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

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***Abstract*—Rekindling old social bonds with individuals who were once a part of our lives but have since faded away is crucial for our well-being. Such connections with dormant ties help us overcome loneliness and provide social support. Recently, virtual reality (VR) emerged as a promising tool for facilitating social interactions, such as online gatherings for formal or casual activities. VR can offer immersive and shared experiences, facilitating genuine connections between people. This provides a unique advantage over traditional computer-mediated communication methods. However, while prior research has explored how VR can aid in forming new social connections, its potential to reconnect dormant ties is largely unexplored. This paper aims to bridge this gap by examining how different features of VR, specifically avatar appearance and virtual environments, influence reactivations of dormant ties. We conducted an experiment involving 24 dyads to investigate the effect of different avatar-self similarities and virtual environments on the perceptions and interactions between dormant ties. Our findings indicate that avatars resembling oneself and dormant ties promote social closeness. Familiar virtual environments evoke shared memories, while unfamiliar ones stimulate more conversations. We discuss the impact of VR features on reconnecting dormant ties and provide implications for re-connecting relationships in VR.**

***Index Terms*—Virtual reality, avatar, virtual environment, nostalgia, dormant ties, social VR.**

Received 16 December 2023; revised 12 March 2025; accepted 19 September 2025. Date of publication 26 September 2025; date of current version 10 November 2025. This work was supported in part by the National Science and Technology Council (NSTC), Taiwan, under Grant NTSC 114-2218-E-002-006, Grant 114-2221-E-002-218-MY3, Grant 114-2222-E-194-002-MY2, Grant 113-2634-F-002-007, and Grant 113-2221-E-194-030, and in part by National Taiwan University under Grant 114L900902 and Grant 114L8922 funded through the Ministry of Education (MOE), Taiwan, and Delta Electronics. Recommended for acceptance by W. Broll. *(Corresponding author: Fu-Yin Cherng.)*

This work involved human subjects or animals in its research. Approval of all ethical and experimental procedures and protocols was granted by National Chung Cheng University Human Research Ethics Center under Application No. CCUREC111062201, and performed in line with the Declaration of Helsinki.

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This article has supplementary downloadable material available at https://doi.org/10.1109/TVCG.2025.3614445, provided by the authors.

Digital Object Identifier 10.1109/TVCG.2025.3614445

I. Introduction

LIFE changes, such as moving to a new city or graduating from school, can cause people to move away from their established social connections. This distance can lead to a reduction in communication and shared experiences, which can weaken social relationships and even cause them to end [1], [2]. As a result, social isolation is a common experience for many people, and the strength of their social relationships can shift from strong ties to *dormant ties*. These dormant ties may not be actively maintained, but they hold the potential for reconnection in the future [3], [4]. Reconnecting with dormant ties has been proven to enhance individuals' well-being, social connectedness, and social confidence [5], [6], [7], [8], [9], [10]. To reconnect dormant ties, people often rely on computer-mediated communication (CMC). However, traditional CMC methods, such as text, voice, or video, have their own set of limitations and risks. While text and voice-based communication may be less intimidating for dormant ties, they lack nonverbal cues, such as tone, facial expressions, or gestures, which can cause misunderstandings unintentionally [11], [12]. Although video calls provide more visual cues, they may limit the sense of co-presence due to the missing physical proximity [13].

On the other hand, emerging virtual reality (VR) platforms show great promise as a sociotechnical medium for reconnecting dormant ties. VR can recreate past experiences by setting up virtual environments and enabling immersive interactions by being embodied with avatars [14], [15], [16], [17], [18], [19]. The adaptation of immersive virtual environments in VR also enables users to feel certain affective states [20]. Although proximity-based virtual meeting platforms (e.g., Gather. Town[1]) [21] and three-dimensional multi-user environments (e.g., Second Life) [22], [23] can also customize virtual worlds and provide a richer remote communication channel compared to traditional mediums, VR offers even richer channels to express non-verbal cues, social presence, and physical embodiment than these platforms.

