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Temporal and Spatial Variations in Presence: Qualitative Analysis of Interviews from an Experiment on Breaks in Presence

Abstract

This paper presents qualitative findings from an experiment designed to investigate breaks in presence. Participants spent approximately five 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' physiological responses were measured throughout to investigate possible physiological correlates of these experienced anomalies. Analysis of subsequent interviews with participants suggests that these anomalies were subjectively experienced as breaks in presence. This is significant in the context of our research approach, which considers presence as a multilevel construct ranging from higher-level subjective responses to lower-level behavioral and automatic responses. The fact that these anomalies were also associated with an identifiable physiological signature suggests future avenues for exploring less intrusive ways of studying temporal fluctuations in presence during the course of the mediated experience itself. 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 virtual environment can fluctuate temporally and that spatial behavior is consistent with what would be expected in an equivalent real environment.

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 our Cave[1] system, but in the physical Cave in our laboratory taking part in an experiment. The purpose of triggering these anomalies was to investigate whether these

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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 Cruz-Neira, Sandin, and DeFanti (1993), rather than to the specific commercial product. The specific product was a Trimension ReaCToR.

clear interruptions in the mediated experience could be associated with an identifiable physiological signature. In a companion paper (Slater, Guger, et al., 2006) we presented a method for using electrocardiogram (ECG) parameters and electrodermal activity to identify BIPs. Here the purpose is to describe the associated subjective experience.

Presence is of interest to practitioners in a number of fields including engineering, computer science, psychology, psychiatry, cognitive science, communication, and philosophy as well as telecommunication and teleoperation (e.g., Held & Durlach, 1992; Sheridan, 1992; Barfield & Weghorst, 1993; Ellis, 1996; Sheridan, 1996; Lombard & Ditton, 1997; Slater & Wilbur, 1997; Draper, Kaber, & Usher, 1998; Sanchez-Vives & Slater, 2005). Research has been driven by both theoretical and practical concerns since a heightened sense of presence is considered essential for effective psychotherapy (Hodges et al., 1995; Rothbaum, Hodges, Watson, Kessler, & Opdyke, 1996; Rothbaum et al., 1999; Rothbaum & Hodges, 1999; Rizzo & Kim, 2005), for performance in training simulations (Biocca, 1997) and for a wide variety of other VE applications.

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 major goal of the experiment discussed here was to investigate presence as a multilevel construct ranging from lower-level involuntary responses to higher-level subjective responses (Sanchez-Vives & Slater, 2005). This approach does not imply that for presence to occur, all of the indicators are consistent with one another. For example, strong behavioral conformity with events within the virtual environment may be accompanied by verbal statements that suggest that the participant did not "feel" present. We would regard "high presence" as occurring when multiple indicators all point to a realis-

tic response to the virtual scenario, and are consistent with one another.

We recorded a range of physiological responses throughout the experience, namely respiration, ECG parameters including heart rate (HR) and heart rate variability (HRV), and finally electrodermal activity (EDA, also referred to as galvanic skin response, GSR). The purpose of the qualitative analysis presented in this paper is to shed light on the physiological data, with a view to investigating the viability of using physiological responses to automatically detect BIPs without requiring participants to signal them. We wished to understand how participants subjectively characterized the triggered anomalies, and specifically whether they experienced them as BIPs. If so, coupled with our physiological data, our findings could inform further explorations of nonintrusive 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 so-called SUS questionnaire (Slater, Usoh, & Steed, 1994) and the presence questionnaire (PQ) (Witmer & Singer, 1998) to assess participants' sense of "being there" in a mediated environment. However, questionnaires present a number of drawbacks when used alone, since inaccurate recall and demand characteristics can distort results. They also capture post hoc rationalizations, as opposed to the experience itself (Freeman, Avons, Pearson, & IJsselsteijn, 1999; Slater, 1999; Usoh, Catena, Arman, & Slater, 2000; Slater, 2004).

