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A Qualitative Case Study on Deconstructing Presence for Young Adults and Older Adults

Abstract

In this paper, we present the results of an exploratory qualitative case study on presence experienced by groups of young adults and older adults during their use of an interactive virtual reality application mixing realistic and fantasy elements. In contrast to most previous studies, we do not focus on a set of predetermined factors but instead adopt an open-ended qualitative approach to identify emerging factors from the users' experiences. We then analyze these factors against the place illusion/plausibility illusion (PI/PSI) framework of Skarbez, Neyret, et al. (2017) to investigate whether PI and PSI, as well as their contributing factors, can be separated. According to our findings, a user can experience PI and PSI independently from each other; however, they often appeared intermixed when investigated on the scope of the whole experience. Breaks in presence, as well as breaks in plausibility, could mostly, but not entirely, be attributed to immersion and coherence factors, respectively. An interesting finding is that both participant groups turned out to have two subgroups interpreting their experience with a particular frame of reference of differing expectations. These frames of reference affected not only PSI, as expected, but PI as well, suggesting that coherence could be a contributing factor to both PI and PSI. Our contribution adds to the relatively small body of research investigating the separation of PI and PSI. Our exploratory findings can be utilized as directions for designing future confirmatory studies.

1 Introduction

The idea of *presence* is one of the most central concepts in immersive virtual reality (VR). The concept was adopted from Marvin Minsky's (1980) essay concerning *telepresence*, a technological concept of an individual carrying out complex tasks over large distances utilizing natural humanlike actions. Minsky stated that one of the central challenges of telepresence was achieving the "*sense of being there*." It was exactly this "*sense of being there*" that was adopted by the VR community as the concept of presence, even if the exact definition was still fluctuating, variations existing on what exactly does or does not constitute presence (Skarbez, Brooks, & Whitton, 2017).

While the exact, unified definition of presence is still lacking, Slater's concepts of *immersion, presence*, and *plausibility* have gained popularity. In 1997,

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Slater and Wilbur proposed a framework separating *immersion* from presence (Slater & Wilbur, 1997). In this framework, immersion constituted objective, technological properties of the system (such as tracking capability, visual fidelity, and other display properties) while presence was the VR user's subjective sensation of "being there." Later, Slater updated the definition of immersion, discarding the exact, individual set of properties in favor of the concept of *sensorimotor contingencies* (SCs) from philosophy of mind literature (Noë, 2004; Slater, 2009). In Slater's context, SCs refer to the extent of the VR system's capability of rendering realistic multisensory output in response to the user's natural, humanlike sensorimotor actions such as turning your head, walking naturally and grasping objects (Slater, 2009).

The relationship between immersion and presence is that immersion is what enables presence to occur; the richness of sensorimotor contingencies offered by the VR system appears to affect presence (Cummings & Bailenson, 2016). Although the "*sense of being there*" can occur, for example, by reading books or watching television, the experience is still very different from those given by immersive VR systems (Slater, Banakou, Beacco, Gallego, Macia-Varela, & Oliva, 2022). Immersive systems can elicit strong lifelike responses, such as fear of heights or social phobia, despite the users of the system knowing for certain that they are not in the place depicted by the VR systems and that the events taking place are not real (Gonzalez-Franco & Lanier, 2017; Slater, 2009). It has even been argued that illusions enabled by VR systems are always involuntary, and even comparable to mental illness, making them very different in practice compared to the sensations rising from traditional media (Cogburn & Silcox, 2014; Langan, 2000).

As mentioned in the previous section, historically, the exact definition of presence has varied among scholars, and there has been debate about whether concepts such as the level of attention VR user is paying to the virtual environment (VE) or the effectiveness of the user in performing tasks inside the VE are affected by presence. In addition, some authors have also raised the question of whether the "sensation of being there" and the sensation of observed events appearing real are separate illusions (e.g., Baños, Botella, Garcia-Palacios, Villa, Perpiñá, & Alcaniz, 2000; Rovira, Swapp, Spanlang, & Slater, 2009). Sanchez-Vives and Slater (2005) also discussed whether the extent of presence essentially equals the extent of VR users responding realistically to the VE. In his 2009 article, to simplify the discussion, Slater coined the term *place illusion* (PI) to refer to his exact definition of presence (Slater, 2009). Therefore, PI refers strictly to the illusion of being in a place, leaving related concepts outside of this definition. Simultaneously, he also coined the term *plausibility illusion* (PSI) to specifically refer to the illusion of events appearing real inside the VE; together, these two illusions are what enable VR users to react realistically to VEs (Slater, 2009). Logically, it should be possible for these two illusions to appear separately; one can experience PSI without PI, for example, by watching a theater performance or playing a classical non-immersive video game, whereas PI can be experienced in a VE where the participant feels the sensation of being in the VE that otherwise does not appear credible to the participant.

Although immersion—in essence, the SCs provided by the system—enable PI, Slater's original framework did not propose a concept that would similarly provide boundaries for PSI to take place. Two such concepts, called *authenticity* (Gilbert, 2016) and *coherence* (Skarbez, Neyret, Brooks, Slater, & Whitton, 2017) appeared contemporaneously. These concepts refer to the internal logic and overall credibility of the VE. More specifically, these concepts do not refer to the accuracy of objective reality the VE simulates but instead how the VE and its behavior matches the VR user's expectations. In their 2017 article, Skarbez et al. suggested an overall framework where presence would be an umbrella term for PI, PSI, and also co-presence and social presence illusions (Skarbez, Brooks, et al., 2017). This suggested framework places immersion as an enabler for PI and coherence as an enabler for PSI. As coherence is specifically dependent on VR users' expectations towards the VE, priming the users can change these expectations and therefore affect the onset of PSI (Skarbez, Brooks, & Whitton, 2020; Skarbez, Neyret, et al., 2017). For example, a magical creature in a fantasy environment would be good coherence, whereas a similar creature in a factory training application would be bad coherence. Despite this definition, however, there has been little empirical data on this relationship between narrative priming and PSI, the recent study of Brübach, Westermeier, Wienrich, and Latoschik (2022) being one of the few exceptions. In addition, there are studies predating the concept of PSI (e.g., Nunez & Blake, 2003).

Given the large amount of research concerning presence, there are relatively few published results concerning presence in different age groups. It has been argued, however, that this connection should not be overlooked, not only because different VR applications target different age groups but also because perceptual and attentional capabilities of humans vary throughout life, and the difference in these capabilities could theoretically affect how different age groups experience presence (McGlynn, Sundaresan, & Rogers, 2018). Moreover, contemporary research, in general, is often criticized for lacking ecological validity due to homogeneous participant populations (e.g., Simons, Shoda, & Lindsay, 2017).

In this paper, we take the PI and PSI components of Skarbez's framework and investigate it against qualitative data we collected with semi-structured interviews from young and older adults about their use of an immersive VR application. Their session lengths ranged between 30 to 75 minutes. Our purpose was not the exact quantification of either PI or PSI, but instead to focus on *why* these participant groups experienced PI and PSI the way they did (using the umbrella term *presence* when referring to both components simultaneously). We chose the qualitative approach because it is more suitable for answering *why* questions and allowed us to identify unforeseen themes emerging from data instead of focusing on predetermined factors. We want to point out that our study is exploratory, not confirmatory. Although qualitative methods do not allow statistical comparisons across data or proof of hypotheses, we believe our findings can point out future directions for such experiments. We delimit co-presence and social presence illusions outside this work to keep factors under investigation manageable. Moreover, the VE we used as the experimental apparatus does not contain virtual humanoid characters suitable for investigating these particular illusions.

The contributions of this paper are as follows: Although PI has been studied extensively in VR literature, there are, as of now, relatively few empirical studies concerning PSI, the separation of PI and PSI, and the relationship between coherence and PSI. The qualitative approach we utilize allows us to investigate PI and PSI without relying on a predetermined specific, limited set of factors. We then discuss whether these illusions can occur independently or if they appear as interrelated. We also investigate whether the contributing factors of immersion and coherence are always specifically related to PI and PSI, respectively, when self-reported by participants. We also investigate how willing participants are to accept unnatural fantasy events as plausible after an interactive priming session. We also investigate the background and social factors of participants and investigate how these factors affected the experience of presence. As this study is exploratory, our findings do not have the same gravity as a confirmatory study would. We, however, believe they are significant enough to warrant directions for more controlled confirmatory studies in the future.