[1]https://www.gather.town/

The potential of VR to enhance social interactions and communication is being explored by many researchers. It can be used to maintain long-distance romantic relationships and provide a more immersive experience for activities like reminiscing together among elderly users with better interaction qualities and stronger senses of immersion and social presence than traditional CMC methods [16], [24], [25]. Although VR has been utilized to support strong relationships, such as romantic partners and friends [26], there is a lack of understanding regarding the potential of current VR features that can aid in re-establishing dormant ties. Further knowledge in this area can assist in designing VR features that facilitate relationship building.

Our study focused on two key factors that are highly relevant to communication and the re-establishment of dormant ties: changes in appearance over time [27] and shared nostalgic memories between dormant ties [25], [28]. To explore this topic, we leveraged VR to manipulate avatar-self similarity and virtual environment (VE) familiarity. Past studies have found that the similarity of avatars to users' actual appearance significantly influenced self-disclosure and trust-building, both of which are crucial for developing social relationships [29], [30]. Additionally, recreating familiar virtual environments helped to foster nostalgia and shared memories, which are also important for successfully reconnecting dormant ties [25], [28]. Therefore, to investigate the impact of these design features on dormant-tie reconnection, we formulated the following research questions (RQ):

RQ1: How does the similarity between the appearance of the embodied avatar and the participant's current appearance (Avatar-self Similarity) influence the reconnection of dormant ties in virtual reality?

RQ2: How does the familiarity of the virtual environment (VE Familiarity) in virtual reality influence the reconnection of dormant ties?

To answer the research questions, we conducted a mixed-method experiment with 24 dormant dyads (48 participants) and invited them to interact with their dormant ties in VR. The results indicated that dyads who used avatars with a high degree of similarity to their own appearance reported more positive social experiences and interactions with their dormant ties compared to those who used avatars with low similarity. Additionally, when dyads interacted with each other in high-familiarity virtual environments (VEs), they engaged in more nostalgic conversations and experienced more memory resonance than those who used low-familiarity VEs. Our results not only provided insights into the importance of avatar-self similarity and VE familiarity but also highlighted the significance of other VR techniques, such as interaction with virtual objects and physical co-presence, in facilitating the interaction and reconnection process between dormant ties.

Our research contributed to bridging the fields of dormant ties with VR. We have discovered that VR, as a novel computer-mediated communication tool, can effectively reconnect long-lost relationships across distances. Our findings suggest that the appearance of avatars and virtual environment familiarity play a crucial role in the reconnection process. We discuss insights for future research on the design of emerging technologies to reconnect dormant ties.

II. Related Work

A. Reconnection of Dormant Ties

The changes in 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 relationships, thus resulting in dormant ties [1], [2], [3], [4]. Dormant tie is defined as the relationship between people who had constantly communicated with each other but have become strange and unfamiliar due to reasons such as separation or divergent interests [3], [4], [8], [31]. As long as one subjectively considers the relationship with another person as less intimate than it was in the past, the relationship can be treated as a dormant tie [3], [4], [8], [31]. Although dormant ties are often overlooked in our relationships, past research has proven that they are an essential resource that can improve our social capital, and can provide more value than active ties [3], [32]. Moreover, reconnecting dormant ties can help people's social networks maintain balance and prevent the negative effects of unbalanced interpersonal relationships [3], [8], [33], [34].

Due to the benefits of reconnecting dormant ties mentioned above, researchers have investigated how different types of computer-mediated channels can help reactivate these ties. To measure the effectiveness of such reconnections, studies often rely on self-report data to measure whether the reconnection was successful (e.g., the dyads felt closer to each other after the reconnection activities) and the interaction quality and social relationship perceived by dyads [3], [33], [34], [35]. For instance, researchers found that over 80 percent of participants reconnected with dormant ties through the CMC medium, such as telephone [3], email [36], and social media [37].

