causes of BIPs, affected subjective presence over time. Participants were asked to draw graphs describing their feeling of presence over time, during their experience in the virtual environment. Although the graphs could not be quantified or directly compared, they proved to be a useful tool in focusing the interviews, and gaining a better understanding of the different ways people experience temporal variations in presence.

The analysis identifies a range of factors contributing to BIPs. These include the apparatus, the limited sensory modality of the VE (specifically the lack of haptics), insufficient consistency in the level of visual realism of the environment, and aspects of the appearance and behaviour of the characters. Our findings suggest that BIPs can have different intensities, resulting in varying recovery times. The majority of participants were able to recover more quickly from environment- and avatar-related BIPs than from the whiteouts. Also, BIPs appear in some cases to have had a cumulative effect, so that recovery time increased with subsequent BIPs, requiring greater effort on the part of the participant in order to feel present again.

One surprising finding was the notion that presence varies in intensity within the same space. The interviews revealed that participants had a pronounced preference for specific areas within the VE that they perceived to be more presence-inducing. They sought out those areas where characters appeared visually brighter and clearer, and more approachable. They also avoided areas where the ambient lighting made the Cave boundaries more evident, reminding them of a physical reality separate from the virtual bar. This, combined with the fact that participants put in effort to recover from BIPs, suggests that they sought to remain present by gravitating towards those parts of the VE that helped them remain present. This desire to remain present

is consistent with Spagnolli and Gamberini's finding [18] that participants experiencing a technical anomaly sought to address it within the logic of the VE, rather than acknowledge it as a BIP.

In summary, our findings support the view [3, 8, 13] that presence is not a stable response. Our content analysis offered insights into how presence varies temporally as a result of apparatus, content and other factors. The thematic analysis allowed us to explore new themes that emerged from the data, and highlighted the notion that presence can also vary spatially within the same environment.

8. Conclusions and future work

This paper presented the qualitative findings from an experiment designed to investigate breaks in presence (BIPs). We sought to investigate presence as a multi-level phenomenon encompassing both involuntary autonomic responses and subjective perceptions. By triggering clearly identifiable whiteout anomalies in the experience, we were able to directly anchor participants' subjective accounts of breaks in presence to specific points of the experience. Our preliminary physiological findings link the whiteouts to an increase in GSR. The fact that our qualitative analysis also qualifies the whiteouts as subjectively experienced BIPs is encouraging, and suggests fruitful avenues for further research into the use of physiological measures to study the temporal fluctuations in presence during any mediated experience.

Our findings offer insights into the subtle ways presence can be undermined, linking different causal factors with BIPs of varying intensities. The analysis also suggests that in addition to varying in time, presence can vary spatially within the same environment, and that participants actively gravitate towards those areas that are more presence-inducing. In future we plan to conduct focused studies with a smaller number of participants, with a view to making detailed cross-comparisons between autonomic, behavioural and subjective responses, to explore the overall picture they paint of presence.

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