2 Related Research

Measuring presence is a notoriously difficult task. Although multiple questionnaires have been developed for measuring presence, and PI specifically (e.g., Schubert, Friedmann, & Regenbrecht, 2001; Slater, Usoh, & Steed, 1994; Witmer & Singer, 1998), the use of questionnaires has also been heavily criticized. This criticism includes questionnaires not being able to differentiate between different immersion levels (or even between reality and VR) (Slater, 2009; Usoh, Catena, Arman, & Slater, 2000) and not being able to identify novel insights or reasons contributing to the experience (Beacco, Oliva, Cabreira, Gallego, & Slater, 2021; Slater & Garau, 2007), as well as uncertainty whether an abstract concept such as presence can be reported reliably using questionnaires or whether it is something that the questionnaire itself conjures in minds of the participants (Slater, 2004). Since presence is also attributed to VR users responding realistically (Sanchez-Vives & Slater, 2005), both biometric (Meehan, Insko, Whitton, & Brooks, 2002) and behavioral (Freeman, Avons, Meddis, Pearson, & IJsselsteijn, 2000; Jung, Wisniewski,

& Hughes, 2018; Slater & Wilbur, 1997) metrics have been suggested for measuring presence. The problem with these methods is that to use the methods, the VR experience itself has to be engineered in a way that is compatible with the measurements. For example, although stressful or fear-inducing experiences can be detected, for example, by measuring the heart rate of the participant or observing their behavior, a similar methodology might not work during more mundane experiences. The concept of a *break in presence* (BIP) refers to the VR user suddenly remembering or experiencing their physical location more strongly than the virtual environment. BIPs have been utilized to measure PI both quantitatively as well as qualitatively (Brogni, Slater, & Steed, 2003; Garau, Friedman, Widenfeld, Antley, Brogni, & Slater, 2008). It has been suggested that multiple measures could be used in combination to measure PI; for example, if all biometric and behavioral measures, as well as questionnaire results, point to a similar result, it can be used with greater confidence than when relying on a single metric (Skarbez, Brooks, et al., 2017).

Currently, the measurement of PSI has even fewer established methods than PI. A psychophysical method adapted from color science has been utilized somewhat often. One of the first examples appeared in the 2010 paper by Slater, Spanlang, and Corominas (2010). This is also one of the first reported experiments to attempt the separation of PI and PSI. The experiment utilized a VE in which the level of various immersive properties could be manipulated. The participants first experienced a VE in which all properties were set at their maximum level, after which they had limited credits to increase the properties to reach either a similar level of being in the VE or a similar level of realism. According to their findings, field-of-view (FOV) and display type were more related to the feeling of being there, whereas illumination fidelity was related to the sensation of realism. In this experiment, having a virtual body was seen as important by both groups (Slater et al., 2010).

A similar approach was later utilized in two studies specifically concerning PSI. In their 2017 study, Skarbez, Neyret, et al. (2017) investigated what individual coherence components are seen as most important concerning PSI. In this study, a virtual body was seen as the most important factor concerning PSI, scenario coherence (the credibility of the appearance of the VE) being the second most important factor. Realistic behavior of a ball, the only interactive object in the environment, varied in importance depending on how much time participants spent time interacting with it. The study of Bergström, Azevedo, Papiotis, Saldanha, and Slater (2017) focused on PSI in the context of a virtual string quartet performance. In their findings, environmental audio corresponding to the external environment as well as virtual characters using gaze to acknowledge the participant came out as most important. Audio realism in terms of auralization and spatialization were less important. As stated earlier, there are relatively few empirical studies regarding how priming affects components contributing to PSI. However, the effect of priming on presence was studied before PI and PSI were introduced as separate constructs. For example, Nunez and Blake (2003) found a significant interaction effect between priming and display fidelity and their effect on presence in VR. We are unaware of any studies that would have specifically focused on plausibility, coherence, and the effect of narrative priming in settings clearly removed from day-to-day life, except for the relatively recent study reported by Brübach et al. (2022).

Skarbez et al. conducted an experiment in which participants experienced 2×2 set of conditions consisting of high and low immersion as well as high and low coherence and found that existing questionnaires were not able to distinguish between effects caused by the two (Skarbez et al., 2020; Skarbez, Brooks, & Whitton, 2018). They did find, however, that low coherence (experienced through unexpected behavior and glitches) could be detected through biometric measurements as stressful reactions. In addition, they found that while both high immersion and coherence factors were present together, high presence resulted. Because of their findings, the authors suggested a term *break in experience* to replace the previously mentioned BIP and break in PSI (BPSI).

Literature contains other examples according to which PI and PSI, and their causes, can be separated. The study of Yu et al. (2012) found that realistic lighting increased PSI but not PI, indicating that the two illusions have different causes. Similarly, studies of Hofer, Hartmann, Eden, Ratan, and Hahn (2020) and Brübach et al. (2022) both reported results according to which plausibility can be broken independently of PI by manipulating gravity conditions of the VE. Interestingly, however, the study of Wang et al. (2010) found improving vision and haptics increased the PSI of a virtual handshaking task, suggesting that SC-related factors can also impact PSI positively.

One of the latest studies on the subject was performed by Beacco et al. (2021), where quantification of PI and PSI was discarded in favor of open-ended participant responses and sentiment analysis. This allowed the authors to identify emerging PSI-related factors of a virtual rock concert experience that might have gone unnoticed with quantitative data collection methods. In a later article, Slater et al. (2022) further discussed this study, suggesting that qualitative data should play a bigger role in future presence-related studies as well.

Past research regarding the relationship between age and presence seems to have mostly focused on PI and other presence-related aspects but less so on PSI. In addition, results regarding PI appear somewhat mixed. McGlynn (2019) found little evidence of PI manifesting differently in younger and older adults. Reportedly, both groups experienced high PI throughout the course of a three-day experiment. However, younger adults did report significantly more BIPs as well as a greater sense of action possibilities, whereas older adults reported paying more attention to the VE. There are, however, studies reporting significant differences between age groups as well. Riva, Wiederhold, Molinari, et al. (1998) found older adults reporting lower levels of PI, whereas Schuemie, Abel, Van Der Mast, Krijn, and Emmelkamp (2005) and Dilanchian, Andringa, and Boot (2021) have found the opposite. There have also been studies concerning age differences within younger age groups. Cadet and Chainay (2021) found preadolescents reporting greater PI in comparison to young adults. Baumgartner, Valko, Esslen, and Jäncke (2006) on the other hand, reported children (age 8–10) experiencing higher PI compared to adolescents.

3 Methods

We planned an experiment with the purpose of studying emergent presence-related factors arising when using an interactive VR system. We were not interested in any particular factors but instead wanted to investigate which aspects rise naturally from quasi-ordinary use. For this purpose, we chose an interactive VR application developed in our research group and modified it slightly for the purposes of this study. The application is a library-themed interactive experience set in various Nordic forest environments, in which the user takes the role of a "spirit of the woods" and searches for missing book pages. The themes, atmospheres, and interactive properties of the application are based on a multistage collaborative design process involving the general public. The design process was based on the Scandinavian Participatory Design (PD, see, e.g., Bjerknes & Bratteteig (1995)). PD is an approach in which the users are involved in the design of an artifact or system throughout the process. This means that the application in question was based on the needs and visions of library staff and library patrons and targeted users of all ages. The specifics of the collaborative design process are reported in a separate manuscript (Ylipulli et al., 2023). A separate but very similar process was reported at Ylipulli, Luusua, and Ojala (2017). The application is meant as a public VR installation placed in libraries across Finland and used by the general public. The application, therefore, was not specifically meant for studying presence; however, there are multiple reasons we chose this application for our study. Firstly, the application contains various fantasy elements we considered interesting because it allowed for studying coherence in a nonrealistic setting. Previous PSI studies have mostly considered more or less "regular" everyday settings despite the acceptance of unnatural elements being part of the definition of coherence (Bergström et al., 2017; Skarbez et al., 2020; Skarbez, Neyret, et al., 2017; Slater et al., 2010). Secondly, we considered the application in which the contents were not specifically geared for particular research questions more appropriate for a naturalistic, exploratory study. Using our own application instead of a commercial one, however, allowed *some* modification for research purposes. Lastly, a commercial application would have been inconvenient for language reasons; our application of choice contained all text and narration in Finnish, which was significantly more convenient for our older adult participants (very few commercial VR applications are localized in Finnish).

Although our aim was to let the participants use the VR system in a naturalistic manner, we also wanted to include a phase in which the participants would experience the same stimuli in the same order across a relatively similar timeframe. Because of this, we modified the application to contain an introduction sequence that would be experienced in a similar manner by all users before letting them explore the virtual environment naturally. The introduction sequence gradually introduced fantasy elements for the purpose of priming the participants into the fantasy setting. This sequence allowed us to more easily compare at least some particular elements between participants. Finally, the introduction sequence also acted as a way to introduce the story and interaction mechanics to the participants. The latter phase allowed the participants to explore the environment at will without controlling stimuli or time spent. We call these Phase I and Phase II, respectively.