However, communicating through text-based and audio-only mediums can often lead to misunderstandings as they lack the contextual information behind the message [11]. While video and proximity-based virtual meeting platforms like Gather.Town[2] can provide more context, they do not convey non-verbal cues such as body language and physical presence, which are essential to building strong relationships [38]. Therefore, VR, being a medium that can provide co-located and embodied experiences, is an effective alternative to overcome the limitations of other mediums.

B. Social Interaction in Virtual Reality

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 [15], [16], [17], [18], [19]. For example, most social VR platforms (e.g., VRChat) provide body-tracking avatars for remote users, allowing them to interact physically. Recent studies have also shown that body movements could enhance users' expressiveness, which can simulate the interactions in

[2]https://www.gather.town/

offline world activities [15], [17]. In addition, locomotion and spatial embodiment in VR allow users to have immersive, spatialized, and navigational experiences in a remote setting [39], [40]. Moreover, social VR allows users to communicate verbally and non-verbally in real-time, thereby recognizing each other's emotional signals (e.g., voice and gesture) easily [14].

In light of these benefits of VR in social interaction, researchers have explored the impact of VR on acquiring intimacy in long-distance romantic relationships [24] and the use of VR in facilitating reminiscence activities for groups of older adults [25]. These studies underscore the benefits of virtual co-presence and immersive experiences in virtual worlds for fostering connections and eliciting reminiscences or shared memories. Although these studies attest to the benefits of VR in maintaining existing relationships and eliciting memories, what remains notably underexplored is the application of VR in the nuanced context of rekindling dormant social ties.

Therefore, this paper aims to investigate the impact of two key design factors of virtual reality (VR) on individuals' experiences and their ability to reconnect with dormant-tie relationships. We have chosen to focus on the perceived avatar-self similarity and the familiarity of virtual environments to dyads due to their significant influence on users' communication, interaction, and ability to recall nostalgic feelings and shared memories [25], [28], [29].

C. Influence of Avatar Similarity and VE Familiarity

Recent research has highlighted the significance of avatar-mediated communication in creating a sense of co-presence in VR. Studies have shown that avatar appearance influences users' thoughts and behaviors in the virtual world [17], [30], [41], [42], [43]. For instance, it has been found that people tend to interact with familiar individuals using avatars that resemble their physical appearance [17]. Furthermore, people tend to find avatars that mirror their own appearances to be more persuasive than those that do not when interacting with the avatars [44]. Using an avatar resembling the user can increase a sense of security and encourage self-disclosure to counterparts [29]. It can also improve trust and a sense of co-presence by interlocutors [45]. Additionally, previous studies have demonstrated that avatars with high avatar-self similarity can significantly improve performance [46] and boost users' self-awareness and self-efficacy [30] on completing the given tasks. One of the key reasons related to avatar-self similarity is the Proteus effect, where individuals tend to alter their behavior to match the attributes of their avatars, as demonstrated by previous research [47]. In order to establish a strong user-avatar relationship, self-similarity, wishful identification, and embodied presence are essential [47]. While prior studies have investigated the impact of avatar-self similarity in various contexts, there is a lack of research on the influence of avatar-self similarity on dyadic social interaction with dormant ties and relationship reconnections.

As for the influence of virtual environments (VEs), prior research has noted that VEs have the potential to enhance memory recollection and build social connections among older adults in VR settings [16], [25]. By enabling them to visit familiar places with personal artifacts in a virtual environment, older adults sparked conversations about their real lives and fostered reflections [16], [25]. Researchers also found that customized virtual environments also have the flexibility to create social catalysts that alleviate awkwardness compared to the real world [25]. Moreover, comparing virtuality- and reality-based social VR environments, researchers have found that reality-based social VR environments can provide familiarity and trigger affectionate responses [48]. These previous studies motivated us to ask whether and how reproducing a familiar virtual environment can effectively reconnect dormant ties in VR. Therefore, this work aims to provide an empirical understanding of how avatar-self similarity and VE familiarity affect the reconnection process and experience of dormant ties.

