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Master Thesis

最熟悉的陌生人：探索社交虛擬實境中虛擬化身與環境之設計用於恢復休眠關係之影響

Strange Familiars: Exploring the Design of Avatars and Virtual Environments for Reviving Dormant Ties in Social Virtual Reality

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最熟悉的陌生人：探索社交虛擬實境中虛擬化身與環境之設計用於恢復休眠關係之影響

Strange Familiars: Exploring the Design of Avatars and Virtual Environments for Reviving Dormant Ties in Social Virtual Reality

本論文係廖方盈君（學號 R09725048）在國立臺灣大學資訊管理學系、所完成之碩士學位論文，於民國 111 年 10 月 3 日承下列考試委員審查通過及口試及格，特此證明

口試委員：

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首先謝謝我的指導教授陳炳宇老師，這兩年您不遺餘力的給了我很多研究資源和建議，做為 Robin Lab 的一份子，可以參與很多大大小小的學術研究、認識很多厲害的學長姐和大佬，真的很驕傲也很幸福！剛考上台大時，我就感受到這個 Lab 大家的熱情和溫暖，靖雯、阿超、漢威和令謙是引領我到這個 HCI 世界的第一步，對當初還懵懂的我介紹了很多，也悄悄的燃起了一咪咪研究熱忱～

然後是升碩一暑假幫自戶鳥 aka 鳥哥 aka 志安賢拜完成了 FrictShoes，這時我對於寫 VR 遊戲覺得真的是超有趣的啦，好像人生找到了一個方向的感覺，但也是這時覺得，啊死都不要碰硬體的東西，好困難好難搞！碩一上認識了一些其他學校升上來的資管資工所同學，新鮮之餘也充滿著恐慌，大家的實力真的都是 Next Level，那我要花多久時間才能彌平這些差距呢，我每天都在想，也每天用忙碌填滿生活，至少我努力過了吧能成長多少是多少，時間緊逼著我，心態也需要維持健全，我該怎麼做呢? 這兩年心中也是各種懷疑自己。

碩一上即將結束時，很幸運的和睿哲 aka 哲哥開始了 Accessibility 領域的研究，第一次從無到有的參與了完整的 project —Daedalus in the Dark，過程中睿哲耐心教導了我很多學術研究上的細節，之前大學時總是追求有解答的事物，而現在我開始學會思考，每件事情背後的「為什麼」、無數個解答中要怎樣去選擇，後來 Daedalus 也加入了志安和 Seraphina，這三位大學長學姊真的是、真的是我生命

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中的貴人！在我短短的碩士生涯中，他們給我了極大的幫助，志安賢拜總是給予技術支援和建議，Seraphina 就是我最愛的姐姐，總是和我一起玩一起聊天，更是傳授我很多 HCI 領域上的豐富研究經驗，而睿哲真的是跟大哥一樣，在生活上和研究上都很罩我，在許多研究崩潰（頂樓風很冷）的時候也是哲哥給我加油打氣。總之，雖然碩士就是悲戰苦鬪，但這些滿滿的關愛讓我有勇氣和毅力繼續前進！

除此之外，我在碩二也經歷了約半年 lead 一篇 project 的生活，也就是 BotSummoner 時期，很感謝我的學弟妹們：云雲、玥綺、Marika、華哥，謝謝你們相信我，也願意和我一起奮鬥，我們一起面對、解決了很多軟硬體問題，成就了一個巨大又複雜（但硬體很 f**kin 脆弱）的系統，在 UIST Deadline 壓力下真的是辛苦你們了，甚至還讓你們過年的假期因此減少，雖然最後這篇論文無法成形，但希望這段日子能對你們有一點點啟發 QQ！碩二老實說非常煎熬，好多學長姊都畢業了，我也從學妹變成了學姊，這個心境轉折上一開始讓我非常辛苦，所幸還有其蓉、奇桓、玄姐、靖雯和睿哲以及同居的朋友，常常給予我心靈支持、研究幫助，沒有你們我真的走不下去啦～

接下來是我兩位生命貴人之二的芙茵和于婷，非常謝謝妳們在我碩論的撞牆期接納了我，一起創造 Strange Familiars，也就是我的這篇畢業論文，從一開始的 brainstorming 到最終寫完論文的五個月間，真的是各種艱辛和刺激，每分每秒都在和時間戰鬥，真的是辛苦妳們了～這段期間我在妳們身上也學到了非常多，于婷在快速消化、學習新事物上有很多技巧，而芙茵則是傳授滿滿的研究經驗，除此之外，暑假的黃金衝刺期也很謝謝妳們讓我在嘉義過得很充實、開心，常常覺得我們不只是戰友、更是姊妹哈哈哈!!! 如果可以，我想要把最近的幸運都留給妳們，希望妳們好好休息與前行！Strange Familiars 真的讓我感悟很多事情、心靈昇華了很多，也謝謝很多人的幫助，旻叡、嘉慶和品瑄謝謝你們剛升碩一就來幫忙重要的 study，認識你們讓我覺得很新鮮有趣～還有中正的專題生們，謝謝你

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們願意在暑假一起完成實驗的瑣碎事項。然後是我的老大睿哲，謝謝你在我最困難、關鍵的時候義不容辭的參與這篇論文，陪我們完成投稿，有你在真的是一劑強心針。

然後是我的家人們，我常常覺得自己很廢物，都二十幾歲了還沒有經濟能力，除了金援之外，非常感謝你們提供了堅實的後盾，讓我雖然身在台北，但非常安心踏實，你們無時無刻的關心都讓我由衷珍視、感受到生命的美好，我會好好回報你們的（等我休息夠哈哈）！也希望你們可以把我視為大人，不再是幼稚的小孩。

最後是我的愛人們：宇宙無敵日本最強男子團體 JO1，從我大四就一直陪伴著我，你們的音樂就是我生命的救贖，孤單、難過、開心的時候都有你們在，希望今年的日本之旅可以成行，我們要一起 Go to the Top！然後今年絕對可以上紅白的！

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中文摘要

重建休眠的友誼有助於人們克服孤獨感並獲得社會支持，這對於個人健康福祉至關重要。隨著全球新冠疫情蔓延，大眾被迫社交隔離，社交虛擬實境的設計透過實現同地體驗與真實互動感來促進更緊密的雙人聯繫。本文探討了社交虛擬實境中的關鍵特徵—虛擬化身相似度 (Avatar Similarity) 與虛擬環境熟悉度 (VE Familiarity) 是如何影響、輔助休眠關係的重建。我們共招募了 24 組受試者進行一項混合方法研究，藉此觀察不同設計的虛擬化身與虛擬環境對於休眠關係的影響。實驗結果顯示高相似度的虛擬化身能提升雙方重新聯繫時的社交親密感。此外，高熟悉度的虛擬環境可以喚醒雙方對相關實體地點的共同回憶，而低熟悉度的虛擬環境可以藉由新奇性引發更多對話。我們歸納並進一步探討這些發現，提出適用於社交虛擬實境的設計建議，期望未來實務上能更有效地恢復休眠友誼。

關鍵字：電腦中介傳播、虛擬實境、擴增實境、探索人與系統之實證研究

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Abstract

The revival of dormant social ties is essential for well-being and helps people to overcome loneliness and acquire social support. With increasing social isolation increasing during the COVID-19 pandemic, social virtual reality has been designed to facilitate dyadic connection through creating co-located experiences and genuine connections. In this paper, we explore how the critical features of social virtual reality platforms can support the reactivation of dormant relationships. We conducted a mixed-methods study with 24 dyads to observe the influence of different avatar- and virtual environment-related features on the dormant-tie pairs. Our results show that highly similar avatars can foster social closeness on reconnection. Furthermore, highly familiar virtual environments can revive shared memory related to familiar physical locations, while those with low familiarity can provide novelty, thus triggering more conversations. We summarize these findings to better inform the design considerations for social virtual reality to revive dormant ties in the future.

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Keywords: Computer Mediated Communication, Virtual/Augmented Reality, Empirical study that tells us about how people use a system

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Chapter 1 Introduction

The outbreak of the COVID-19 pandemic has isolated billions of people from their familiar places, acquaintances, and families. Even before the outbreak, changes in people's lives (e.g., moving to a new city or graduation) caused many to leave their original social environments and face geographic separation [38]. Such situations can weaken previously strong relationships due to the lack of contact and decreasing shared context [18, 50], and the relationships often end [38]. Social isolation increases the number of dormant ties, defined as a relationship between two individuals who have not communicated with each other for a long time but have the potential to reconnect in the future [38, 62], is thus imposed on many people under social isolation [65]. The loss of relationships can affect one's life negatively by exacerbating loneliness and thus inducing further mental distress [2, 86] and even undermining one's health [34]. Previous research has found that, to prevent such negative consequences, people naturally develop feelings of nostalgia induced by loneliness [87]. Moreover, these feelings further motivate people to reconnect with individuals they have dormant relationship with, bringing them increased social connectedness, social presence, and confidence [1, 2, 39, 57, 87, 96].