To lower the threshold to participate, the experiment was set up at the local city library instead of the university premises. The library provided two conference rooms which were separated from the main library premises, allowing a peaceful and quiet setting for spending time inside VR as well as for the interviews. These rooms were used depending on their availability. Although the rooms were slightly different in terms of size and furniture, they can be considered identical in terms of the VR experience and experiment process. The experiment was run during a time when the incidence level of COVID-19 was low in the local community, and the older adult population had already been double vaccinated. In addition, we enforced hygienic conditions using alcohol wipes, masks, and hand sanitizer as well as using a "Cleanbox"[1] device to disinfect the HMD between participants. Participants were compensated with a gift card worth 20€. The study was approved by the University of Oulu Ethics Review Board. Further details regarding the experiment process can be seen in Section 3.2.

[1] https://cleanboxtech.com/

3.1 VR Application

The application was made in Unity. It was run on Oculus Rift S in room-scale with a roughly 2 × 2-m walking area. Rift S controllers were used for interaction and no additional tracking or other equipment was used.

3.1.1 Phase I. As stated above, the first phase is based on content that was developed particularly for this study. The purpose of this phase was to provide controlled stimuli appearing in the same order for all participants, as well as to gradually introduce fantasy elements for participants. The first interactive scenario begins in an open forest area with various types and sizes of trees and vegetation (see Figure 1). A large rock is situated close to the user. The room setup was performed in a way that the user was able to walk right next to the rock but not through it.

The participants were given time to get used to VR and instructed to walk around to get accustomed to the boundaries. Once they were ready, they were informed to pay attention to their surroundings and that if they saw a book, they should try to read it and follow its instructions. They were also told that, unless necessary, we would not provide more instructions or answer questions until after this section was over. After confirming that this was understood, a chain of events was triggered, which proceeded as follows:

- A rabbit runs past the participant but stops nearby (see Figure 1).
- When the user looks at the still rabbit, it looks back before continuing on its way.
- A buzzard flies towards the nearby rock carrying a book and audibly flaps its wings as it lands, setting the book underneath it (see Figure 2a).
- The participant must approach the buzzard to make it fly away.

Figure 1. *The first forest environment. A rabbit can be seen in the middle.*

Figure 2. *Fantasy elements were introduced gradually to participants. A buzzard brings a magical book to the participant (left). Magical lights appear as the participant is indoctrinated as the spirit of the woods (right).*

The book has written instructions to manipulate wind by making a large motion with their hand. Events proceed after making this gesture.
The book lands on the participant's hand, now advising the participant to listen to the voice of the spirit of the woods.
The book disappears, and a series of magical lights appear (see Figure 2b).
A voice introduces the background story and instructs the participant on how to use the book and a map in the next phase.
The participant can now use the map to move to a different forest environment.

Phase I took approximately five minutes and ended when the participant had learned how to use the map. After the participant removed the VR hardware, the first interview took place (see Section 3.2).

3.1.2 Phase II. During the second part, the participants were free to explore the three different forest environments. Unlike in Phase I, participants now had to rely on teleportation to navigate. As stated earlier, the

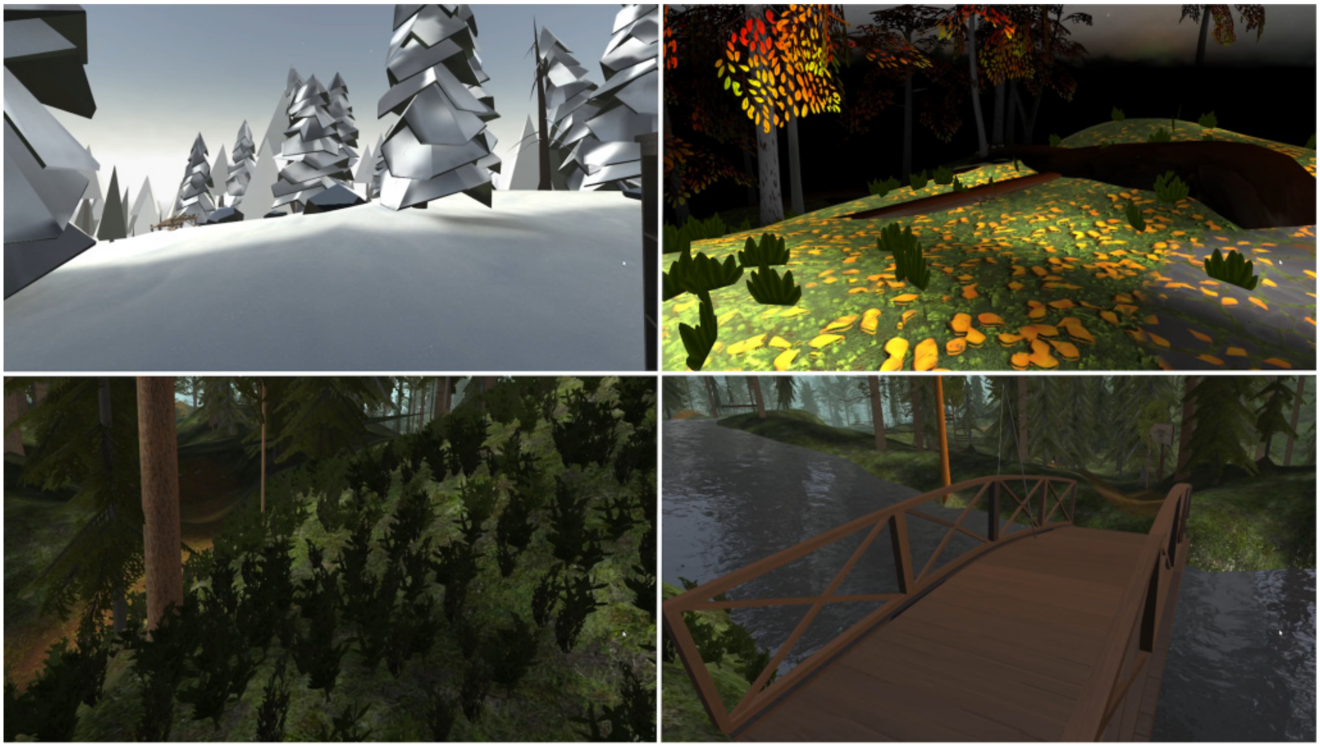

Figure 3. *The forest environments of the second phase. A snow environment with an abstract art style (top left). A dark autumn environment with a cartoonish style (top right). A summer environment with a realistic style (lower left and lower right).*

application content in this phase was based on a collaborative design process that was unrelated to this study (Ylipulli et al., 2023); however, we considered the content suitable for us. The forests included a snowy forest with an abstract art style, a dark forest in the fall season, and a summer season forest with a realistic art style (see Figure 3). The task of the participants was to collect objects that contain citations and return them to a bookshelf at the start of each area. These objects can be found lying around in the environment and as rewards from activities. As part of the naturalistic experiment setting, we did not control for time but instead allowed the participants to explore the environment in Phase II practically for as long as they wanted. Once the participants had had enough or time was running low (a total of 120 minutes was reserved for both phases and all interviews), the VR experience was concluded.

All of the forest environments include multiple activities (see summary in Table 1). A narrator's voice explains the story behind them and explains what must be done when the player gets within their assigned radius. The snowy forest contains a sled ride, snowball bowling, and the "ABC Game." The sled ride is initiated by crouching on top of the sled. The sled moves with linear motion on a predetermined track, but the player can move left and

Table 1. *An Overview of Interactions Provided in the Application Used in Phase II*

Snow forest	Dark forest	Realistic forest
Sled ride	Slingshot game	Pine cone collection
Snowball bowling	Whack-a-demon	Archery
ABC game	Robot invasion	Fishing puzzle

NOTE. Each minigame provided a literature-related item for the user upon successful completion. Each environment contains a bookshelf where items can be traded for book pages. Users can move between the environments at will.

right by tilting their head. Snowball bowling requires the user to roll snowballs down the hill to hit icicles. Snowballs can be picked up, thrown, and moved by manipulating wind. Rocks are placed as obstacles that will break snowballs if hit. The "ABC Game" is played entirely by manipulating the wind. Large letters, A, B, and C, made of snow, are scattered and must be aligned on the board in front of the player. The wind moves in the direction of the hand motion and only affects objects in the user's view.