It has been argued that rather than being a stable constant throughout the mediated experience, presence

may vary over time (Sheridan, 1992; Biocca, Burgoon, Harms, & Stoner, 2001; IJsselsteijn, Freeman, & de Ridder, 2001). Slater and Steed explored a BIPs approach, asking participants to signal each time that their sense of presence in the VE was interrupted by a sudden awareness of their physical surroundings (Slater & Steed, 2000). They reported a strong positive correlation between questionnaire-based presence and presence as estimated by the number of reported BIPs. However, by the authors' own admission, the drawback of this approach is that subjective reporting of BIPs requires prior training, and can therefore potentially introduce bias in participants' responses. This is also true of IJsselsteijn and colleagues' use of manual sliders to capture a continuous subjective rating of presence during the course of a 3DTV viewing experience (IJsselsteijn & de Ridder, 1998; IJsselsteijn, de Ridder, Hamberg, Bouwhuis, & Freeman, 1998). The additional drawback of both the BIP and continuous assessment methodologies is that the act of signaling such subjective ratings can potentially interfere with the presence experience itself, although arguably this problem is less significant for the reporting of BIPs since these are by definition reported only after presence has already broken down.

Alternative approaches have been explored to study temporal variations without requiring participants' conscious attention. Freeman et al. investigated the use of behavioral measures, studying postural shifts in response to motion stimuli (Freeman, Avons, Meddis, Pearson, & IJsselsteijn, 2000). 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 (Meehan, Insko, Whitton, & Brooks, 2002). 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 BIPs are associated with observable physiological responses (Slater, Brogni, & Steed, 2003). Their findings suggested an association between BIPs signaled by the participants

during the VE experience and increases in skin conductance level and heart rate, and therefore have implications for the nonintrusive observation of responses to a wide variety of VEs. However, they cautioned that the physiological changes may be at least partially caused by the act of signaling the BIP.

The experiment reported in this paper expands previous BIP studies by disambiguating the physiological responses from the signaling of BIPs; participants in the main condition were not briefed on "transitions to real" and were not asked to report them. The experiment involved inducing "whiteout" anomalies in the experience, and the analysis involved matching physiological responses with these clearly identifiable anchor points in participants' experiences. 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.

In Spagnolli and Gamberini (2002), a study was described that explored 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 this 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

Thirty participants were recruited from the campus area and were paid the equivalent of $10 for volunteering their time. 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 prequestion-

naire covering their age, gender, occupation, and previous experience with VEs and computer games. The study was approved by the Ethics Committee and followed all standard procedures, including informing participants that they were free to withdraw from the study at any time, without needing to provide a reason.

Participants were then led through to the four-screen Cave-like system described in the companion paper (Slater, Guger, et al., 2006)—where they were shown how to connect the ECG and respiration sensors. EDA sensors were attached to their nondominant hand, and they were asked to stand still in the Cave for 2 min while we took a baseline reading. During this time, no images were displayed on the screens.

Next, participants were asked to complete a brief exercise in a virtual "training" room designed to make them comfortable moving around the Cave. This room consisted of white walls and a floor, and was mapped to the dimensions of the system so that participants could explore the entire virtual environment by walking, rather than by using a 3D mouse. Knee-high three-dimensional objects representing the numbers 1 through 9 appeared throughout the environment. Participants were asked to move through each number in turn, so that they could become accustomed to moving in the Cave with the equipment on.

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 afterward we would be asking them questions about the experience. When participants confirmed that they were happy to begin, curtains were drawn across the entrance to the Cave to partially isolate them from the experimenters. However, the entire experience was videotaped, so that experimenters were able to observe the participant on a video monitor throughout.

The participants remained in the virtual bar for the duration of two songs (approximately 5 min). 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—see Figure 2 in Slater, Guger, et al. (2006). Head tracking made it pos-

sible to determine the participants' position and orientation, and the avatars were programmed to respond to proximity. When approached by the participant, the characters would turn, engage in mutual gaze and 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 s. Two experimental minders observed the subjects throughout, noting their bodily and verbal responses to these whiteouts. Participants' autonomic responses were also monitored throughout. Figure 1 in Slater, Guger, et al. (2006) shows a participant in the bar environment, wearing the physiological monitoring equipment.