Previous research has indicated that the evocation of shared and nostalgic memories between the two individuals (dyads) of a dormant tie is critical for their reconnection (i.e., revival from a dormant to a strong tie). Participating in a conversation about the shared

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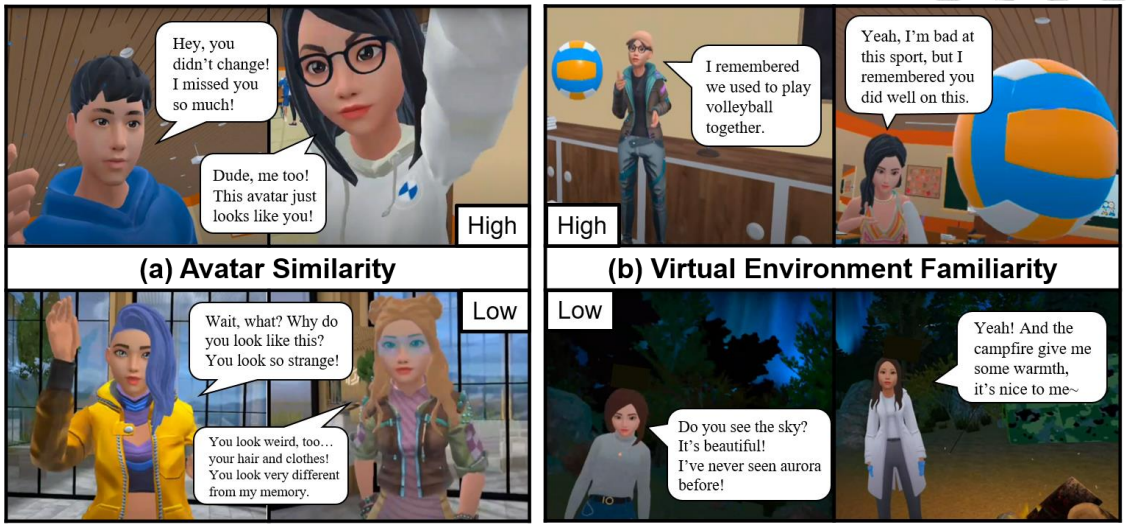

Figure 1.1: Findings regarding two design factors (*avatar similarity* and *virtual environment familiarity*) in the social virtual reality (VR) platform (Spatial) to revive dormant ties. (a) Avatar similarity: Highly similar avatars led to more engaging conversation, while dissimilar avatars impeded interaction due to the lack of self-identification. (b) Virtual environment (VE) familiarity: More familiar VEs can trigger shared memories of a dormant tie and open nostalgic conversation, while less familiar VEs can still facilitate conversation through the novelty of the VE.

experience is one of the approaches to evoking shared memory, but studies have found that feelings of awkwardness often prevent the initiation of a conversation within a dormant tie [11, 28, 33]. The other effective way of evoking shared memory is to revisit the locations that the two individuals have been to jointly [41]. However, social distancing due to the pandemic and geographical constraints often deters the dormant-tie dyad from conducting such activities. Therefore, it is crucial to understand how to help reconnect a dyad with dormant ties remotely and revive their relationships under the physical constraints of the COVID-19 pandemic.

The literature on computer-mediated communication (CMC) has identified communication context and medium as critical factors that influence relationship formation, development, and remote reconnection [34, 59]. Traditional mediums (e.g., text, voice, or video), however, have several drawbacks for remote communication and pose more risks

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for dormant ties. For instance, although text- or voice-based mediums are often perceived as less awkward for communication with a dormant tie, they provide fewer contextual cues, which may hide the intent of the messages and lead to misunderstandings [16, 37]. Video streams show communicators the current context on the other side but do not allow the use of non-verbal language [94]. In contrast, the emerging social virtual reality (VR) platforms are a promising sociotechnical medium for reviving dormant ties. They have the capacity to recreate memorable experiences (e.g., glimpses into the past or familiar places) and render co-located interactions, while avoiding direct face-to-face contact, to increase intimacy. Researchers have investigated social VR affordances to determine how they influence meaningful human experiences within long-distance relationships, including emotional bonding and intimacy [95].

Among all the design features of social VR that influence communication, previous work has indicated that avatar similarity has a particularly significant impact on self-disclosure and trust-building [27], both of which are necessary for relationship development. Moreover, social VR can also foster nostalgia by recreating virtual environments (VEs) associated with places in shared memories [7, 71], building familiarity with the past and potentially kindling nostalgic feelings. However, to our knowledge, little research has examined how the affordances that current social VR platforms provide can be designed to facilitate the revival of dormant ties.

To close this knowledge gap, we conducted a user study with 24 dyads (48 participants) of dormant relationships to explore how affordances provided by social VR platforms, such as the similarity of avatars to users' appearance and the familiarity of VEs, can help revive dormant relationships. We defined two levels for the avatar, perceived high and low similarity to the participant's appearance, to answer the first **research question**:

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Does the similarity between the appearance of the generated avatar and the participant's current look (Avatar Similarity) influence the revival of dormant ties in social virtual reality platforms? We also defined two levels for VEs, high and low familiarity, to answer the second research question: *Does the familiarity of the virtual environment (VE Familiarity) in social virtual reality platforms influence the revival of dormant ties?* We conducted a mixed-designs experiment to answer the third question: *How does the interplay of different degrees of Avatar Similarity and VE Familiarity influence the revival of dormant ties?*

Through the experiment, we collected the participants' questionnaire responses, video-coded behaviors in social VR, and data from qualitative interviews. The experiment results showed that the avatars with high similarity enhanced conversation engagement between dyads through the increase of self-identification and the recalling of their past and closeness. Although using low-similarity avatars could encourage interaction for people who are not satisfied with their appearance, we found that it hinders the dyads' conversation due to the misrepresentation of the self. Moreover, high-familiarity VEs tend to trigger nostalgia and memory resonance for the dyads, thereby preventing awkwardness. In contrast, low-familiarity VEs provide novel information (e.g., places and objects both have not reached before; Figure 1.1 (b) bottom) to facilitate conversation.

In this paper, we offer three primary contributions. First, we conducted a mixed-methods study that extends the limited understanding of dormant-tie revival via social VR platforms. Second, to identify how critical features of social VR affect the connection of dormant ties, we synthesized our findings and those of previous research to close the knowledge gap. Third, we provide design recommendations for future work on the revival of dormant ties.

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Chapter 2 Related Work

In this section, we discuss our motivations from prior works in reviving dormant ties, and the benefits of social interaction in VR.

2.1 Revival of Dormant Ties

The changes of modern society have caused people to move from place to place frequently, such as for work or study. Interpersonal relationships are often ignored due to long-term separation and the difficulties in remote relationship, thus resulting in dormant relationship.

Unlike other relationships, dormant ties represent people in the relationship have spent enough time in the original relationship and been close to each other; and to date, they still consider their relationship important, memorable, and worthwhile for reconnection [23, 38, 39, 62]. Due to the outbreak of COVID-19, the pattern of livings has changed substantially, and social networks have suffered.

Many strong ties have been turned into dormant ties [93], causing feelings of loneliness. Loneliness can cause further psychological distress [4] and undermine the health system. Thus, it is necessary to investigate ways to to relieve loneliness.

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Previous research has pointed out that nostalgia is a psychological resource that people naturally generate when they feel lonely [88, 97]. Various triggers can induce nostalgia, such as sensory inputs (e.g., smell, sound), similar events, anniversaries, and settings [9, 87]. During quarantine, people can still use digital media to connect with friends to share updates or try to rediscover shared experiences [22]. Shared experiences is crucial for reviving dormant ties as the key is to stimulate *previously attained common understandings and feelings* [23].

In one study, researchers found that over 80 percent of participants revived dormant ties through social media [60], and different forms of CMC have been studied (e.g., telephone [34, 38, 83], email [34, 58]), or video [92]. However, text-based and audio-only communication mediums fail to provide the contextual information behind the message, resulting in misunderstandings between the communicators [16, 37]. Although video can provide more context, it is unable to convey non-verbal cues such as body language [15, 25] or smell [25, 74], which have been shown to be essential to deepen a relationship. It has also been found that geographical closeness, which allows many intimate interactions, can be a key factor for maintaining friendships [30]. Considering the influence of COVID-19 and any social changes in one's life, the golden standard of communication — Face to Face — is also not an appropriate method. Thus, as a medium that can provide co-located and embodied experiences, social VR may be an effective alternative under such constraints.

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2.2 Social Interaction in Virtual Reality

Social VR has developed into an innovative sociotechnical system that transforms social interactions in a more immersive way. Previous research has explored how social VR can be used as a medium supporting geographically separated people to engage in essential social activities and acquire emotional experiences similar to those experienced in face-to-face interactions [8, 40, 44, 49, 51, 76]. For example, Zamanifard and Freeman investigated the possibility of acquiring intimacy in long-distance relationships through embodied VR experiences [95]. Moreover, various technical features have been employed in social VR applications to support multi-user social interaction, such as empowering users to control the virtual avatar and designing choices for the virtual environments [31]. According to the findings of previous research about dyadic communication in social VR, the avatar appearance significantly affects the realisticness of interaction and quality of conversation [6, 21, 26, 32, 61, 81]. Also, Hooi and Cho [27] stated that using an avatar that resembles the self can lead to a sense of security and encourage self-disclosure. However, at the same time, privacy concerns can inhibit self-disclosure. In addition to considerations of avatar appearance, McVeigh-Schultz et al. developed a design framework that considers aesthetics of places, embodied affordances, and social mechanics in social VR [48]. Baker et al. also explored how virtual environments can support reminiscence, which has been linked to increased well-being in older adults [7]. As a means of evoking memories, we suggest that dormant ties can also be revived through the customization of a VR equivalent of the physical places where the dyads have spent time together before. Given the lack of previous research focusing on dyads with the dormant relationship in social VR, this work aims to investigate how social VR could help them revive their friendship.