The dark autumn forest has a slingshot game, Whack-A-Demon, and an evil robot invasion. With the slingshot, the player must shoot down flying origami bats. The slingshot must be picked up with one hand, and the projectile pulled back and released with the other. The projectile automatically returns, so the player can keep shooting repeatedly until enough origami bats have been hit. Whack-A-Demon is functionally a game of Whack-A-Mole, but with four holes and two ghostly demon heads that must be hit several times as the game gets progressively faster. The mallet with which to hit them is found on the ground nearby. Evil robot invasion requires the player to use a magic wand to zap robots. The wand must be charged by holding it above the user's head and released by lowering it. It should then be pointed at the target before it fires. The robots have stationary positions where they try to saw a tree but flee if the player gets too close. Thus, it is necessary to remain within the range of lightning magic but far enough to fool the robots. The narrator explains the usage of the lightning wand.

The realistic-style forest contains a pine cone collection, archery, and fishing. Pine cone collection requires moving enough pine cones from the ground to a basket nearby. This can be done by picking up and carrying them, throwing them, or by manipulating wind. Archery works much like the slingshot, except the targets are balls of energy. The first three are stationary, after which three vertically moving balls appear, increasing the challenge. There are two fishing spots. One contains two citation objects, whereas the other is a part of a puzzle. To fish, the fishing rod must be picked up and its hook flung into the water. Then, objects that are assigned to that area can randomly get caught in the hook which can then be pulled up and grabbed. The puzzle involves fishing up a stepladder and using it to climb and grab a stick from a nearby tree, then using that stick to hit another tree, which will then drop the objective. These two trees have a distinct red hue and are hinted at in the book that the player carries.

At the end of Phase II, the second interview, as well as a background interview, took place (see Section 3.2).

3.2 Research Data Collection

Our research method was the collection and analysis of qualitative data through a thematic semistructured interview process. We recruited 20 participants, of which ten were young adults aged 20–29 years and ten were older adults aged 65–78 years. Six of the young adults identified as women and four as men, and the older adult participants had the same gender ratio. The recruitment advertisements were spread through various channels, including the premises of the local library, notice boards of grocery shops, etc. In the end, most of the older adult participants were recruited through the local retirees association and younger ones through social media services, Jodel and Facebook. This resulted in a versatile pool of participants: Besides including different genders and generations, the participant pool had a wide range of educational backgrounds, which varied from high school level to academic degrees; occupational backgrounds included healthcare, retail, education, and telecommunications. The participants had not participated in the PD process described earlier.

In the interview process, we utilized the graph drawing method described by Garau et al. (2008). After the first phase, the participants drew a graph depicting their PI. The graph was mainly used to support the following interview but not as data in itself. The thematic interview followed roughly the structure of the following questions, the exact wording and order somewhat varying between participants. Most of the questions were adapted from the works of Garau, Slater, Pertaub, and Razzaque (2005) and Garau et al. (2008) as well as the extended SUS questionnaire (Slater et al., 1994; Usoh et al., 2000).

"Can you tell me, with your own words, what happened in the forest environment?"
"Were there any surprising elements in the experience?"
"Were you surprised by your own reactions?"
"Can you tell me what happened at this/that time"? (using the graph to point out dips and bumps)
"Were there any specific moments that made you remember being in this room"?
"How easy or difficult was it for you to recover from these moments"?
"On overall, which felt stronger, being in the forest, or being in this room?"
"Did the forest feel more like a place you were visiting, or more like something you were watching from a screen?"
"Did the events in the forest feel real or unreal to you? Did it change during the experience?"
"Did you respond to the creatures in the forest more as if they were alive or more as if they were computer programs?"
"Did the creatures in the forest respond to you?"
"Did you feel your own capability to act in the forest was realistic?"
"Were there any moments you especially felt like something in the environment was not actually happening or not feeling realistic?"
"Did the sensation of realness come back to you?"
"Were there moments you felt you were present in the forest, yet the events taking place seemed simultaneously unreal?"
"Were there moments you felt you were back in this room, yet the events taking place in the forest felt real?"

The interview above took place after both phases. Additionally, as a final part of the experiment process, we asked questions regarding the background of the participants, and about their previous experience and interest in VR, digital games, and digital technology in general. All the interviews were recorded and transcribed. The length of the interviews ranged between 5 and 15 minutes after Phase I, and between 18 and 37 minutes after Phase II. In addition to data collection through interviews, researchers also observed the participants during Phases I and II and took written notes concerning participants' responses. An overview of the experiment process can be seen in Figure 4.

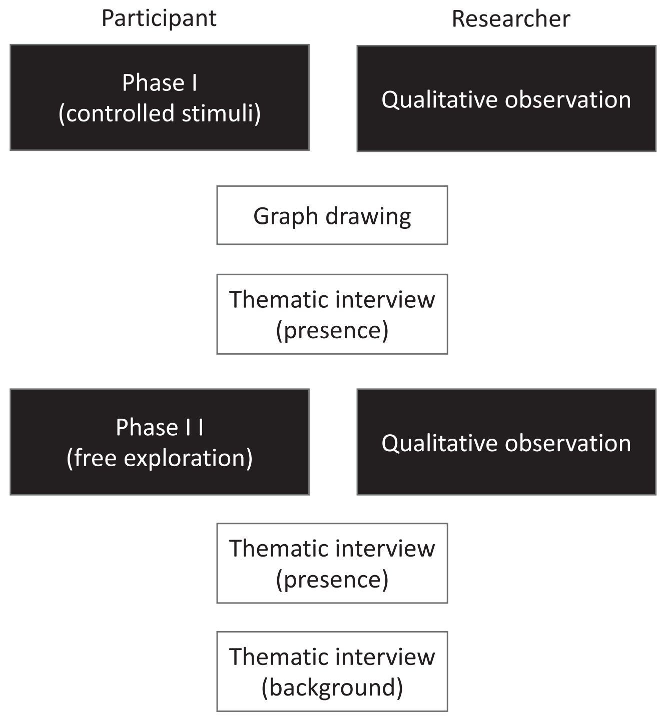

Figure 4. *An overview of the experiment process.*

3.3 Analysis Methods

In previous research, qualitative presence-related data has been analyzed using a combination of content analysis and thematic analysis (Garau et al., 2008), as well as using sentiment analysis to identify emergent themes (Beacco et al., 2021). We analyzed the transcriptions of the interviews with qualitative content analysis, using a combination of the *directed analysis approach* (theoretically informed analysis) and *conventional analysis approach*. The directed content analysis approach entails starting with a theory or relevant research findings as guidance for initial codes. In the conventional content analysis approach, the researcher draws coding categories directly from the data (Hsieh & Shannon, 2005). In our case, theories concerning PI and PSI provided us with codes to start with. However, we also looked at the data more generally and derived part of the categories from the data itself. This approach allowed us to scrutinize some hypotheses related to PI and PSI, and at the same, to more openly explore why different people experienced PI and PSI differently.

3.3.1 Factorization of PI and PSI. In practice, the initial coding phase was a combination of both approaches and was realized by two researchers separately. This enabled us to compare the results of the two individually made analyses and resulted in a more comprehensive understanding of the data. The results of the first round of coding were discussed to ensure that the initial observations were aligned, and the rest of the work was conducted by the researcher more familiar with qualitative analysis. The first round enabled us to answer questions directly related to PI and PSI: (1) whether the participants experienced PI; (2) whether they experienced PSI; (3) what aspects broke these illusions; and (4) whether they experienced these two separately.

Our assessment of the participants' PI and PSI was based on the results of the interviews using definitions from previous research as guidelines (Skarbez et al., 2020; Skarbez, Brooks, et al., 2017; Slater, 2009). Coding categories for directed content analysis were as follows: PI-related factors (such as breaks and other fluctuations) were attributed to comments and responses related to participants' sense of being in the virtual forest or visiting a place. On the other hand, PSI-related factors were attributed to the questions and comments related to the general sense of realism, credibility, reacting realistically to virtual creatures, and "events appearing as if really happening." We also identified factors causing or breaking PI and PSI and categorized them as immersion or coherence to investigate whether or not the factors were coupled with their respective illusions. Factors classified as immersion were related to SCs, such as various correctly or incorrectly perceived bodily sensations and sensorimotor actions, audio quality, and graphics realism and resolution (as defined in Slater, 2009, although we had limited capability to assess whether graphics and audio judgments were related to sensorimotor actions, specifically). Factors classified as coherence were related to events and properties of the environment, such as the behavior of creatures, contents of the forest environments, properties of virtual objects, and non-SC-related properties of events and interactions. Further, during the first coding round, we looked at participants' backgrounds, their overall comments on the experiences, and issues that were identified as surprising. Table 2 gives an overview of BIP and PSI factors for older adults, whereas Table 3 overviews the same factors for the young adult participants. Instances where PI and PSI were experienced independently are summarized in Table 4. Although the graphs collected during the experiment process were used for guiding the interviews, they were less informative for the analysis itself. Instead, the results are mostly based on interview transcripts and notes taken during interviews and qualitative observation (see Figure 4).