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. The purpose of this video playback was to give participants a chance to discuss the whiteout incidents without being directly asked about them; we wished to discover what the participants considered the most salient aspects of their experience, before broaching the topic of presence and BIPs. Any additional comments about other aspects of the experience that came up during the video playback were noted and returned to during the semi-structured interview that followed.

4 Semi-Structured Interview

One of the reasons for gathering physiological data is to shed light on participants' involuntary responses during 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 only 27 were kept in the data pool, because the audio quality on three interviews made them unsuitable for transcription. Interviews lasted approximately 15 min.

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 (Smith, 1995). 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. The questions for each theme were as follows:

General opening questions:

1. What did you think was going on in the bar?
2. Was there anything that stood out in the experience?
3. What were your expectations?
4. Was there anything about the experience that surprised you? (bar/people)
5. Was there anything about your responses that surprised you?

About the overall sense of presence:

1. Did you feel more as if you were in the bar or in the laboratory?
2. Did this change over time? If so, how so?

About BIPs ("transitions to real"):

3. Were there any moments when you became suddenly aware of the laboratory?
4. When?

5. How often?
6. What triggered these moments?
7. How did they make you feel?
8. How easy or quick was your recovery (recovering your sense of being in the bar)?
9. Did the intensity of the transitions vary?

About the avatars ("people in the bar"):

10. Can you talk briefly about the people?
11. What did they look like?
12. How did they behave?
13. What was their attitude to you? (neutral/negative/positive)
14. How did they make you feel?
15. How did you respond to them?
16. Did any particular person stand out?

Additional impressions:

17. Is there anything else you would like to add?
18. How do you think you will remember this experience?
19. Was the bar something you saw or somewhere you visited?

In addition, we experimented with the use of visual graphs to help participants describe their presence experience. Before being asked explicitly about the whiteouts, 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 (see Section 6.2.1).

5   Data Analysis

The interviews were taped and then transcribed verbatim. The transcripts were analyzed by combining two methods of qualitative analysis: content analysis (Weber, 1990), and thematic analysis (Kellehear, 1993).

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" (Riffe, Lacy, & Fico, 1998), 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 (Kellehear, 1993). 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 (Kellehear, 1993). The combination of these two methods allowed us to classify preconceived themes, as well as themes that emerged from the data itself; this allowed us to expand beyond our own preconceived notions of what was relevant to the research, to include information deemed important by participants. Throughout the analysis, an additional researcher, not involved in the experimental study, performed credibility checks (Barker, Pistrang, & Elliott, 2003) to ensure that the analyst's findings were consistent with the data in the transcripts. This approach did not involve independent coding of the transcripts, so we cannot speak to inter-rater reliability. The second researcher's role was to ensure that the analyst's findings stood up to subjective scrutiny, and to subsequently contribute to thematic analysis by searching for new themes not covered in the list of categories for content analysis.

6 Findings

This section describes our analytical findings. First, we address the overall sense of presence, beginning with participants' responses 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* behavior during the experience. The findings are illustrated by direct quotes from the interviews with participants; participants are identified throughout by number and gender.

6.1 Overall Sense of Presence

As mentioned above, before taking off equipment or leaving the Cave, participants were asked two questions concerning their immediate impressions:

1. On the whole which place did you *respond to* most, the physical laboratory or the bar?
2. On the whole which place did you have a sense of *being in* the most, the physical laboratory or the bar?

In both cases they were asked to report whether they'd felt they were in the bar less than 50% of the time, about 50-50, or more than 50% of the time. Analysis of these immediate questions showed that the majority of participants experienced a sense of being in, and responding to, the bar more than 50% of the time. This validation is critical to our discussion; had this not been the case, there would have been little sense discussing breaks in presence. The results are illustrated in Figure 1.

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 rationalizations. 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 or feeling of being 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:

A   Immediate Question 1

B   Immediate Question 2

Figure 1. *Responses to the immediate questions.*

"*I was going to see . . . where, um, where I could put my hands, but then, obviously, it was on the wall and I realized 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).

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 re-

sponse 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 behaviors 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 summarizing 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 subjectively experienced BIPs.