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Chapter 3 Experiment Design

We aim to understand how the design features, which are critical for communication and relationship formation in social VR [7, 20, 47, 64], namely avatar similarity and VE familiarity, mediate the process of reviving dormant tie. Moreover, we seek to determine whether the different combinations of these features effect dyads' interaction and experiment differently. By summarizing these findings, we provide design implications for social VR applications with the purpose of reconnecting people with dormant relationship. To reach this goal, we set the following research questions:

1. Does the similarity between the appearance of generated avatar and the current look of the participant (*Avatar Similarity*) influence the revival of dormant ties in social virtual reality?

2. Does the familiarity with the VEs (*VE Familiarity*) in social VR influence the revival of dormant ties?

3. How does the interplay of different degrees of *Avatar Similarity* and *VE Familiarity* influence the revival of dormant ties?

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3.1 Participants

Through public recruitment posts on social media, university forums and online forum of VR enthusiasts, we recruited a total of 24 dyads with dormant ties. Participants were aged from 20 to 63 years (mean = 28.96) and had 12 to 120 months (mean = 35.33) without any online or offline contact prior to our study. In the recruitment form, prospective participants were asked to provide the contact information of the person wanted to reconnect with. To prevent the other person from feeling uncomfortable, we asked the participant to briefly confirm their partner's interest in taking part in the experiment and their agreement to share the contact information without engaging in any more online or physical interaction or conversation beyond this experiment.

After obtaining the other person's contact information, we sent a recruitment form to them to obtain their formal consent to take part in the experiment. We then made separate appointments with the dyads to participate in the experiment to avoid their offline contact. This experiment was approved by the institutional review board of the university. In the following sections, we use A/B to denote the two participants of a dyad and the numbers 1-24 to identify each dyad (e.g., **A1** represents participant A in dyad number 1). The detailed information of each dyad is listed in Table A.1 in the supplementary material.

3.2 Apparatus and Social VR Platform

In the experiment, we used the social VR platform Spatial[1], because it allows a high degree of customization of the VE. Moreover, Spatial has adopted the common features

[1] https://spatial.io/

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used by most of the social VR applications, Our findings are therefore generalizable to other social VR platforms.

Figure 3.1 shows the environment setup of the experiment. During the experiment, the participants used Oculus Quest 2 headsets and controllers. For the video recording, we used the built-in function in Oculus to screencast the VE to another monitor with screen recording. We also setup another camera to ensure participants activities and conversation could be fully captured in case the screencast of Oculus was unstable. To ensure that the dyad remained dormant tie before the experiment, the two individuals in each dyad were placed in separate space and not able to see or interact with each other. The experiment followed the epidemic prevention protocol issued by the local institution and the experimenter who do not wear head-mounted display wore mask throughout the experiment. All equipment were sanitized before and after the experiment.

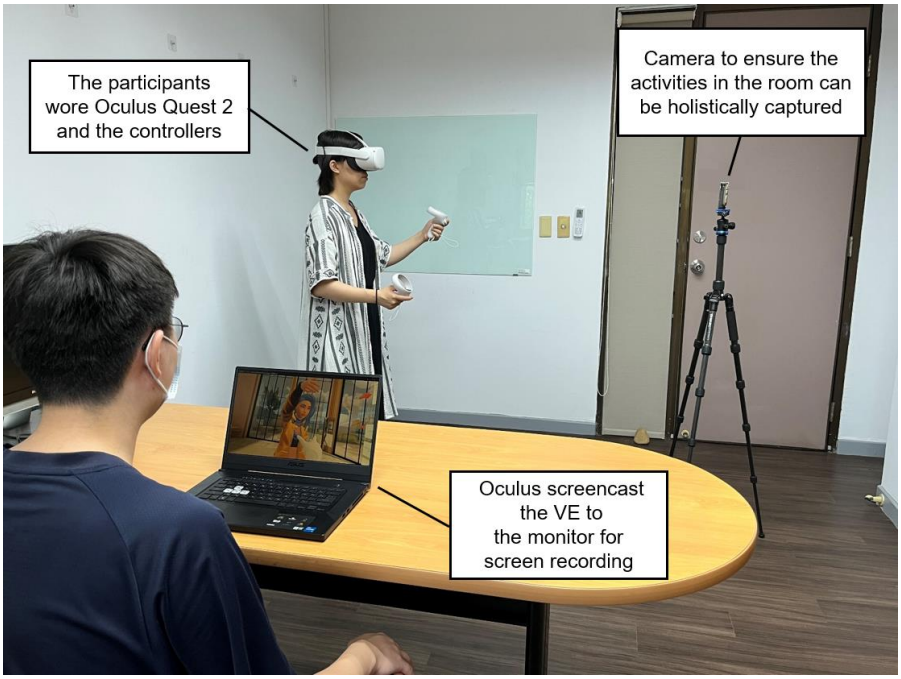

Figure 3.1: Experiment setup for a single participant in a dyad. The other half of the dyad is in a separate room with the same setup.

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3.3 Avatar Similarity and Virtual Environment (VE) Familiarity

We designed two levels (high and low) for (avatar similarity and VE familiarity). To investigate the effects of these two factors, we conducted a 2×2 mixed-design experiment in which the avatar similarity was the between-subject factor and the VE familiarity was the within-subject factor. We randomly assigned the dyads to one of the two groups (high-similarity avatar vs. low-similarity avatar). Next, the dyads in each group experienced the conditions of high- and low-familiarity VE in counterbalanced order. The following sections described how we manipulated the level of the two factors.

3.3.1 Manipulation of Avatar Similarity

We conducted the following process to create avatars with high and low similarity based on the dyads' perceptions. Before the experiment, each participant was asked to provide two photographs with their face showing clearly. These photographs were used to generate two 3D avatars using Ready Player Me (https://readyplayer.me/avatar), which is a commonly used online tool to generate and customize avatars in several social VR platforms. Two photographs were required from the participants to avoid creating a dissimilar avatar due to the poor quality of a single photograph.

Next, we created the other two avatars by fine-tuning the avatars generated by Ready Player Me to make them look as similar as possible to the photographs through our visual inspection. Then, we asked the participants to rate the similarity of these four avatars on a 7-point Likert scale (1 = very dissimilar; 7 = very similar), which we modified from the

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survey commonly used by previous research to measure avatar similarity [43]. In addition, we asked the dyads to use the same scale to rate the similarity of each other's avatar based on their memory of the other person, which can help confirm whether the other individual in the dyad perceived a similar level of avatar similarity. The Pearson's correlation coefficient between the avatar similarity reported by the participants themslves and the similarity reported by their partners was 0.606, which shows that the dyads achieved strong mutual agreement on the similarity of each other's avatar.

For the dyads assigned to the high-similarity avatar group, we selected the avatar that received the highest rating of similarity from the participants (mean rating of avatar similarity = 6.167). For the dyads assigned to the low-similarity avatar group, we randomly chose one of the avatars and changed its hairstyle, hair color, eye color, and clothing to make it look different from the original avatar (mean rating of avatar similarity = 4.958). Figure 3.2 shows the example of the original photograph and the generated avatars with high and low similarity. We did not use avatars of other people or non-human objects to avoid the novelty effect and ensure that the comparison between the avatars was concentrated on their similarity. We intended the avatars with low-similarity to still be identifiable as the other participants in the dyads, even though the participants would consider the avatar less similar to themselves or the others. The other reason we did not use photo-realistic avatars for the high-similarity avatars was to avoid the uncanny valley phenomenon reported by previous research [26, 69, 70].

3.3.2 Manipulation of VE Familiarity

We defined VE familiarity based on whether the environment is familiar for both members of a dormant-tie dyad. For example, a classroom would be a highly familiar

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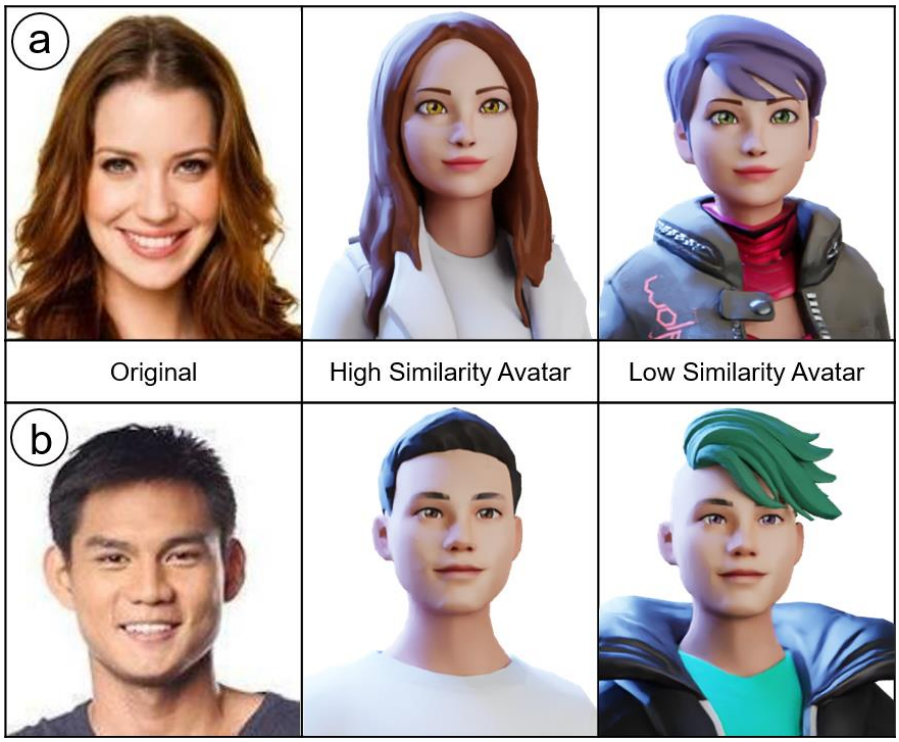

Figure 3.2: Examples of avatars with high and low similarity generated from the original photographs of (a) a woman's face and (b) a man's face. The photographs in these examples are from the open-source dataset CelebA [42].

environment for a dormant-tie pair who were high-school classmates. To determine VE familiarity, we first asked the participants to rate how familiar they felt with a list of different environments on a 7-point Likert scale (1 = very unfamiliar to 7 = very familiar) based on their memory of their dormant-tie partners. We created the list of environments from several previous studies of image processing of background scenes [19, 90]. We then removed environments that were not common and accessible in local daily life (e.g., casino). To avoid the participants' judgment of familiarity being guided by photographs of the environments, we provided the list of environments in text format for the participants to rate so that they could rate the familiarity based on their experience and memory.