3.3.2 Generation of Presence Spectrums. To get a more in-depth understanding of the study participants' experiences and to be able to answer even further "why" questions, another round of coding was needed. This second phase utilized the conventional content analysis approach and focused on exploring what social and cultural factors affected participants' experiences. This entailed creating two *spectrums* where the participants were positioned within two age-specific linear scales according to the extent to which they experienced presence. Results focusing on participant experiences on PI and PSI were utilized in creating these scales, but this phase also required using interpretation: we looked at what kind of expressions and words the study participants used while describing their experiences connected to presence, and also how continuous they said their PI and PSI experiences were. Thus, the spectrums are not absolute but relational and subject to the researchers' interpretations; however, they are also practical tools that enable exploring several interesting social and cultural factors that appeared to have an impact on presence.

4 Results

Overall, the analysis showed clear differences in the experience of young and older adults. As already described, we created two age-specific linear spectrums that reflect the overall sense of presence in the VR environment the study participants were experiencing, according to their own assessments. The spectrums for the older and young adults can be seen in Figures 5 and 6, respectively. The experiences of the older adults appeared to have a broad variance: On the one end of the scale, we have individuals who seemed to have very strong presence, having strong and continuous PI and PSI, and on the other end are participants who stated that their feeling of presence was very weak (Figure 5). Often the weak presence was associated especially with the second and longer part of the test, which included several interactions with virtual objects and numerous gamified tasks. On the other hand, the spectrum intended to highlight the differences and similarities between young adult participants' experiences included more subtle differences in presence (Figure 6). Nevertheless, differences did also exist in this group. In the following, we first take a broader look at how different age groups experienced presence and trace the social and cultural factors that appeared to have an impact on their experience. Second, we take a closer look at the participant experiences concerning PI and PSI.

4.1 Overview on the Older Adults' Presence

Roughly half of the older adults experienced presence strongly throughout the test. These very same individuals also stated that using digital technology was familiar to them either from their occupational background or due to their own interests. Thus, the previous knowledge and interest in digital technology, in general, seemed to have an impact on their experience. One of them even had acquired VR gear for himself but said that he had only used it a couple of times so far (5M77).[2] Further, these participants described that the experience was like being inside a fairy tale: *"Like a fairy-tale forest, not real nor unreal"*; *"Not real but fabled"* and *"Magical."* One participant (2F66) described that she *"lost her sense of reality completely"* and was like *"Alice in Wonderland: the environment is like a fairy tale, but you're still part of it."*

On the other hand, the latter half of the older adults had a very different kind of experience: They felt being immersed in Phase I, which consists mainly of observing the VE with animated objects and events, and the user doesn't need to use the controllers much. They described it as a *"natural event"* (3F76); *"wonderful, beautiful forest"* (10F); *"like being in the real forest, everything else disappears"* (16F67); and as a *"pleasant, peaceful and familiar forest environment"* (15M66). These participants also commented that in physical reality, they enjoy being in a forest. However, the second part of the test was alienating for them. They felt that the environment was too game-like, not natural, and unreal. The events and objects did not belong to the forest, and thus, they were not plausible at all. Also, the numerous interactions were experienced as challenging and controllers as too difficult by this group of older adults, which created breaks in presence.

It appears that the older adults experiencing strong presence interpreted their experience through the frame of a *fairy tale*. The strong presence also seems to correlate with previous experience with digital technology in general. On the other hand, the study participants who approached the VR experience as a *representation of a real forest* did not experience strong presence during Phase II of the test. One of them commented aptly that "*I thought I was in a real forest! I didn't expect anything special to happen"* (16F67). As these "special" occurrences kept on happening, these participants lost both PI and PSI. Further, most of these participants also had less experience with digital technology (Figure 5). Interestingly, the participant who had the weakest presence, according to our interpretation, was by no means inexperienced in technology; he had made a career in telecommunications. However, he drew his expectations strongly from the experiences concerning real forests: *"It was not real. It was more like a game. The environment didn't feel natural" "I felt being more in this room than in a forest."* (15M66).

We also noted that there seemed to exist gendered differences in experiences: When referring to the

[2]We refer to the study participants with a coding that includes a running number, gender F or M, and age.

Table 2. *Breaks in PI (Left) and Breaks in PSI (Right) for the Older Adults. Aspects Not Associated with Immersion (Left) or Coherence (Right) Are Highlighted in Italics*

BIP	BPSI
Interaction "You had to use your hands more, so you were a little like "what" and your thoughts stayed there all the time"	**Credibility of events** "At that point, I was doing things and I was just there. Then when I was supposed to—you're a spirit now—then I thought it's a fairy tale. It became a fairy tale at that point."
HMD cable "When you were walking around there, and felt the cord touch your feet, then it made you realize a little bit that you're not in the forest"	**Bird too close** "At least for me the bird was a bit unreal. It certainly wouldn't come that close to a human."
Uncertainty "I think there was a time I didn't know what to do!"	***Graphics*** "It (the forest) didn't look natural"
Chaperone "when you move and hit that wall, at that point you know that you're in this room"	**Object coherence** "there was no bait, there was nothing in the hook. And there was no movement in the water either, so I was getting suspicion, that this is probably useless, like fishing at a well"
Environment coherence "That I was feeling, that it was a cartoon world, that felt like, this is not your everyday reality"	**Navigation** "I couldn't do things the right way, or move around"
Lack of body, *Shrubbery* "In this one you couldn't look at your feet, when you're in a forest you always look at your feet. So there was this small undergrowth, of course these are those times exactly. I had to think a little bit like, where was I now?"	***Interaction*** "when I didn't know how to use them, I spent my all time thinking, how should I, where should I, where's my hands"
Voluntary "For a moment, I was wondering if there's something in the forest, something illusory that you could touch . . . there's this branch, but I didn't notice anything"	***Floor*** "At least when I go to a forest, I have to think and watch my step all the time . . . I couldn't get the same feeling with my feet, what my eyes and ears were seeing, the feet were not in the forest"
Gamelike feeling "During that entire game-world, I had a strong feeling that I'm in this room and playing a video game"	**Chaperone** "When I felt like I want to go walking . . . was it rocks, kind of hill-like, then I was next to the wall"
Floor "That snow forest wasn't like you know . . . it didn't bring me a feeling of being in a place . . . you're used to ski while on snow, you can't just walk like that. I wasn't real."	***Lack of haptic feedback*** "But there was no tugging on the bait, even if you tried different orientations, clearly there was no life at the other end of the fishing line"
External disturbance "Then there were your voices, they came from this reality, so that's kind of a distracting factor. It would be better if they came from headphones as well."	**Environment coherence** Various comments regarding missing forest elements, such as squirrels, birdsong and undergrowth

experienced difficulties in interaction and problems in using, for example, the controllers, male participants explained how the technology did not work properly or as expected, whereas female participants blamed themselves. The latter used expressions such as *"I thought that I'm very stupid because I didn't always know if I'm*

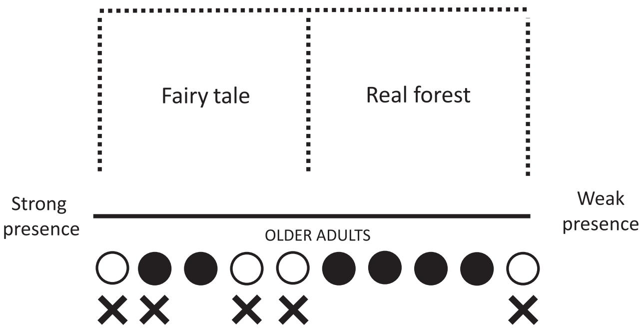

Figure 5. *During the analysis, we created a linear spectrum to depict older adults' presence. Black circles represent female participants, and white ones male participants. The participants who stated they have significant previous knowledge and interest in digital technology are marked with a cross. Boxes above the line refer to the primary frame of reference, that is, whether the participants interpreted their experience in the VE as a fairy tale or as a representation of a real forest.*

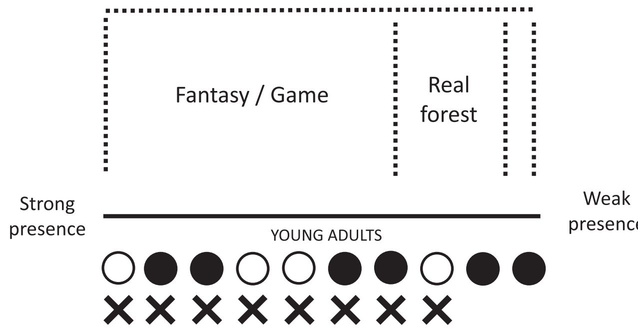

Figure 6. *The linear spectrum depicting young adults' presence. Black circles represent female participants, and white ones male participants. The participants who stated they often or sometimes play digital games are marked with a cross. Boxes above the line refer to the primary frame of reference, that is, whether the participants interpreted their experience in the VE as a fantasy or game or as a representation of a real forest.*

pressing a button or what I am doing" (10F); or *"I didn't cope very well"* (16F67). These comments could be connected to the gendered nature of technology; in the country in question, the IT field and technology in general are somewhat masculine domains (e.g., Tømte & Hatlevik, 2011), and due to this, female participants could have more easily felt that they didn't have enough knowledge or skills, instead of thinking that it was the technology that was not good enough.