III. Experiment Design

A. Participants

Through public recruitment posts on social media, university forums, and online forums of VR enthusiasts, we recruited a total of 24 dyads with dormant ties (Male = 19, Female = 29). We specifically targeted participants who had dormant friendships in various settings, including the workplace, school, interest groups, and neighborhoods, because friendships are the most common relationships that tend to lapse into dormancy according to previous literature [3], [4].

Participants were aged from 20 to 63 years (mean = 28.96, *SD* = 12.11) and had self-reported that they had 12 to 120 months (mean = 35.33, *SD* = 24.56) without any personal contact before attending our study. In the recruitment form, prospective participants were asked to provide the contact information of the dormant tie they wanted to reconnect with. We conducted brief individual telephone interviews with each participant and their respective dormant ties after receiving their contact details. The purpose of these interviews was twofold. First, we confirmed with each participant that they had not had any contact for the stated duration preceding our study, and we also checked that they resided in different geographic locations within the country where the study was carried out. Second, we sought to understand the nature of the dyads' relationships and the reasons behind the loss of contact. This was done to ensure that both parties were genuinely interested in rekindling their ties through this experiment. Once we obtained the contact information from the participants' dormant ties, we obtained formal consent from the participants and their dormant ties to take part in the experiment. This experiment was approved by the institutional review board (IRB) 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 II in the supplementary material.

B. Apparatus and VR Platform

In the experiment, we used the social VR platform, Spatial,[3] because it allows a high degree of customization of the VE.

[3]https://spatial.io/

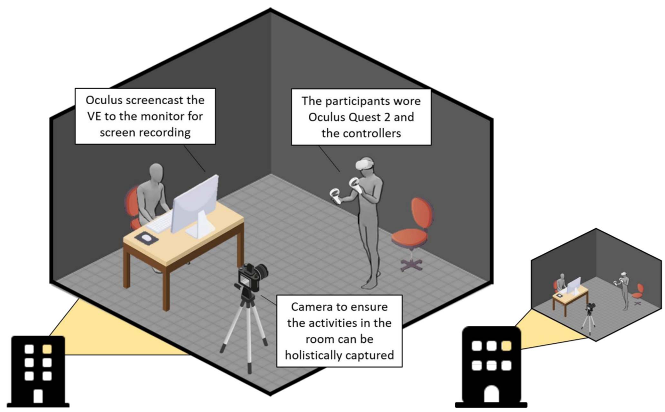

Fig. 1. Experiment setup for a single participant in a dormant-tie dyad. The other half of the dyad is in a separate room with the same setup.

Moreover, Spatial has adopted the common features used by most VR applications (e.g., head and hand tracking, voice chat, and manipulation of virtual objects by controllers), which enables us to enhance the generalizability of the findings.

Fig. 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 set up another camera to ensure participant activities and conversations could be fully captured in case the screencast of Oculus was unstable. The experimenter stayed quietly in the same space with the participants to ensure their safety and prevent them from touching walls or other objects while wearing a VR headset without interfering with the dyads' interaction process.

C. Manipulation of Design Factors

We designed two levels (high and low) for avatar-self similarity and VE familiarity. To investigate the effects of these two factors, we conducted a 2×2 mixed-design experiment in which the avatar-self similarity was the between-subject factor, and the VE familiarity was the within-subject factor. The rationale behind this mixed design was that individuals possess the freedom to transition between different locations at will. However, an abrupt change in an avatar's appearance during an ongoing interaction would deviate from the typical dynamics of a face-to-face encounter. We randomly assigned the dyads to one of the two groups (high-similarity avatar versus low-similarity avatar). Next, the dyads in each group experienced both high- and low-familiarity VEs in counterbalanced order. The following sections describe how we manipulated the level of avatar-self similarity and VE familiarity.