Next, we selected for the high-familiarity VE the environment with the highest average familiarity as rated by both participants in each dyad (average familiarity rating by

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all dyads = 6.791). To customize the high-familiarity VE for each dyad, we asked them to detail their memory and provide contextual information (e.g., the size of a classroom) and personal artifacts (e.g., personal photographs and the volleyball in Figure 1.1 (b)) related to the selected environment. If the VEs provided by Spatial included the selected environments, we customized the VEs by adding the information given by the participants and virtual personal artifacts. If Spatial did not offer the virtual version of the selected environments, a 3D interior designer whom we had hired created the VEs of the selected environments based on contextual information and personal artifacts. This process of preparing the high-familiarity VEs ensured that we successfully recreated and customized the virtual environment based on each dyad's shared memory.

For the low-similarity VEs, we selected the environment that received the lowest rating of environment familiarity for each dyad (average familiarity rating = 1.125). Similarly, the VE with low similarity was either created by the hired designer or selected from the VEs provided by Spatial without customization. To ensure that participants perceived similar familiarity of the VEs, we asked them to rate the familiarity of VE again during the experiment. The correlation between the familiarity rating of the environment and the created VEs was strongly positive (Pearson's $r = 0.705$), which shows that the environment and the VEs received similar familiarity ratings. Moreover, the two members of each dyad reported similar VE familiarity (Pearson's $r = 0.554$). Figure 3.3 shows examples of VEs with high and low familiarity that we generated and used in the experiment. All the VEs we used in the experiments are listed in the Figure A.1.

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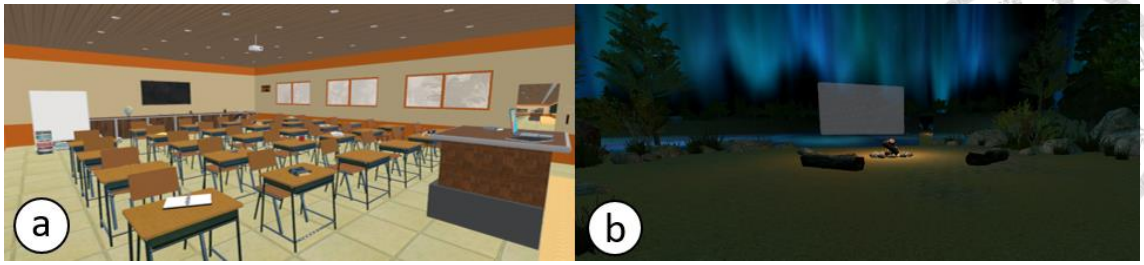

Figure 3.3: Examples of VEs with different levels of familiarity that we used in the experiment. (a) The classroom was frequently rated as a high-familiarity VE by the participants, (b) the campground was rated as a low-familiarity VE by most of the participants.

3.4 Task and Procedure

Participants were first introduced to the study procedure, signed the informed consent, and took a training session on using VR accessories in Spatial for about 15 minutes. After familiarizing themselves with the apparatus, each dyad experienced two VE conditions: high and low familiarity. In both conditions, participants used the same avatars with either high or low similarity determined through the process described in section 3.3.1. The order the of the high- and low-familiarity conditions was counterbalanced throughout all dyads.

During each condition, participants can access sharing games [5, 75] if the conversation did not go smoothly, but they were not required to do so. Both conditions were followed by semi-structured interviews and questionnaires, which are explained in the next section. The two conditions were set 10 minutes apart to allow the participants to take a break. The entire experiment took around 2 hours to complete. The procedure is illustrated in Figure 3.4. Our experiment was approved by our Institutional Review Board (IRB). Each participant was compensated with $50 for their participation.

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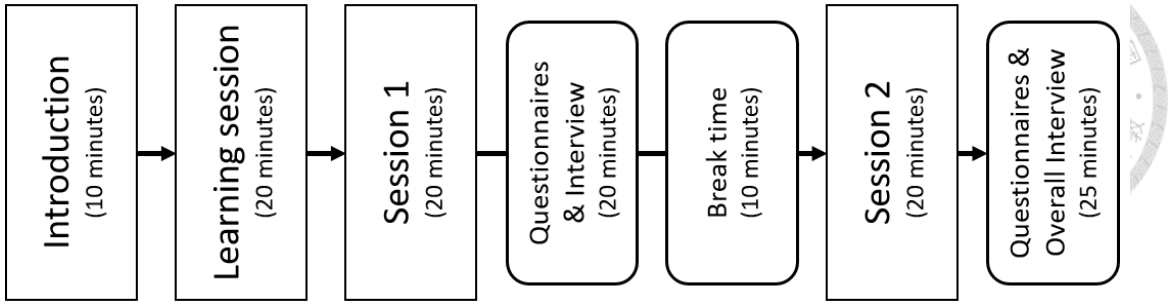

Figure 3.4: Procedure of the experiment.

3.5 Measurements and Data Analysis

To observe how the design factors mediated the reconnection process of the dyads, we first used the self-report questionnaires proposed by Li et al. [40] to assess their perception and experience of each condition. The questionnaire was designed to measure users' sharing experience and capture the nuances of their social interaction in VR. The questionnaire contains three components that comprehensively cover different aspects of dyads' social experience and perception in social VR: quality of interaction (QoI), presence/immersion (PI), and social meaning (SM). Each component contains several corresponding statements for participants to rate their agreement on a 7-point Likert scale. The QoI component focuses on how participants interacted and communicated with their partners in social VR to ensure that the dyads understood each other's behavior [77, 78]. The PI component requires participants to report whether they felt immersed when using social VR and interacting with the VE [29, 68, 72, 89]. Lastly, the SM component assesses participants' mental and physical experience, including sense of togetherness and memory recall/recreation during dyadic interaction in social VR [10, 77, 80]. As well as the self-report measures, we recorded the interaction of each dyad in social VR to derive video-coded behaviors as shown in Figure 3.1. Video coding has been shown to be an effective means

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to capture and understand users' high-level behaviors, which are hard to automatically detect [35, 63]. Through video coding, we observed dyads' various interactions under each condition in social VR. Moreover, the temporal nature of recorded video allowed us to recognize and categorize different behaviors based on their social intentions so that we can obtain the video codes tailored to our research questions. To explore the underlying reasons for participants' quantitative feedback and behaviors, we interviewed each participant about their experience after each condition to obtain a qualitative understanding of the effects of avatar similarity and VE familiarity. The following sections describe how we analyzed each measure.

3.5.1 Questionnaire

We used the Shapiro-Wilks test to determine the normality of the collected data of each component. The results show that most of the data are not distributed normally ($p < .001$). Hence, we used the non-parametric methods to analyze the effect of the factors on the participants' self-report data. The Kruskal-Wallis test [17] was used to analyze the one-way effect of individual factors. Since we used a mixed-design experiment, we used the Durbin test to analyze the two-way effect of the two factors (avatar similarity $\times$ VE familiarity) with the group as the block variable following the suggestion in previous literature [14].

3.5.2 Video Coding

We analyzed the video through grounded theory [24, 82, 91]. We recruited two coders to watch the recorded videos and tag participants' behavior with low-level codes describ-

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ing their basic behaviors and interactions. Then, the two coders grouped the codes into high-level schemes. We developed the coding scheme based on the literature on social interaction [3, 12] and refined it through iterative discussion between the two coders of the research team. The coders achieved an inter-rater agreement validity of Cohen's kappa equal to 0.855. The final code scheme is defined in Table A.2.

For the statistical analysis of the code counts in different conditions, because the result of the Shapiro test showed that the counts were not normally distributed, we also used the Kruskal-Wallis test for the one-way test and the Durbin test for the two-way test to determine whether the counts of each code varied significantly depending on the avatar similarity and VE familiarity.

3.5.3 Interview

The interviews were analyzed using thematic analysis [13]. After the interview data of the 48 participants were transcribed, two coders from the research team identified an initial set of codes by browsing all the interview transcripts and separately creating codes associated with each statement. Then, the two coders jointly arranged these codes into broader themes within the context of our research. Finally, the research team reviewed the themes to ensure they reflected the original transcribed interviews and revised them accordingly with the mutual agreement of both coders.

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Chapter 4 Result

In this section, we present the overall results, including the results of the quantitative analysis of the questionnaire data, the analysis of the video coding, and the qualitative analysis from the participant interviews.