4.2 Overview on Young Adults' Sense of Presence

As stated, the spectrum we built to describe the young adults' experiences of presence had more subtle differences. In other words, their experiences cannot be as easily divided into two groups of participants experiencing either strong presence or weak presence in terms of both PI and PSI. Instead, these participants fell somewhere in between, although differences did exist. In this group, previous experience with *gaming* appeared to correlate strongly with the level of experienced presence (see Figure 6). Six of the participants stated they were playing digital games or had been playing actively in the recent past; these very same participants (except one) appeared to be experiencing strong presence throughout the experiences. Two of the participants commented that they sometimes play digital games; they were located next on the presence spectrum. All participants with strong gaming experience also commented that their experience being in the VE got stronger the longer they spent time in the environment.

The participants who experienced the strongest presence were also highly oriented toward performing the gamified tasks. One commented that *"I thought that I'm the spirit of the woods"* (the protagonist and role given to the user at the beginning of the experience) (12M29). The other one described that despite knocking the controllers together, which caused a quick BIP, she did not lose PSI and just *"had to carry on and focus on the task"* (14F27). Most of the young adult participants reported that being active in the environment increased presence: it helped them to focus and immerse themselves in the virtual environment.

The three young adult participants who did not experience strong presence throughout the test appeared to have two main reasons for their weaker experience: similar to approximately half of the older adults, two of these participants approached the VR environment as a representation of a real forest, with the result that numerous fantasy elements and objects that do not belong to a natural forest were experienced as alienating.

Table 3. *Breaks in PI (Left) and Breaks in PSI (Right) for the Young Adult Participants. Aspects Not Associated with Immersion (Left) or Coherence (Right) Are Highlighted in Italics*

BIP	BPSI
Interaction "I did not know what to do with those buttons"	**Credibility of events** "Well, at least I've never heard about shooting light balls in a forest or making books fly by waving your arms"
HMD cable "that cable, I felt like it gets tangled up with my legs every once in a while"	***Interaction*** "when lifting something and stuff, you would know how it's supposed to rotate, and then it's not rotating according to your hand movements, that brought like an unreal feeling to it"
Uncertainty "I had this confused sensation that I don't know what I'm doing, then I returned to this space completely"	**Narration** "and then there was this speech you could hear."
Lack of body "when you looked down, you didn't see legs or anything like that, and that could felt even dizzying, and then you especially realized" [that you were in the room]	**Creatures computer-like** "they felt kind of programmed, or like, also the bird went right past me, so it made me feel like it didn't even see me"
Floor "Maybe when you need to walk around, then you kind of feel your own tennis shoes and the hard floor beneath you, maybe your brains anyway know that you're just in a space like this"	**Object coherence** "The slingshot was like, you had to pull the rubber band almost behind your neck for it to do anything"
Lack of smell "there are no real forest smells or atmosphere"	***Graphics*** "But those graphics . . . of course they'll improve over time, but maybe with better graphics the experience would feel more real"
External disturbance "once in a while I heard those car noises, and they didn't fit the landscape"	**Story** "Well, yeah, maybe because the story was like, supernatural"
Chaperone "Well, especially when this warning came that said, don't walk further or you'll walk into a wall"	**Glitches** "Those bugs took away the plausibility . . . especially the bridge, everything just sunk in there in a weird way"
Graphics "Well, let's just say an actual forest looks different, graphics-wise"	***Feeling of HMD*** "Probably the consciousness that you're there, you know that, you can feel the headset on your head and like that" (on events feeling unreal)
Voluntary "you maybe try to calm yourself like, remember man, this is just a game"	**Shrubbery** "The only thing I went, there was those bushes that I was looking like, those are funny looking bushes, but nothing else"
Environment coherence "That green forest felt like a place I'm visiting, but that snow forest and the fairy-tale forest, those felt exactly like watching a screen, maybe because the green forest felt most familiar"	**Lack of body** "Those bugs took away the credibility, and the fact that you couldn't see your own legs"
Teleportation "The space was maybe somehow limited, you couldn't walk by yourself almost at all, but you had to go with that A button all the time"	***Teleportation*** "At least my moving around was relying on teleportation really heavily, of course that doesn't feel very real. And because I was doing it most of the time, the might have made the whole thing feel very unreal"
Glitches "The more I was doing things, the more I started noticing small bugs, things like the bridge and the fishing rod"	**Gamelike feeling** "I wouldn't say that it felt real, I felt more like I was doing small virtual tasks, or low-key like playing a video game"
Gamelike feeling "Hmm . . . maybe, because it was more interactive, it felt more game-like . . . But was I visiting there . . . or watching a screen? Maybe half and half."	***Lack of weight*** "When you picked something up, I know it's impossible to accomplish, but like, things would actually feel heavy"

Secondly, two of the young adults who, according to our interpretation, had the weakest presence, did not play digital games and were not particularly interested in new digital technology. These two reported that trying to learn how to use the controllers and repeatedly failing in interactions and in task performance resulted in weak PI and PSI as well as multiple breaks especially in the second phase of the test. The participants were women, and their comments had similarities with the older women's expressions: one woman stated that she *"failed repeatedly"* (4F24) or did not know what to do, which resulted in frustration and in being confused. However, the differences between how different genders commented on the difficulties with the technology were not as striking as within older adult participants.

Interestingly, one of the young adult participants having a weaker presence was a frequent gamer and his comments were curiously split. On the one hand, he repeatedly compared the VR environment to a real forest and said that *"the lack of feeling and smells of a real forest"* (20M28) decreased his presence; on the other hand, he commented that gamified aspects and even unreal tasks increased his presence. We can interpret that this actually reflects the *two contradictory frames of reference*, visible both in the older and young adult participants' experiences: (1) the frame of play means that the participants saw the experience through the lens of fantasy, as a game (young adults) or as a fairy tale (older adults); this resulted in stronger presence, and (2) the second frame of reference is a representation of a real environment. This means that the user expected that places, events, and objects represent physical reality, and when they did not, presence got weaker.

4.3 Separating PI and PSI

Overall, the majority of the participants belonging to both age groups had strong or relatively strong PI with a varying number of BIPs during Phase I. On the other hand, approximately half of the older adults and two young adults lost PI for longer periods of time during Phase II. Furthermore, PSI seemed to be more fragile than PI, resulting more often in breaks during both phases. There were numerous instances when PI remained, but PSI was lost. A few times PI was lost but PSI remained: when a participant knocked the controllers together (14F27), or when sledding felt real but the cartoonish environment was not plausible (7M26).

Most of the participants recovered quickly from both BIPs and BPSIs. "Moving on," that is, literally moving on in the VE after a BIP or focusing on something else after a BPSI, were mentioned as factors that helped to recover from breaks. Further, if a particular object became implausible, the plausibility did not usually return. However, a couple of times, the participants commented that even though a particular object became implausible, the plausibility returned to the task itself: *"I didn't lose [plausibility after a glitch] completely when it [a fishing rod] began to work and I was able to catch fishes, the feeling of fishing came back"* (8F26).