1) Manipulation of Avatar-Self Similarity: 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,[4] which is a commonly used online tool to generate and customize avatars on several 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 between the rendered avatar and the given photo they provided for these four avatars on a 7-point Likert scale (1 = very dissimilar; 7 = very similar) before the experiment, which we modified from the survey commonly used by previous research to measure avatar similarity [49]. To make high-similarity avatars, we selected the avatars that received the highest rating of similarity from the participants (mean rating of avatar similarity = 6.167, SD = 0.637).

To make low-similarity avatars, we selected an avatar that was rendered based on participants' photos and altered its hairstyle, hair color, eye color, and clothing using the customization options provided by Ready Player Me, with the objective of making it significantly distinguishable from the original avatar. First, two of the authors reviewed all customization options for hairstyle, hair color, eye color, and clothing available in Ready Player Me. They filtered out those options deemed unrealistic, thereby ensuring the modifications remained within the realm of potential real-world variations. After that, both authors worked together to modify the avatar's hairstyle, hair color, eye color, and clothing until they came to an agreement that the updated avatar was significantly different from the high-similarity avatar but still accurately portrayed the intended person. To maintain the identity of the individual it was created to depict, we kept the facial features of the avatar intact while modifying it to have low similarity with the original design. The lower similarity rating observed for the low-similarity avatar group (mean rating of avatar similarity = 4.958, SD = 1.601) validates the effectiveness of our manipulation. The average rating scores suggest that participants still perceived more than neutral similarity (4.958 on a 7-point Likert scale) with the low-similarity avatar. This indicates that the dyads could still recognize each other through these low-similarity avatars despite the alterations.

We asked participants to look at themselves in the mirror while they were embodied in avatars in VR. This procedure was intended to ensure their sense of embodiment in the avatars. In addition, we asked the dyads to view their dormant tie's avatar and use the same scale to rate the similarity between the rendered avatar and their friend's image that lasts in their memory after the experiment. By doing this, we aim to validate whether both parties had high certainty in associating their friend with their friend's avatar. The Pearson's correlation coefficient between the avatar-self similarity reported by the participants themselves and the similarity reported by their dormant ties was 0.606, which shows that the dyads achieved high-degree mutual agreement [50], [51] on the similarity of each other's avatar. Fig. 2 shows the example of the original photograph and the generated avatars with high and low similarity.

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 environment for a dormant-tie pair who were

[4]https://readyplayer.me/avatar

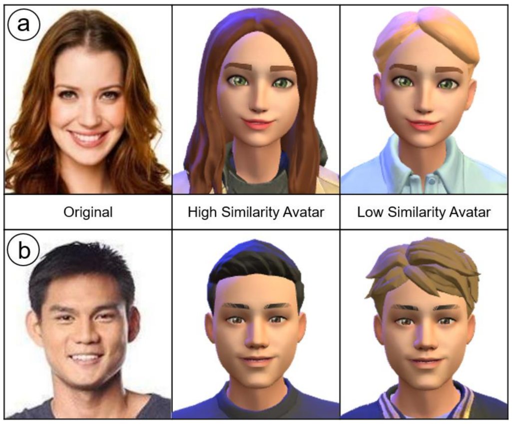

Fig. 2. Examples of avatars with high and low similarity generated from the original photographs of (a) a woman's face and (b) a man's face. To protect participants' privacy, we used the photographs from the open-source dataset CelebA [52].

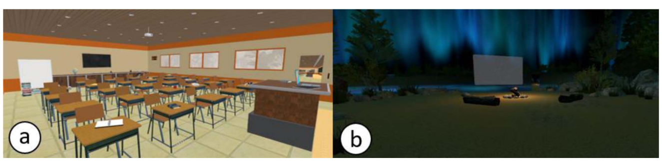

Fig. 3. Examples of VEs with different levels of familiarity that we used in the experiment. (a) The classroom was frequently rated as a high-familiarity VE by the participants, and (b) the campground was rated as a low-familiarity VE by most of the participants.