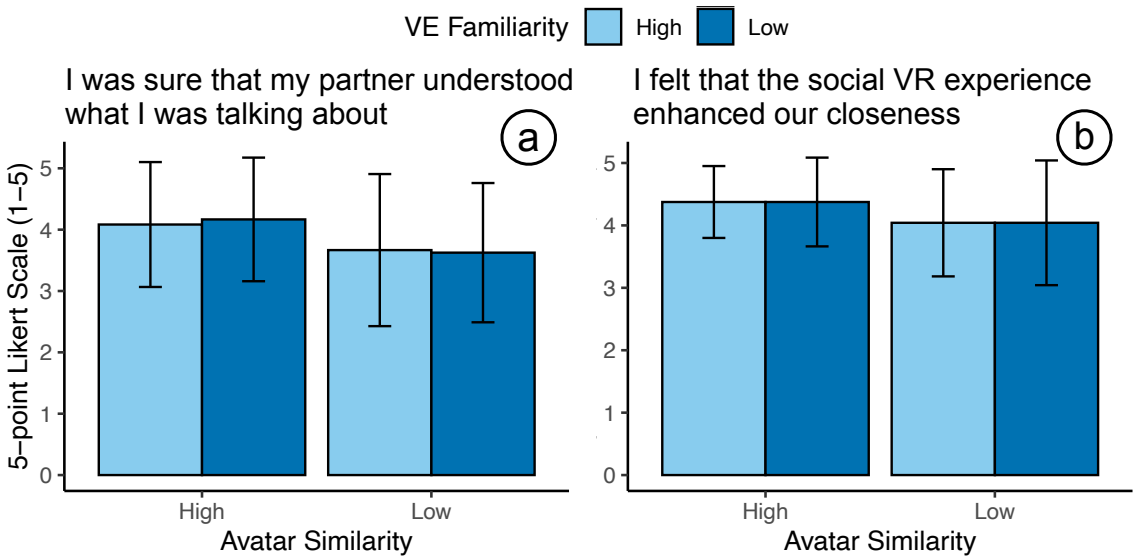

Figure 4.1: Self-report results of the individual positive statements in QoI and SM. The values of the y-axis range from 1 (*strongly disagree*) to 5 (*strongly agree*). (a) shows the rating result for whether the participant's partner could understand their conversation, and (b) shows the result for whether social VR experience enhanced closeness (the original descriptions in the paper of Li et al. [40] categorized this item in the SM component). The error bars represent the standard deviation.

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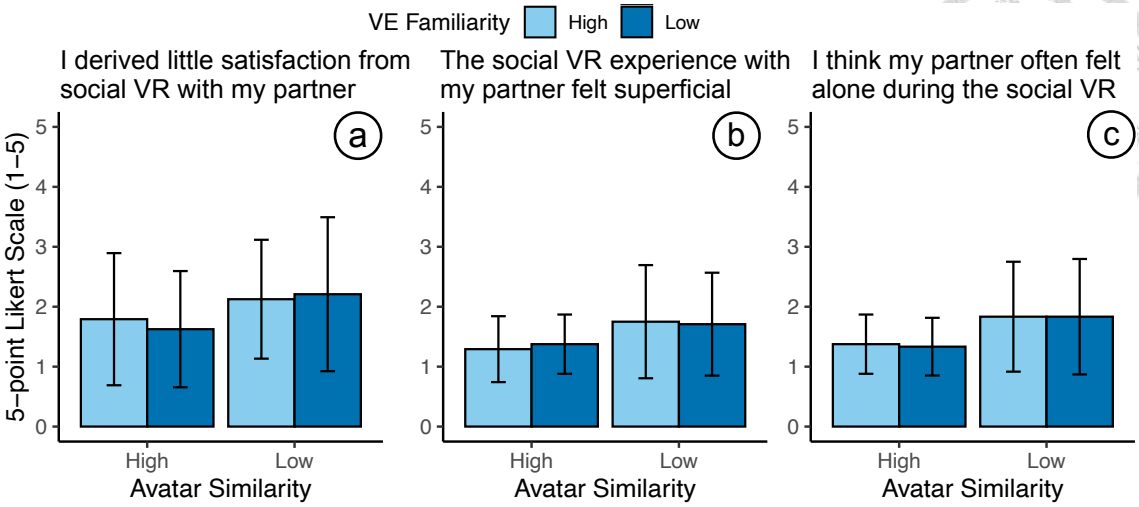

Figure 4.2: Self-report results of the individual negative statements in SM. The values of the y-axis range from 1 (*strongly disagree*) to 5 (*strongly agree*). (a) shows the rating result for satisfaction in social VR, (b) shows the result for the experience of being with their partner in social VR, and (c) shows the result for whether participants think that their partners often feel alone when using social VR. The error bars represent the standard deviation.

4.1 Questionnaire Results

4.1.1 Effect of Avatar Similarity

Although we did not find a significant effect of avatar similarity on the integrated scores of each questionnaire component, we found that the similarity level of avatars has a main effect on specific items in different components. Hence, we report the results of these individual items of each component separately.

First, our participants gave significantly higher scores for the item "I was sure that my partner understood what I was talking about" of QoI when they both used the avatars with high similarity ($\chi^2(1) = 4.274$, $p < .05$). This result indicates that the dyads with the high-similarity avatars thought that their partners had a higher comprehension of their conversation than those with the low-similarity avatars. Next, for SM, the participants who used low-similarity avatars showed higher agreement for the negative statements "I

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derived little satisfaction from social VR with my partner" ($\chi^2(1) = 4.832$, $p < .05$), "The social VR experience with my partner felt superficial." ($\chi^2(1) = 4.980$, $p < .05$), and "I think my partner often felt alone during the social VR" ($\chi^2(1) = 7.124$, $p < .01$) than the participants who used high-similarity avatars. These findings show that using avatars with lower similarity made the participants in the dormant relationships perceive less social meaning (e.g., satisfaction and companion) than those who used higher-similarity avatars. Additionally, the positive item "I felt that the social VR experience enhanced our closeness" received marginally significant higher agreement from the participants who used the high-similarity avatars than those using the low-similarity ones ($\chi^2(1) = 3.223$, $p = .073$). Although this finding did not reach statistical significance at the level of .05, together with the other findings for SM, it shows the trend that using high-similarity avatars better assisted the participants to reconnect with the dormant-tie partner than using low-similarity avatars.

4.1.2 Effect of VE Familiarity

We did not found a main effect of VE familiarity on the integrated score of any questionnaire component (QoI: $\chi^2(1) = 0.098$, $p = .754$; PI: $\chi^2(1) = 0.050$, $p = .823$; SM: $\chi^2(1) = 0.161$, $p = .688$) or their individual items. This finding reveals that the participants' perceptions of the quality of interaction, presence/immersion, and social meaning were not influenced by our manipulations of the VE's familiarity.

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4.1.3 Effect of Avatar Similarity × VE Familiarity

The participants' reports in all components revealed no significant difference in the conditions (QoI: $\chi^2(3) = 0.545$, $p = .909$; PI: $\chi^2(3) = 0.211$, $p = .975$; SM: $\chi^2(3) = 0.028$, $p = .999$). Moreover, the condition has no main effect on the results of individual items in each component. The results indicate that different combinations of avatar similarity and VE familiarity did not significantly influence participants' self-reported perceptions about the interaction quality, social presence, and social meaning.

4.2 Video Coding Results

As shown in Table A.2, we found that the participants using low-similarity avatars commented more often on their partner's avatar (higher counts for *Comments on Avatar*) than those using high-similarity avatars ($\chi^2(1) = 7.514$, $p < .001$), which shows that the alien appearance of the partner's avatar made the participants surprise with each other's look and thus triggered more relevant conversations between the dyads. Furthermore, we found that in the VEs with high familiarity, the counts were higher for *Attracted by Objects in the VE* ($\chi^2(1) = 4.022$, $p < .01$) and *Conversation About Nostalgic and Shared Memory* ($\chi^2(1) = 4.070$, $p < .01$). This finding matches the result of previous research [79], which found that the locations in which a dormant tie has joint experience could provide more external stimuli to trigger nostalgic conversations and shared memory.

Neither avatar similarity nor VE familiarity showed a main effect on the counts of the video codes *Distraction*, *Playing With Virtual Objects Together*, *Small Talk*, and *Silence*. In particular, the counts for Distraction and Small Talk were distributed evenly in each

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condition, which might imply that the frequency of these behaviors were not influenced by the manipulations in our experiment. Similar to the findings in the questionnaire, the experiment condition had no main effect on the counts of any video code. This finding might show that although the avatar similarity and VE familiarity have separate effects on particular video-coded behaviors, the present factorial design of these two factors could make their joint effects less significant on participants' behaviors.

4.3 Qualitative Findings

In this section, we answer our research questions on how avatar similarity and VE familiarity affect the revival of dormant relationships using qualitative feedback from our participants

4.3.1 Avatar-Induced Effects on Dormant Interactions.

We observed that different designs of one's avatar appearance induced different effects on the interaction with one's partner. The majority of participants (N = 11) reported that high-similarity avatars helped them rapidly and intuitively associate with their partner's appearance in the past based on characteristics such as the avatar's facial features, hairstyle, and dressing, as mentioned by one of the participants (B1): *"He has a very similar stubble in his avatar's face as how his face looks like. [...] Since I can remember, he always looks like a monkey!"* If the participants found that their partner's avatar was slightly different from the past, they also recalled the difference between the past and the present appearances: *"His hairstyle is quite similar to my impression. The difference, I think, is the height, he still looks a little short inside."* (B6). However, despite being

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presented with a high-similarity avatar, some participants ($N = 3$) still felt mentally distant from their partner due to being out of touch for long periods and, therefore, were hesitant about close interactions during the study, as one (A21) commented that:

> *"Even though I knew he is my old friend, I still tried to get the feeling back as it has been a long while without any contact. I was uncertain whether he would be the same as before since people may change after such a long time. That's why I wanted to further interact with him to see if our feelings and memory remain."* (A21)

According to A21, simply using an avatar to resemble their partner did not reduce their vigilance completely, but it encouraged them to initiate conversation and take other actions.