6.2.1 Graphs. Participants were asked to draw a graph describing the extent to which they felt they were
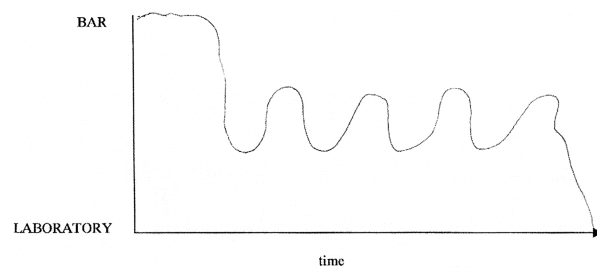

Figure 2. *Presence graph illustrating one female participant's experience. Subjective presence starts off high, is interrupted four times by the triggered anomalies, and finally diminishes toward the end of the experience.*

in the bar versus being in the laboratory throughout the experience. A sample graph is shown in Figure 2.

We have classified the graphs into 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. Strong in the end: a low initial sense of presence, steadily increasing until the end of the experience;
3. Strong in the middle: an initially low sense of presence, increasing toward the middle, and decreasing again toward the end;
4. Stable: a fairly high sense of presence throughout.

Nineteen participants reported that their sense of being in the bar changed significantly through the course of the experience. It should be mentioned that not all participants were accurate in their recall of the whiteout anomalies. Although four whiteouts were triggered during the course of each session, one participant remembered three whiteouts, another remembered two, and two others could not recall the number. The sample graphs illustrate some ways in which the sense of presence varied for different participants.

Twelve participants (6 males and 6 females) reported that their feeling of being in the bar was stronger at the beginning of the experience. The graphs in Figure 3 illustrate a fairly stable overall decline in presence. Participants cited several reasons for this decline. They gradually became bored as they became more familiar with the bar, and this led them to begin exploring the
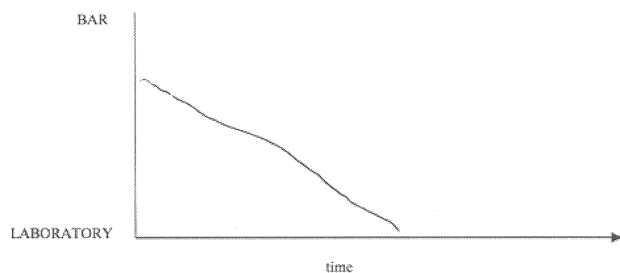
Figure 4. *Graph showing presence starting off low and increasing through the course of the experience.*

Figure 3. *Graphs showing high initial subjective presence.*

bar in a more game-like way, with a view to provoking a response. However, the avatars' responses did not appear sufficiently convincing and humanlike, and this was compounded by their often unnatural facial expressions. As they spent more time in the bar, they also became increasingly aware of the Cave boundaries, and this reminded them of the physical reality of the laboratory in which they were really located.

Conversely, five participants reported feeling increasingly present through the course of the experience (Figure 4). They explained that it took them some time to become used to the bar, after which it began to feel more real to them. One female participant explained that she discovered that when she knelt down and experienced a corresponding change in perspective in the bar, she began to feel more as if she were really there. This highlights again the importance of being able to move freely and physically around the VE in the course of an immersive experience.

Several participants explicitly mentioned that their sense of being in the bar fluctuated throughout the ex-
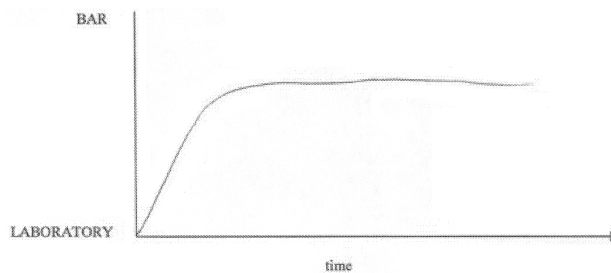
perience. For two male participants, the sense of presence increased as they became gradually more accustomed to the environment; however, various factors then started to undermine this sensation. They mentioned in particular their growing awareness of the Cave walls, and the way the images appeared jerky at times. Figure 5 shows this pattern of presence peaking in the middle of the experience. The four whiteout-related BIPs are clearly shown in the graph on the right.