The older adults having the strongest presence throughout the experiment had very strong PI during the whole time. They experienced only brief BIPs and were able to return to the VE quickly. These quotes describe their PI: *"Views and paths in the forest were so natural"* (11M75). *"I lost my sense of reality"* (2F66). One participant (5M70) described how he was surprised to be so immersed in the VE although he does not often play digital games. He also mentioned that in the wintry forest, he pondered whether he needs to put on more clothes. For these participants, only some disturbances from the physical reality caused BIPs—noticing the cable of the HMD, "kicking" the floor, and the need to ask help from the research team were mentioned. They also reported having strong or relatively strong PSI during the whole test, although the events and objects appeared somewhat unreal. However, these same participants were interpreting their VR experience through the frame of a fairy tale, as discussed in previous sections; thus, they considered that for most of the time, the events and objects were plausible in their context. BPSIs were rare, and these participants overcame them quickly. Common reasons for BPSIs included difficulties with controllers, first fantasy elements in Phase I, cartoonish aesthetics of Phase II, and interactions not working as they would in real life (e.g., fishing). Several participants also mentioned that the capability to

Table 4. *Occurrences of PI and PSI Appearing Independently*

Older adults	
PI no PSI	PSI no PI
Credibility of events "I did feel like being in the forest, but then you get this sense of what's real, and you're like this is not quite real after all" **Becoming the spirit** "It was right at the end, when there was this 'be a forest spirit,' or how was it, so to me that was the kind of fable I could tell to a grandchild" **Bird coming close** "Well, it's that eagle again, an eagle doesn't sit that close and just bump there . . ." **Gamelike feeling** (describing a constant feeling of being in intermediate space) "when you tried to remember how to move forward, what to do next, and you couldn't remember those buttons anymore . . . that's when it hit you like, this is not real, this is a game" **Interaction, activities** "Well, all these kinds of things where robots would come flying around in a forest and I would be destroying them with a magic wand" **Glitches** "Well, there was that kind of moment when . . . there were ladders in the forest and they were jumping around when you moved them"	**HMD cable** "When the cable went around my leg, that's when I felt being in the room. But I was there. I was able to stay with things."
Young adults	
PI no PSI	PSI no PI
Credibility of events "Yeah, because the story was kind of supernatural at that point" **Computer-like creatures** "Yeah, I had a feeling like that because you're conscious they are just animations. But there was also clearly a sensation that you're more in the forest than you're in this room." **Sounds and voices** "Well, that narration for example, it just came out of nowhere" **Magic lights** "Well, those things when some energy balls started flying around, like I don't think that would happen for real. I got a feeling like I was in a movie" **Interaction** "Well, all the time of course, when things appear by turning your hand, but, you knew what you were supposed to do there, so I did not let it disturb me . . ."	**Chaperone** "Maybe when you started walking and again you hit this border, and you were like oh yeah, I'm still in this room" **Creatures / unreal forest** "Those animal movements felt real, even surprisingly real. But when you look around, you see it's kind of pixel-like . . . I feel like it's more of a virtual place, not real" **Creatures / feeling the floor** "Yeah, it was like that since the beginning. Those animals started coming, but consciously you think like, I have my feet on the hard ground . . . Your mind is somewhere over there in the virtual world, but physically you feel you're in a room"

Table 4. *Continued.*

Young adults	
PI no PSI	PSI no PI
The buzzard "I've never met such a friendly owl either" **Uncertainty** "I'm here in the woods, and suddenly I can't remember where I have or haven't been. And when you hit that border, so you kind of wake up like, okay, you're not supposed to go there" **Unnavigable areas** "Moving around and stuff. You have these constraints you wouldn't have in a real life"	**Sound of the river** "The lapping of the waves, or stuff like that. In a way, it was very real for me, but of course I knew I wasn't actually there" **Sledding** "Well, maybe for example that sledding thing, that was moving. . . . It felt real, but you felt, and you had to consciously remind yourself that you're still, you're not really moving anywhere and you don't need to fall down" **External disturbances** "When I was banging those (controllers) together, you could hear it was not in the same soundscape" **HMD Cable** "I walked on the cable exactly when I was supposed to do something, so I was like, just focus on the task and ignore this cable issue for now."

act was not plausible because of limited skills in using controllers, which affected the overall plausibility.

Overall, the older adults with weaker presence experienced strong and quite continuous PI during Phase I. During Phase II, however, some still experienced both strong PI but also numerous BIPs. One commented that "*Now I would say that I was at times in the forest and suddenly again in the room. I couldn't get into the same kind of flow as in the first [phase]"* (3F76). Further, they all experienced weaker PSI than PI. These participants expected to visit a representation of a real forest, so all the fantasy elements and unrealistic aesthetics caused BPSIs, and this significantly accelerated during Phase II. Four of these participants said that their inability to use controllers and failure in interaction also had a significant effect on the experience. However, one of these participants was experienced in digital technology due to his background, and he felt that he learned to use the controllers easily, but his expectations towards the VE strongly colored his experience. He reported several times that the experience did not correspond with his experience in being in a real forest: *"I ski a lot, you cannot just walk around in snow like that. It was not real"* (15M66). He also mentioned that he experienced the strongest PI in the realistic forest (see Figure 3b and 3c).

The young adults who experienced stronger presence according to our scale (roughly half) described that their PI was strong all the time and, importantly, got stronger throughout the experiences. They experienced only a few BIPs, and similar to the older adults, only disturbances from the physical reality broke their PI. Reasons for BIPs included noticing the HMD cable, "clanging" the controllers together, and the need to ask for help from the research team. Their PSI was also relatively strong. These were the participants who interpreted the experience as a game: for them, the experience was play, real in its context. They had a few BPSIs which were caused almost exclusively by virtual objects not functioning as in the real world; for example, the fishing line was not flying in a natural way, or the VEs displayed noticeable glitches. They described the events (PSI) as a *"Fantasy but real in that environment"* (12M29); *"Unreal but* *a game world is a real world, too"* (14F27); *"Unreal but real in its context"* (17M27); *"Unreal but I got immersed in the thingy"* (9F20); *"Unreal but a game"* (1F26).

The young adult participants closer to the weaker presence all reported having stronger PI than PSI. This was due to multiple reasons: the participants were not sure what they had to do, and being confused or frustrated was causing breaks both in PI and PSI. Similar to some of the older adults, two of the young adults also expected the VE to represent a real forest, which diminished especially their PSI but also PI to some extent. One of them explained that *"the green forest was the most plausible, I was immersed . . . but the snowy forest and the fairytale forest just felt like watching a screen"* (6F26). She also commented that "natural objects" in the realistic forest increased PSI.

5 Discussion

From our interview data, we found cases that both did and did not support separating PI and PSI. According to the participants' self-reporting, the illusions themselves did appear separately from time to time. A very common example of the existence of PI without PSI was when the participants reported being constantly under the illusion of being in the virtual forest, but the events, properties, or interaction aspects feeling entirely unreal. PSI without PI was less common but appeared especially in the case of slight external disturbances that caused a minor BIP, such as stepping on the HMD wire or accidentally hitting the controllers together. There were also cases when SCs failed due to the sensation of the floor beneath, but the events of properties of the VE, such as riding the sled, or realistic creatures, maintained PSI. In addition, it appears as if some mixed reactions to environment coherence caused an occurrence of PSI, but no PI in young adults. An overview of different occurrences of PI and PSI can be seen in Table 4.

It appears that a majority of reasons for BIPs and BPSIs followed the framework proposed by Skarbez, Neyret, et al. (2017). There were many examples of SCs failing, leading to BIPs, such as difficulties using controllers, external disturbances, lack of smell, and sensation of the floor underneath feeling different from what should be experienced. In addition, many attributes related to coherence, such as the appearance of magical elements, animals coming too close to a human, bad object coherence, and computer-like creatures, were what the participants reported as BPSI, as expected.

There were, however, many examples where making or breaking PI and PSI were not caused by strictly immersion or coherence, respectively. For example, interaction difficulties, "not knowing which buttons to press" was a very common reason for self-reported BPSI in the second phase, even though it could be attributed to failing SCs. There were also other, less often mentioned SC-related factors breaking PSI, such as audio quality, unrealistic sensation when walking (due to inability to feel the terrain), lack of haptic feedback, or not getting wet when in a stream. Similarly, there were also comments regarding coherence factors affecting PI, such as the general credibility of the appearance or events in the forest environments making participants experience being back in the room. Other coherence-related factors appearing to break PI were the general "gamelike" sensation caused by the environment and activities, as well as the uncertainty on how to proceed in a task. Graphics realism, as well as the appearance of the chaperone, were reported as aspects appearing to affect both PI and PSI.

What became evident from the data was that the *expectations* of the users were clearly not only related to PSI. Although many BIPs were ultimately caused by the failing of SCs, the expectations of the participants (the frame of reference from which the participant was experiencing the application) also affected how much and what SCs could be violated. The participants expecting a more naturalistic forest-like experience also experienced BIPs due to failing of SCs that did not bother other participants, for example, not having the ability to ski in the snowy landscape or the lack of smells. It could be said that, according to our data, *coherence affected the extent to which the participants accepted failing SCs before the loss of PI*. In addition, there were examples of failing SCs resulting in BPSI, such as during fishing or otherwise entering the river. These findings were interesting in the sense that they are in between the existing definitions of PI and PSI and their contributing factors. Perhaps some kind of concept of *sensorimotor coherence* could be interesting to study the relationship between expectations and PI in future experiments.