Compared to high-similarity avatars, avatars with low similarity were more difficult to identify and associate with the past images of participants' partners. B3 described this situation as follows: *"His avatar looks totally different from what I can remember. [...] So even though I was aware of who he is, I felt incongruent to my memory and deviated from the reality."* Such feeling hindered some participants ($N = 11$) from initiating a conversation and may also explain why participants with low-similarity avatars in Figure 4.1 felt less certain about if their partners understood what they were talking about. However, we also observed that some participants (B1, B12) developed a stronger identification with their partners through their voice or discursive patterns: *"At first, I struggled to talk to my partner, as his avatar was not like himself. But I could still try, as he behaved the same I remember in terms of his personality and discourse. And eventually, the feeling of disconnection disappeared."* (B12). In light of these results, we speculate that

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avatars with low similarity would cause confusion and awkwardness in the early stages of reviving dormant ties. However, such negative feelings may diminish as the sense of the partner's identity increases.

We also observed the positive and negative influences on participants when they perceived and identified their own avatars, as detailed in the following. Previous findings [27] indicate that an avatar similar to one's own would increase the sense of security and the willingness to open one's mind. We observed this phenomenon across some participants ($N = 7$) in our study, as one (A13) who was assigned a high-similarity avatar reflected the following: *"The avatar looks very similar to me in the past, the bubbly and cheerful me; thus, I found myself more open minded in the VE and willing to open conversation."*

On the other hand, the avatars with low similarity benefited the people who were not satisfied with their physical selves in the real world. The avatar can serve as a social mask to conceal what people do not want to expose and encourage them to interact with others: *"It's amazing we both got younger in VR and wore clothes we had never worn! Though it wasn't like our original look and style, I still took it as an extension of ourselves"* (B7). Some participants ($N = 5$) also noted that an avatar could mitigate the physical boundaries and let their guards down: *"Sometimes, the awkwardness derives from our physical appearance and barriers when face to face. We have decades of not seeing each other and have become old and ugly. Thus, I think I prefer to stay away from him if we meet physically. But in VE, I am comfortable to share anything with my partner using my avatar, as the potential embarrassment, such as body odor or age changes, are not imposed anymore"* (B16). However, few participants assigned to low-self-similarity avatars had difficulty in adapting to the revival process as a result of feeling out of place: *"I am not familiar with my avatar, as it was not like me at all, so I was not comfortable*

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to interact with others, as it cannot represent myself" (A17).

4.3.2 VE-Stimulated Nostalgia and New Memories.

Our participants also echoed prior research that high-familiarity VEs can evoke shared memories and contribute to nostalgia [7, 79]. For instance, A18 described how the virtual classroom affected the revival process with B18: *"The photo of us in childhood I prepared has amazed her, and she was surprised about I was still keeping it. This further spurred us to recall the badminton rackets we used and popular artists we adored in the past. These points are good to trigger our shared memory."* The objects also evoked nostalgia for our participants: *"The basketball and volleyball reminded us of how we were capable of playing them in the past, and we chatted a bit about that experiences."* Furthermore, the high-familiarity VE caused emotional resonance to a dyad by bringing up past events and people. This finding was confirmed by the experience of A11/B11, who were assigned the classroom as their high-familiar VE: *"My partner said our teachers in our junior high school have been bedridden now. This overwhelmed us with complicated sentiments."*

We also observed that participants (N = 8) who were familiar with the VE could be immersed in the VE and paid closer attention to their conversation: *"In the virtual classroom we were both familiar with, we felt more relaxed and chatted. [...] The environment was not stressful to us, so we could focus and pay attention on each other"* (B12).

On the other hand, participants (N = 9) who were assigned low-familiarity VEs with their partners leveraged the novelty of objects and scenes to facilitate their interactions. For example, B22 reported, *"We used to be in those fixed workplaces and had no chance*

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to reach different places together. The virtual museum is really fresh and interesting to us, where we took selfies and explored the scene together. It's like we went through an adventure together, which differs from the daily interactions."

A18 also praised that the low-familiarity VE (campground) unexpectedly disclosed their current interests that they did not have in common before and enriched their conversation: *"We grew up in the city and had the rare experience in nature, but we just found our current shared interest is camping, which surprised me greatly. Thanks to this scene, the remaining conversation revolved around our shared outdoor activities."* However, aside from mentioning the benefits of novelty that a low-familiarity VE can provide, several participants ($N = 4$) expressed concerns about the many occurrences of silence or the aimless nattering due to a lack of inspiration to start a conversation, as described by B17: *"As the virtual objects in the museum were unrelated to us, we only chitchatted a little bit. I did not really know what we were talking about."* There was a belief among participants ($N = 3$) that the nature of the VE would dominate the atmosphere of the dormant-reviving process: *"Despite being unfamiliar to us, this virtual villa was cozier than our familiar but stressful classroom"* (A12). This belief is in line with previous research that VEs can influence social expectations with their environmental characteristics [48]. Some participants ($N = 8$) also highlighted the high- and low-familiarity VEs could be used in different stages during the revival process, as summarized by B18: *"It will be great to be in a high-familiarity scene for the first meet, as this can remind us of many shared memory. After being reconnected, I think something new in the low-similarity VE can be brought to us for further interaction and discussion."*

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4.3.3 VR-Enabled Co-Located and Embodied Experience.

In addition to identifying the above-mentioned two primary themes that we aimed to explore, we also found VR a suitable means to realize embodied interaction for reviving dormant relationships. This finding also echoes recent studies that physical contact can facilitate reconnection by providing intimate interactions [56, 95]. Our participants (N = 6) depicted how the VR-embodied experience strengthened their relationship during the study: *"Wandering in the VE is the alike experience as in [the] real world. I think if two people want to be more intimate, they should be in the same space, and VR gives me such promise for its sense of physicality"* (B12). A10 also described how his partner's unconscious behavior in real life was replicated in virtual reality: *"He used to be a tagalong, always following me. Even in VR, he performed the same, which made me feel like he was right beside me just as in the past."* These experiences demonstrate how VR-collocated and -embodied experiences can rekindle memories of long-forgotten relationships even with a subtle cue. Some participants (N = 8) also reported that the VE provided them with an improved ability of self-expression without the worry of awkwardness posed in the real world: *"VR allows me to express myself more comfortably, as, sometimes, in the real world, you may perform awkward body languages. I really fear my clumsy movements"* (A10).

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Chapter 5 Discussion

In this section, we discuss the knowledge gained from our experiment, the links to prior works, and the implications of avatar and VE selections for further works or future applications in reviving dormant ties in social VR platforms.

5.1 The Effects of Perceived Avatar Similarity in Dormant Ties Interaction

Through the experiment, we found that high-similarity avatars positively affect the revival process by enabling engaging conversation and increasing self-presence. This finding may derive from the reason that an avatar reminiscent of established images of one's partner can reduce one's uncertainties even if the dyad has not met in a while [32, 53–55]. Moreover, high-similarity avatars tended to induce feelings of security, encourage higher self-disclosure, and prompt resonated topics for conversation (e.g., personal information and deep conversation) [8]. This finding confirms the insights from previous research that high-similarity avatars brought people higher self-identification and the desire to share private topics with others [27, 46], rather than being fearful of exposing themselves.

On the other hand, low-similarity avatars had two opposite effects on the conver-

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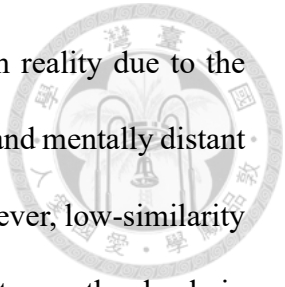

sation. First, low-similarity avatars detached some participants from reality due to the lack of self-identification and self-presence, where they felt awkward and mentally distant from their partners and had difficulty understanding social cues. However, low-similarity avatars were also useful in prompting more conversation starters between the dyads in our study, as evidenced by our results of video coding in which the counts for *Comments on Avatar* are significant higher when the participants were using the dissimilar avatar (Table A.2).

Overall, through the findings of our study, we want to emphasize the importance of avatar design in the context of reviving dormant ties through social VR platforms. Our findings echo prior works on the influences of avatar design for dyadic communication [20, 81]. For the different phases of the conversation, we observed that the perceived avatar similarity (both high and low) was quite noticeable at the early stages of the conversation and then diminished over time. We speculate that this phenomenon may stem from *halo effects*, which create a cognitive bias that our participants have more precautions on the alien appearance of low-similarity avatars at first glance [52, 81], but as the conversation progressed, our participants perceived the other as the one they were familiar with through other non-visual cues (e.g., pet phrases, body language, shared memories). Hence, the adoption of avatars could contribute to the first impressions of partners and play a critical role in determining the development of upcoming conversations. We recommend that future works on reviving dormant ties in social VR platforms integrate physical characteristics (e.g., voice) and homophily (e.g., values, attitudes, and beliefs) with high-similarity avatars [27] to aid the revival process.