Only one female participant said that she felt she was in a virtual bar throughout. Although others reported a fairly stable overall sense of presence, they mentioned that this diminished at various points in the experience, not least as a result of the whiteouts. Figure 6 illustrates graphs drawn by participants who felt a fairly high sense of presence throughout, interspersed with BIPs. The number of BIPs does not correspond to the four whiteouts in all cases; this is because participants also cited other causes, such as turning to face the open wall of the Cave, or a virtual character behaving in an unexpected way.

Finally, Figure 7 illustrates the experience of one participant, whose sense of being in the bar increased relatively rapidly at the beginning of the experience, and then gradually and regularly declined with each successive BIP. This notion of BIPs having a cumulative effect is further discussed below.

In summary, the subjective presence graphs illustrate that the subjective experience of presence in the bar varied significantly among participants. For some, a high initial sense of presence gradually diminished due to insufficient stimuli in the VE. Others reported the op-
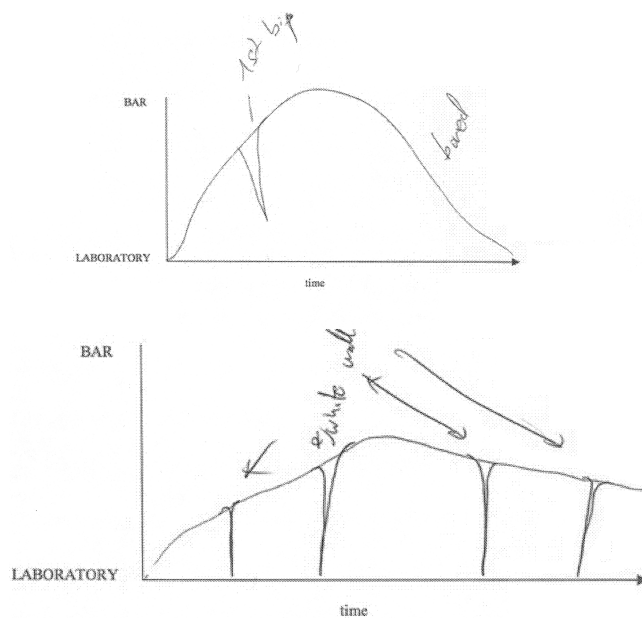
Figure 5. *Graphs showing a higher level of subjective presence in the middle of the experience. The annotations, for example, "1st bip" and "bored" were added by the interviewer.*

posite, 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 Figures 6–7), the most obvious of which were caused by 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 sud-
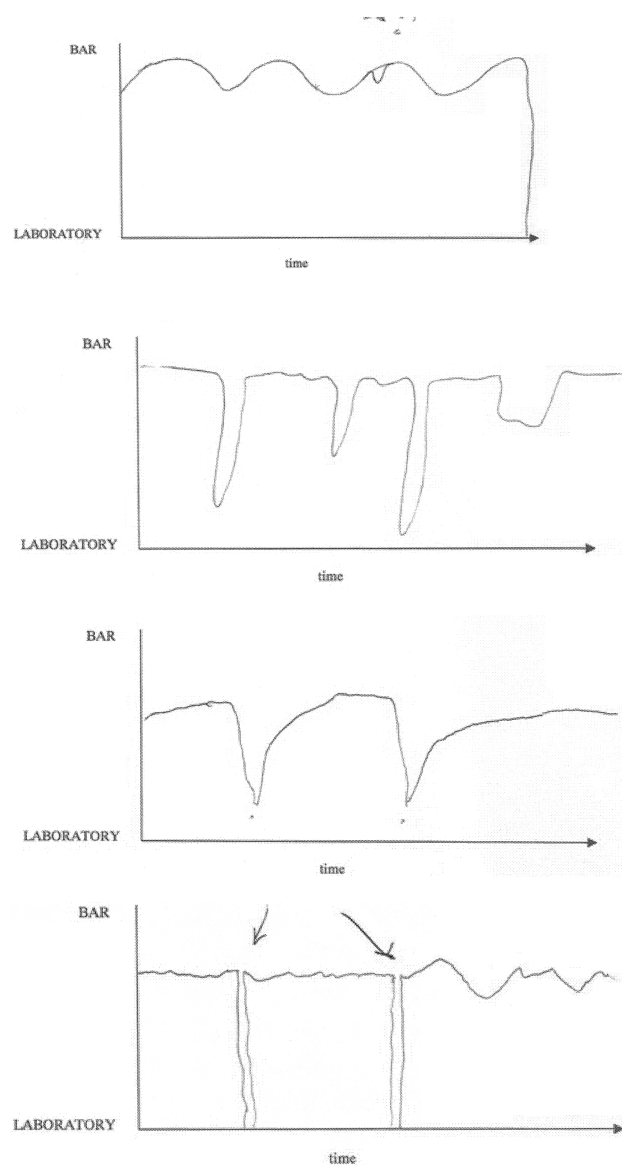