Besides individual BPSIs, the overall sense of lack of realism and credibility was often associated with the participant experiencing being in the room more strongly in comparison to being in the virtual forest. In addition, what often happened was that the scenario coherence made the participants comment that they felt like they were neither in the room nor in the forest, but *in between*. Especially older participants commented about PI that could be described as being inside a "fairy tale," or "story" rather than a room or a forest. These different frames of reference seemed to be related to the participants' backgrounds. It appears that gender, technology experience, and, perhaps, even the extent to which the participants had experience in forest-related activities were affecting how they interpreted the experiences. Some of the young participants had no issues utilizing controllers; they mentioned that interactive tasks found alienating by others even increased PI or PSI. On the contrary, it appears that interaction that would have conformed more closely to SCs would have potentially caused fewer BIPs for the older adults, especially during the second phase. It is hardly a surprising finding that more natural interaction mechanisms would benefit VR users; improving SCs within VR systems is a nontrivial task. In addition, according to previous research, it appears that incremental increases in fidelity might not even be helpful (e.g., Nilsson, Nordahl, & Serafin, 2017). Some participants commented on lack of weight; pseudohaptic feedback methods (Lécuyer, 2009) could perhaps be utilized to reduce BIPs in object interactions.

Interestingly, unlike previous works suggest, our participants self-reported being able to recover from BPSIs, at least in the general scope of the experience. However, PSI that was lost on a particular object or scene element did not appear to return.

5.1 Accepting Unnatural Events Due to Priming

One of the reported aspects of coherence is that priming affects what type of events can make or break PSI; for example, a dragon in a fantasy world or the ability to jump high in a sci-fi environment would appear as good coherence and not break PSI (Skarbez et al., 2020). In our case, the first phase acted as the priming session for the second one: we made participants experience the first phase without letting them know about the contents beforehand; however, during the second phase, everyone was already aware of the experiment's magical fantasy-like elements.

According to our findings, there were differences among how participants accepted the fantasy-like elements despite similar priming. Some participants accepted all magical and game-like events effortlessly without experiencing them affecting either PI or PSI. Some experienced these elements as unreal but were still willing to accept them as part of the experience, while to some, they were clearly PSI-breaking elements. These reactions seemed to depend not only on video game experience but the frame of reference the participants chose to experience the application with. It appears the participants made the decision whether to accept the experience as a game or fairy tale in a relatively short time, as the first fantasy elements (the buzzard approaching with the magic book) were introduced quite soon after beginning the first phase of the experiment. After this initial decision, the participants appeared to stay with their chosen frame of reference throughout the experience. This could be interpreted as evidence that our priming was not able to set all participants' expectations to accept fantasy elements. Instead, expectations dictated by our participants' backgrounds might have overridden the ones set by the priming session. As an example, the work of Nunez and Blake (2003) utilized a booklet that study participants familiarized themselves with prior to the experiment and found priming to have a mediating effect for presence. It could be that our interactive priming session did not have this kind of effect on all participants. If it was our priming strategy that allowed different expectations to occur, it raises an interesting question: what kind of priming is sufficient to affect presence, and, in addition, what is a feasible priming strategy for various applications? For example, the application used in this study is eventually meant to be used in public libraries where lengthy priming processes may not be feasible. However, there could be other contexts in which more involved priming processes could be utilized. A future confirmatory study could perhaps investigate experimentally whether the existence or lack of a strong priming process can truly cause significant differences in PSI between groups of VR users.

5.2 Task Performance and Presence

According to Skarbez, Brooks, et al. (2017) there has been debate as well as mixed results on whether presence is helpful for task performance. There is no way we can interpret from our data whether the existence of PI or PSI increased performance in the tasks in our VE; however, there were a few instances where success or failure in tasks resulted in fluctuations in PI or PSI. For example, for some participants, succeeding in tasks helped in recovering PSI, whereas confusion and bad performance caused breaks. It appears, though, that being focused on tasks influenced PI and PSI more than performance itself. There were also comments that supported the separation of task performance and presence; for example, the frustration of failing in tasks or the sense of being lost was seen as a similar reaction to what would have taken place in a corresponding situation in reality. Therefore, one could perform poorly yet still maintain PI and PSI, as suggested by earlier claims (Skarbez, Brooks, et al., 2017).

Our suggestion for future research regarding task performance is to look more closely at the relationship between SCs and task difficulty for presence. A future confirmatory study could examine how difficult tasks utilizing natural SCs affect presence compared to easy tasks carried out using unnatural SCs.

5.3 Limitations

All results, discussions, and conclusions presented in this work are based on qualitative analysis. The obvious limitation of our chosen method is that all findings are the results of subjective interpretations, even if the coding in the analysis phase was conducted by two researchers separately and the results were compared to avoid biased views. As a countermeasure, we took steps to open up and describe the research and analysis process carefully, which is seen as a way to validate studies in qualitative research. Nevertheless, all aspects regarding PI and PSI are self-reported by participants, and we did not utilize any objective quantification methods, such as biometric or behavioral measures. While we queried participants' responses, we had only limited capabilities to interpret whether participants were experiencing genuine responses to the VE, and whether these responses were in agreement with their self-reported experiences of PI and PSI. More studies are needed to investigate whether PI or PSI can actually be manipulated in experimental conditions, as suggested by our findings.

Our chosen experimental setting had limitations that could be seen as trade-offs between internal and external validity. Firstly, participants were allowed to spend significantly different amounts of time using VR. Although the purpose of Phase I was to control for both stimuli and time, Phase II had no such limitations. Instead, participants were able to spend as much or little time in VR as they wanted. Since this resulted in significantly different times under immersion among participants, we cannot rule out the possibility that time spent in VR was a confounding factor. It should also be noted that experimenters sometimes had to verbally instruct participants during the course of the experience, which might be considered a confounding factor for presence. Although our purpose was to provide a naturalistic setting in which there were few BIPs or BPSIs that could be considered to be outside the scope of the experiment, discussions with experimenters can be considered an unintended confound.

We also need to note that we used a VR application depicting a forest environment which has a central sociocultural meaning in Finland; people, in general, consider forests important, and they are even a part of national identity (Hayrynen, 2000). The strong images and experiences attached to this specific environment could have affected the participants' experiences. We can see how the participants' responses regarding the forest setting even raised some questions on how participants' prior experience of certain environments could affect their presence either positively or negatively. A forest may not have the same kind of connotations in different cultural spheres. Therefore, if a replication study were to be carried out in another country, it might be wise to choose the environment carefully to correspond to something socioculturally central for the study participants.

6 Conclusion

In this paper, we presented the results of our exploratory case study on presence experienced by groups of young adults and older adults using an interactive virtual reality application mixing realistic and fantasy elements in two phases. Instead of focusing on a set of predetermined factors, we utilized a qualitative approach to identify emerging factors arising from the users' experiences. We then applied these factors to the existing Slater/Skarbez PI/PSI framework (Skarbez, Brooks, et al., 2017) to investigate whether PI and PSI, as well as their contributing factors, can be separated in the case of our data. According to our findings, participants could experience PI and PSI independently from each other; however, they often appeared intermixed when investigated on the scope of the whole experience. PI without PSI appeared more often than vice versa. BIPs as well as BPSIs could mostly, but not entirely, be attributed to immersion and coherence factors, respectively. We especially found cases where coherence seemed to affect PI in addition to PSI. An interesting finding was that both user groups appeared to separate into two subgroups forming frames of reference of differing expectations that affected their experiences. These frames of reference not only affected PSI but PI as well. Our contribution is adding to the relatively small body of research concerning the separation of PI and PSI. For future work, we suggest experimental studies investigating the possible correlation between PI and PSI. We also suggest further studies investigating the eliciting of PI and PSI as well as BIPs and BPSIs by controlling immersion and coherence factors. We would also suggest investigating the role of interaction in PI and PSI due to interaction-related factors arising in the context of both illusions rather often in our data. We also suggest looking at the onset and recovery of PSI by investigating the relationship between individual elements of the VE and the whole scope of the experience. We would consider it especially interesting to investigate priming and PSI through a controlled experiment where the effect of different priming strategies on PI and/or PSI could be quantified; this could provide interesting data regarding the relationship between coherence and fidelity. Finally, although this work focused on analyzing presence as described by the Slater/Skarbez model (Skarbez, Brooks, et al., 2017), other frameworks have already emerged since our experiment took place. For example, it could be interesting to conduct a similar qualitative analysis using the framework of Latoschik and Wienrich (2022).

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