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5.2 The Effects of VE with Different Levels of Familiarity

Our results indicate that high-familiarity VEs can elicit feelings of nostalgia and facilitate conversations through shared memories for reviving dormant ties. Many participants mentioned that revisiting familiar places took them back to when their relationship was close and meaningful. Experiencing nostalgia was also indicated by prior works [22] as an effective strategy to acquire spiritual resources by reliving pleasant memories. Though this process may bring mixed feelings of joy and loss, such empathetic immersion would render the dyads stronger bonds [22]. Our qualitative findings also reflect that high-familiarity VEs can decrease vigilance and stress and enhance conversation quality by increasing interpersonal attention (section 4.3.2). Previous research has highlighted that VEs that are similar to the places in memories can evoke participants' memories and serve as icebreakers [7].

In contrast, low-familiarity VEs lack memory cues, making our participants likely to explore the space to familiarize themselves with the VEs. Two opposite behaviors and consequences were observed. First, when exploring an unfamiliar VE, our participants felt more awkward if these social catalysts (i.e., novel environment and objects) failed to form a conversational intention [48, 67]. Second, as mentioned in section 4.3.2, participants were found to take advantage of the novel objects in the VE as conversational sparks to initiate conversation.

Therefore, many of our participants suggested that it would be better for them to first talk about old memories in the high-familiarity VEs when meeting a dormant-tie friend. After participants have relived old memories, the VE can be transitioned to a low-familiarity (novel) one to induce more novel conversation topics to avoid awkward

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silences or aimless chitchat during the reconnection. This strategy resonates with the advantages Levin et al. [38] have proposed that dormant ties may provide efficiency and novelty benefits. If people discuss only memories instead of reciprocating novelty (i.e., knowledge exchange), they will only prevent the decay of dormant ties but not achieve successful reconnection and further development [38, 83]. Also, through the understandings of our participants' backgrounds, we observed that each dormant dyad underwent a different process of becoming dormant, so the degree of social anxiety before reconnection varies from person to person [28]. Given our results (section 4.3.2), we argue that social anxiety can be mitigated and comforted in certain VEs, as prior works have indicated that features of places can conduce different social expectations and feelings [7, 48], such as the need to be silent in a museum, feeling of freedom in countrysides, or tendency to relax in the atmosphere of a villa in our case (section 4.3.2). Overall, the VEs for reviving dormant ties in the future should consider the aforementioned factors, such as different reconnection phases for the application of high or low similarity and the backgrounds of and anxiety levels between a dyad.

5.3 Overall Effects of Avatar Similarity and VE Familiarity

Although our quantitative results reveal no significant difference across conditions, we want to briefly conclude how these two factors (i.e., avatar similarity and VE familiarity) would interplay with each other based on the qualitative findings. We plan to conduct further research with a larger sample size to provide quantitative support for the following descriptions. We found that avatar similarity directly impacts participants' willingness to

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get closer to their dormant-tie partners because humans tend to perceive other people from their appearance first, as in face-to-face encounters [81]. As the avatar similarity induces a relatively instant and overt effect on dyads, VE familiarity plays an indirect but continuous role in reviving dormant ties. With the environmental memory cues (e.g., nostalgic personal artifacts), high-familiarity VEs could trigger shared memories or even lead to a more extended conversation. As previously noted by the participants, the co-located and copresent senses allowed by social VR enabled the dormant-tie dyads to experience a reunion approximated to face-to-face scenarios in situations where the physical location was absent [7, 48]. Additionally, the flexibility to adjust avatars and VEs in social VR provides opportunities for technical interventions to facilitate reconnecting people with dormant relationships with consideration of their current interactions and individual differences. Due to the different events a dormant-tie dyad may encounter, we propose design implications for dealing with the events.

5.4 Implications for Reviving Dormant Ties with Social VR Platforms

5.4.1 Making VR Platforms Responsive to User Contexts

Our observations indicate a dynamic social atmosphere, where participants' emotional states can quickly change due to conversation content, empathy, and nostalgia triggers during dyadic interactions. Avatar appearances and the VEs in our study were static, so they may not be able to meet a dynamic demand for reconnection. In this regard, we recommend future works to exploit context-awareness VR components such as VE and avatar, to automatically adapt the dyadic interaction in VR. For example, a VR sys-

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tem can detect conversation engagement by capturing non-verbal cues such as gestures, body leans, or head nods, all of which can represent different dimensions of engagement [40, 45, 73, 84]. In addition, audio analysis is another possibility to be integrated through its ability to detect emotions and conversation patterns [40]. With all the given user information and the conversational context, a VR system is promising and capable of dynamically customizing the VR features to fit the context needs in reviving dormant ties.

5.4.2 Prevent Awkwardness

A lack of understanding of a dormant-tie friend's recent history often leads to an overestimation of the awkwardness of the reconnection. Because of such awkwardness, it might be difficult for partners to start a conversation once they meet in social VR. Using high-similarity avatars and high-familiarity VEs may help them adapt to the reconnection process initially due to a greater degree of security. It may also trigger more nostalgia-inspired conversation starters. Therefore, we anticipate that the conversation about the past will revive the dormant friendship and expand new topics moving forward. Some participants (N = 4) noted that their friendships were not formed through chatting but rather through engaging in enjoyable activities, such as playing online games, together. Consequently, *topic-driven VR activities* are recommended for dormant ties so that partners do not feel overwhelmed by awkward situations.

5.4.3 Enhance Intimacy

First, many participants (N = 8) mentioned that high-similarity avatars helped them identify their partners because they could start a conversation only after removing uncer-

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tainty. By replicating familiar environments, social VR enables people to recall shared memories within a pair of dormant ties, thus strengthening their bond and restoring intimacy. Additionally, through embodied physical contacts (e.g., habitual interactions), people can experience nostalgic feelings and closeness. Apart from mimicking daily interactions, social VR allows participants to perform actions that are impossible in reality but possible in social VR, thereby achieving intimacy they cannot achieve in the real world. We suggest that designers create engaging environments and events to inspire dormant-tie friends to rekindle old memories and strengthen their bonds.

5.4.4 Encourage Conversation Beyond Small Talk

Unlike strong ties, dormant ties may know less about each other and may not share the same values because people can change after long separations. Thus, dormant ties may go through a series of small talks at the beginning of a reconnection. In most cases, such trivial chats cannot lead to meaningful conversations. In our experiment, environmental memory cues served as a catalyst to develop deep conversations about the past. We observed that participants were hesitant to ask about more sensitive topics because it was difficult to gauge their partner's emotional state only through their voice and facial expression only through an avatar. To facilitate non-verbal communication, Lee et al. examined how people perceive avatars with integrated biosignal visualizations [36]. Understanding each other's emotional states better can help dormant ties disclose themselves, have meaningful conversations, and avoid intrusions.

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5.4.5 Establish Future Reconnection

During the conversation, we observed that participants were more satisfied with the chat when they revealed a balanced amount of information about their recent lives. In other words, recalling memories can enhance emotional connection, but it may not be enough to build a strong-tie relationship after the first reconnection. In social VR, low-familiarity VEs can provide novelty triggers for a pair of dormant ties to focus on new topics about unfamiliar contexts for each other. We recommend participants disclose more about themselves to find more in common and facilitate future reconnection to achieve a solid friendship. Furthermore, revival is a step-by-step process, not an overnight effort. Therefore, we recommend integrating other social media (e.g., Instagram, Facebook) into social VR platforms to facilitate the connection of dormant ties so that they can always stay in touch and use the media that meets their needs.

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Chapter 6 Limitations and Future Work

First, our study was a laboratory study focusing on how the different designs of avatars and VEs can affect the perception and effects on our participants, which took 20 minutes for each of the two sessions. However, reviving dormant ties may require a longer duration or several iterations for participants to get along with each other to achieve successful reconnection and long-term benefits [38]. Future work should conduct long-term studies to observe the influence and development of dormant relationships, such as conducting field studies to observe how or how often dormant ties use VR as CMC with their partners or enabling them with several options of avatars and VEs to observe how they utilize them during conversation. Second, in this paper, as the first study to explore how the different designs of avatars and VEs influence the revival process of dormant ties, we did not limit our participant recruitment policy. The variation of age across our participants (from 20 to 63) may also influence the revival process and outcome, as prior works suggest varying effects on elders and youngsters [22, 66]. We did not explore the time of separation of a dyad, which may also account for the success of reconnection other than age [85]. Therefore, future studies should examine other individual differences (e.g., age, time of separation, gender, etc.) to gain a comprehensive understanding of different types

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of dormant ties. Finally, because we want carefully control the experiment to answer our research questions, we did not fully leverage the overarching capacity of VR (e.g., more kinds of games, cowatching immersive VR videos, etc), creating an opportunity for future research. Therefore, future works can explore how different icebreakers, activities, or any VR property can intervene in the revival of dormant ties.

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Chapter 7 Conclusion

We designed and conducted an mixed-designs experiment with 24 dyad of dormant ties to understand how the designs of *avatar similarity* and *VE familiarity* in social VR platforms affect the interaction between the participants in a dormant relationship. By analyzing questionnaires, qualitative feedback, and coded activities in video footage, we found that participants with high-similarity avatar had higher self-identification and more engagement in conversation than others using low-similarity avatars, who struggle to interact with their partners. We also found that high-familiarity VEs evoked the shared memories for our participants and further facilitated the conversation. The low-familiarity VEs also benefited the interactions between our participants by offering novel objects. In light of our findings, we proposed design implications for future works on using social VR as a means to revive dormant relationship.