Figure 6. *Graphs showing a stable overall level of subjective presence, interspersed with BIPs.*

den 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*
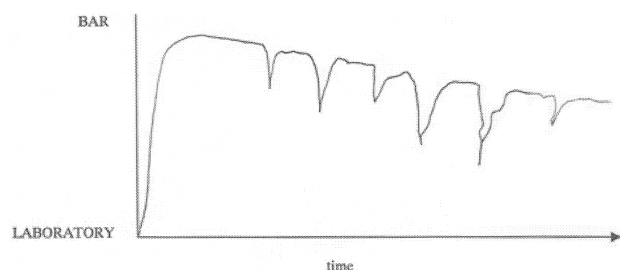
Figure 7. *Graph illustrating a sharp increase in presence at the beginning of the experience, followed by a gradual decline linked with the cumulative effect of successive BIPs.*

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 BIPs. 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 handheld 3D pointing device for locomotion. 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 behavior 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). Several participants cited the characters' unreal body parts and non-photorealistic appearance as disruptive to their sense of being in a real space with real people.

In addition to appearance, the behavior 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). Others particularly stressed the lack of coherent responsiveness from the characters as a major factor undermining their sense of being in a real bar, because they did not converse the way real people would.

Both the characters' appearance and behavior 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 realized 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 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).

In most cases, 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). However, there were some exceptions. For one participant (P20 male), the fact that the images appeared slightly blurry was much more significant than the whiteouts, which did not cause him to experience "transitions to real." For another participant (P2 female), the fact that the avatars' faces sometimes appeared to "flash" in brightness was far more disruptive than the overall BIPs.

Participants generally 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 Use of the Space

As discussed above, participants sought to maintain a sense of presence in the VE. They also exhibited presence through their occupancy of the space, behaving much like we would expect people to behave in a similar real 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 near the boundaries of the Cave wall, so it was not possible to physically approach them as closely as the couple standing by the bar. This was also because the table in front of them acted as an additional barrier. 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, 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 . . . . 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 toward 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*
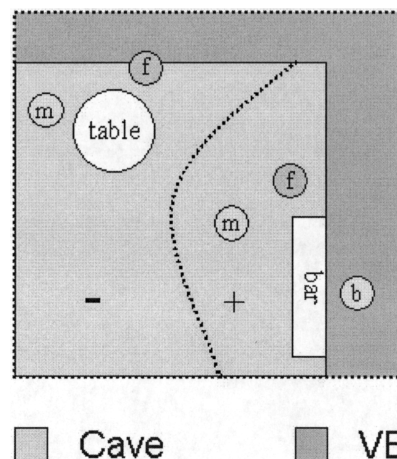

Figure 8. *The diagram above illustrates a common theme that emerged in the interviews regarding the way participants were drawn toward the right-hand side of the bar. On this side, near the standing couple and the barman, they felt more present than on the left near the seated couple.*

walls, the corner. The left one is a little obvious because I think it's in a dark area." (P27 male).

A combination of factors including avatar placement and behavior, and ambient lighting, meant that many participants spent the bulk of their time toward 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 as well as participants' subjective sense of presence varying temporally in the course of the experience, they also tried to maximize this through their spatial positioning (Figure 8).