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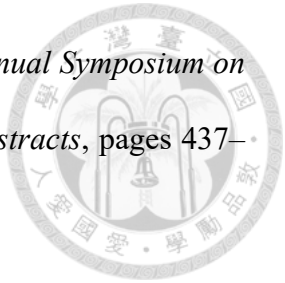

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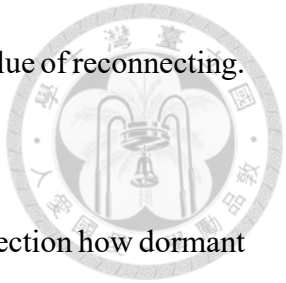

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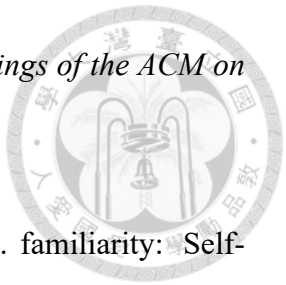

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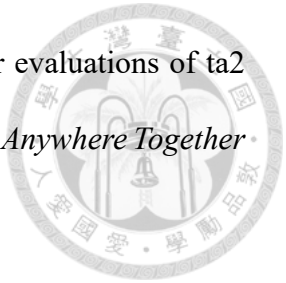

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Appendix A — Supplement Figures and Tables

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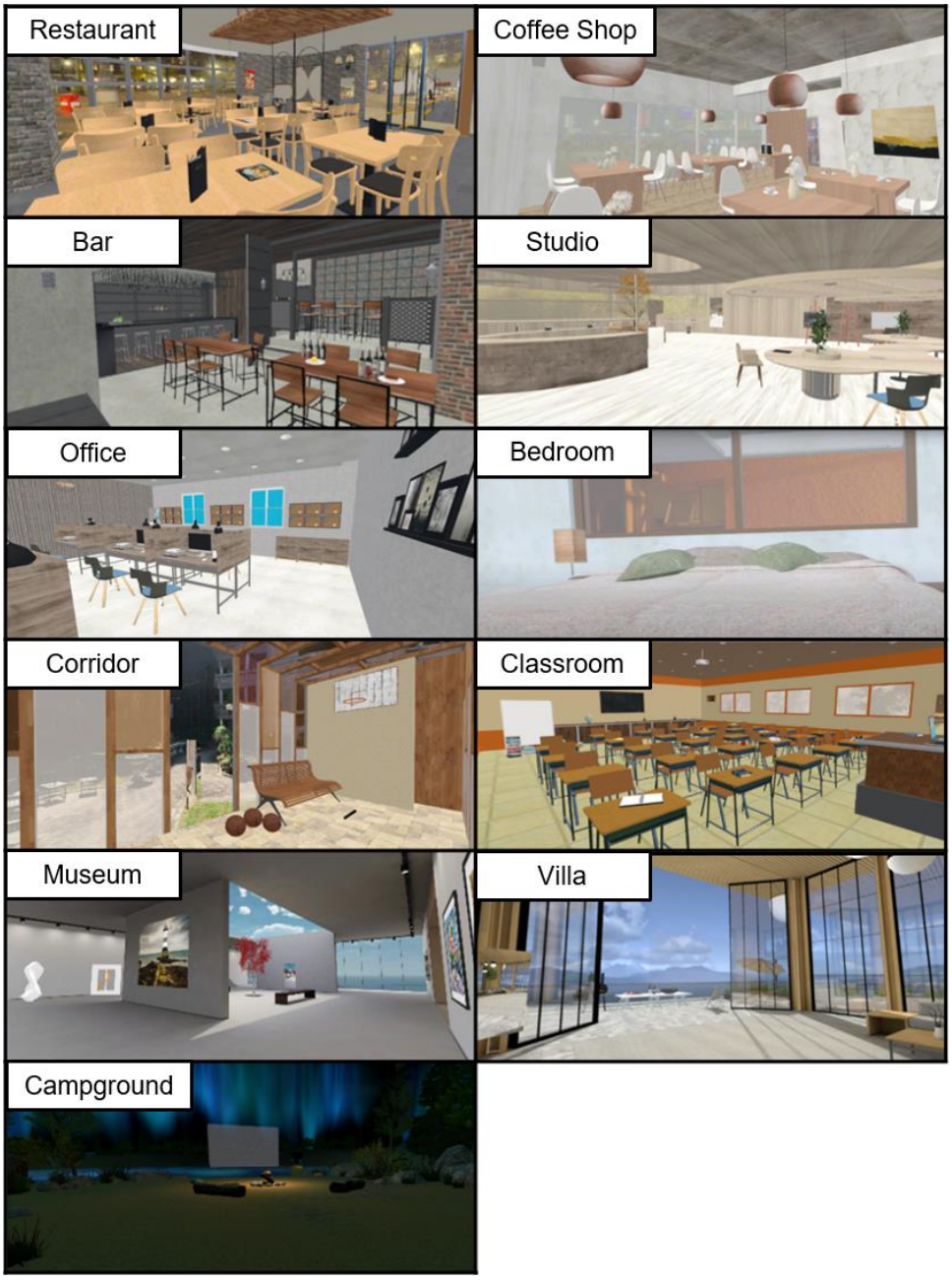

Figure A.1: Virtual Environment (VE) template. We provided 18 VEs in the pre-questionnaire for the participants to score (only text descriptions and no pictures). The following 11 VEs were used in the experiment. The unused VEs, which did not receive sufficient scores for high or low VE familiarity, are as follows: Living Room, Gym, Library, Church, Temple, Game Center, and Transportation Platform.

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Table A.1: Demographic information of our participants and their assigned conditions for avatar similarity and VE familiarity.

ID	Age	Gender	# of Months w/o Physical contact	# of Months w/o Virtual Contact	Avatar Similarity	1st Scene (Familiarity)	2nd Scene (Familiarity)
A1 B1	28 26	Male Male	18	2	High	Coffee Shop (Low)	Classroom (High)
A2 B2	21 21	Male Female	24	24	Low	Classroom (High)	Villa (Low)
A3 B3	25 25	Male Male	36	12	Low	Museum (Low)	Classroom (High)
A4 B4	24 24	Female Female	72	60	High	Corridor (High)	Campfire (Low)
A5 B5	63 58	Male Female	30	24	High	Campfire (Low)	Restaurant (High)
A6 B6	21 21	Male Male	72	3	High	Corridor (High)	Bar (Low)
A7 B7	58 63	Female Female	24	24	Low	Campfire (Low)	Office (High)
A8 B8	23 23	Female Female	24	3	High	Classroom (High)	Villa (Low)
A9 B9	21 21	Female Female	36	5	Low	Studio (Low)	Classroom (High)
A10 B10	21 21	Male Male	12	9	High	Classroom (High)	Coffee Shop (Low)
A11 B11	23 23	Female Female	60	60	Low	Museum (Low)	Classroom (High)
A12 B12	26 26	Male Male	24	24	Low	Classroom (High)	Villa (Low)
A13 B13	30 29	Female Female	24	12	High	Villa (Low)	Bedroom (High)
A14 B14	26 24	Female Female	36	12	Low	Classroom (High)	Campfire (Low)
A15 B15	20 20	Female Female	24	3	High	Campfire (Low)	Classroom (High)
A16 B16	58 54	Male Female	48	48	Low	Restaurant (High)	Studio (Low)
A17 B17	22 22	Male Male	36	12	Low	Museum (Low)	Classroom (High)
A18 B18	31 31	Female Female	120	84	High	Classroom (High)	Campfire (Low)
A19 B19	21 21	Female Female	18	12	Low	Bar (Low)	Corridor (High)
A20 B20	20 20	Female Male	12	18	High	Classroom (High)	Bar (Low)
A21 B21	29 29	Female Male	12	12	High	Bar (Low)	Classroom (High)
A22 B22	34 33	Male Female	24	12	Low	Museum (Low)	Studio (High)
A23 B23	25 25	Male Female	36	24	High	Classroom (High)	Villa (Low)
A24 B24	30 30	Male Female	26	7	Low	Villa (Low)	Coffee Shop (High)

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Table A.2: Video coding descriptions and counts (percentage) for each condition labeled by avatar similarity (High Ava. or Low Ava.) $\times$ VE familiarity (High VE or Low VE). $***= p < .001$

Code	Description	High Ava.×High VE	High Ava.×Low VE	Low Ava.×High VE	Low Ava.×Low VE	Total
Comments on Avatar ***	Participants initiated conversations regarding the appearance of the avatar.	7 (9%)	16 (21%)	24 (32%)	29 (38%)	76
Attracted by Objects in the VE **	One or both participants were attracted by the objects in the VE, which was determined if they turned to an object and said its name.	63 (31%)	34 (17%)	62 (31%)	42 (21%)	201
Distraction	A period of distraction was defined to start when one or both participants left the conversation and turned to look around the VE.	95 (25%)	93 (25%)	100 (27%)	88 (23%)	376
Playing With Virtual Objects Together	This period was defined to start when both participants were playing with the objects.	279 (28%)	259 (26%)	282 (28%)	175 (18%)	995
Small Talk	One or both participants made small talk during their conversation, such as “How is your job?”, and “How about the weather?”	185 (27%)	156 (23%)	155 (23%)	191 (28%)	687
Conversation About Nostalgic and Shared Memory **	One or both participants started conversations that recalled their shared memory.	29 (36%)	11 (14%)	28 (35%)	13 (16%)	81
Silence	Both participants became silent for over 5 seconds.	22 (33%)	23 (35%)	10 (15%)	11 (17%)	66

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