7   Discussion and Conclusions

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." Experimenters observing the participants' behavior in the Cave noted anecdotally that the first whiteout was often accompanied by "star-

tle" behaviors, with participants suddenly standing still and sometimes expressing verbal surprise. In many cases, verbal and physical responses to successive whiteouts were less pronounced. This observation tallies with participants' accounts 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, their bodily behavior and subjective responses 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. These 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. We limited our analysis of the graphs to grouping them into general patterns illustrating how subjective presence can vary through the course of the experience. The four main patterns were: overall increase, overall decrease, presence peaking in the middle, and overall stable sense of presence. Within each of these patterns, different participants placed varying emphasis on illustrating the BIPs they had experienced.

It was not possible to directly compare the graphs in our analysis, because participants did not chart their experience according to an absolute timeline. For example, the two graphs in Figure 3 show a similar pattern, but direct comparison would mislead us into believing that one participant had spent longer in the Cave than the other. The four whiteouts were designed to enable direct comparison between physiological and subjective responses by tying them to defined anchor points in the experience.

However, not all participants were accurate in recording all four whiteouts on their graphs, and some did not remember how many had actually occurred. In future, comparison between graphs could be facilitated by the introduction of unique and clearly identifiable anomalies. For example, instead of triggering four identical whiteouts, an alternative would be to create distinct anchor points in an unfolding narrative, enabling partici-

pants to graph the experience along memorable and meaningful events on a timeline.

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 behavior 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, and required greater effort on the part of the participant in order to feel present again.

In terms of overall presence, the analysis opens an interesting question. Several researchers (Held & Durlach, 1992; Meehan et al., 2002; Slater, 2004) have considered presence operationally as the extent to which observed behavior is similar to what it would be in an equivalent real-world situation. In Meehan's research, for instance, a steep precipice in a virtual room would be expected to elicit similar anxiety responses to an equivalent precipice in a physical environment. In our bar scenario, some participants expressed surprise at finding themselves responding to the virtual characters in socially realistic ways in spite of the fact that they were not entirely convincing. For example, some attempted to converse, while others felt shy about approaching them; they cited their degree of introversion or extroversion as being similar to what they exhibited in real-life social situations.

Conversely, other participants were equally surprised at having behaved in a more "daring" way than they would in a real bar. The fact that they had been more extroverted than usual did not, however, translate into a diminished sense of being in the bar. This raises interesting questions concerning the operational definition of presence cited above, which hinges on the requirement that responses to the VE be comparable to those exhibited in an equivalent real-world situation. For practical applications, such as in psychotherapy for social phobia, this result is very useful. It has to be remem-

bered that virtual reality is not reality, and as noted in Slater, Antley, et al. (2006) it is the very gap between reality and virtual reality that makes it a very powerful tool, allowing us to carry out experiments and procedures that would not be possible in reality, while nevertheless obtaining realistic responses to virtual situations and events.

One interesting finding to emerge from the thematic analysis was the notion that people distributed their location in space much as we would expect them to do in reality. The interviews revealed that participants had a pronounced preference for specific areas within the VE, deliberately seeking 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 made an effort to recover from BIPs, suggests that they sought to remain present by gravitating toward those parts of the VE that helped them remain engaged. This desire to remain present is consistent with Spagnolli and Gamberini's finding (Spagnolli & Gamberini, 2002) that participants experiencing a technical anomaly sought to address it within the logic of the VE, rather than acknowledge it as a BIP.

Regarding BIPs, the results support the idea that not only do these occur, but that they are not simply instantaneous events. The Markov Chain based statistical model of the distribution of BIPs (Slater & Steed, 2000), required transitions between "present in the virtual" and "in real" states to be instantaneous events, switching between these binary states. As noted in the original paper, this is not meant to be a psychological truth, but an abstraction that forms part of a statistical model. Of course a more sophisticated model could be constructed that incorporates time into BIP transitions.

In summary, our findings support the view 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 the use of space conforms to realistic behavior.

This paper presented the qualitative findings from an experiment designed to investigate 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. Physiological findings presented in our companion paper (Slater, Guger, et al., 2006) indicate that ECG and EDA responses can be used to identify those whiteouts. 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.

Acknowledgments

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