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. The question contents and the environment list are provided in Table IV of the supplementary material.

For the high-familiarity VEs, we selected the environment with the highest average familiarity, as rated by both participants in each dyad (average familiarity rating by all dyads = 6.791, $SD = 0.544$), to create the virtual environment with high familiarity. 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 or toys) related to the selected environment. We added the information provided by participants and virtual personal artifacts to customize the VEs. By preparing the high-familiarity VEs, we were able to recreate and customize the virtual environment for each dyad based on their shared memory.

For the low-familiarity VEs, we selected the environment that received the lowest rating of environment familiarity for each dyad (average familiarity rating = 1.125, $SD = 0.531$) to create the virtual environments with low familiarity, without customizations. To ensure that participants perceived similar familiarity from the VEs, we asked them to rate the familiarity of VE again after the experiment. We observed a strong positive correlation (Pearson's $r = 0.705$) between the familiarity rating of the environment and the VEs created, which suggests that the created VEs accurately reflected the environment. Fig. 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 Fig. 5 of the supplementary material.

D. Task and Procedure

Before the experiment began, each participant was instructed to go to separate rooms in different buildings where they could not see or interact with their dormant ties. Once they arrived at their designated locations, each participant in the dyad was introduced to the experiment procedure, signed the informed consent form, and received training on how to use VR accessories in Spatial. After familiarizing themselves with the apparatus, each dyad experienced two conditions with high and low VE familiarity. In both conditions, participants used the same avatars with either high or low avatar-self similarity.

During each condition, the dyads were tasked with chatting freely and had access to sharing games, which are known to facilitate dyadic communications in prior studies [53], [54], for 20 minutes. After experiencing the respective VEs, the participants completed survey questionnaires and had semi-structured interviews at the end of the experiment for 25 minutes. To allow for a break, the two conditions were set 10 minutes apart. The entire experiment lasted approximately 2 hours. As compensation for their participation, each participant received \$50.

E. Measurements

We started by using the self-report questionnaires proposed by Li et al. [19] to assess the participants' perception and experience of each condition. This helped us investigate how the similarity between the avatar and the self, as well as the familiarity with the virtual environment, influenced the reconnection process of the dyads. The questionnaires include three subscales that evaluate the quality of interaction (QoI), presence/immersion (PI), and social meaning (SM). The complete questionnaires can be found in Table III of the supplementary material.

1) Quality of Interaction (QoI): The QoI subscale focuses on how participants interacted and communicated with their partners in VR to ensure that the dyads understood each other's behavior [55], [56]. Example items include "I could fully understand what my partner was doing in the social VR." Participants answered all six items on a 5-point Likert scale, where 1 indicated strongly disagree, and 5 indicated strongly agree.

2) Presence/Immersion (PI): The PI subscale requires participants to report whether they felt immersed when using social VR and interacting with the VE [57], [58], [59], [60] Example items include "I had a sense of being in the same space with my partner." Participants answered all nine items on a 5-point Likert scale, where 1 indicated strongly disagree, and 5 indicated strongly agree.

3) Social Meaning (SM): The SM subscale assesses participants' mental and physical experience, including the sense of togetherness and memory recall/recreation during dyadic interaction in social VR [56], [61], [62]. Unlike QoI and PI, SM contains six items with negative narratives and two items with positive narratives. For example, positive narrative items include "My social VR experience felt like face-to-face sharing," while negative narrative items include "I often felt alone during social VR." Participants answered all eight items on a 5-point

TABLE I
VIDEO CODING DESCRIPTIONS AND COUNTS (PERCENTAGE) FOR EACH CONDITION LABELED BY AVATAR SIMILARITY (HIGH AVA. OR LOW AVA.) × VE FAMILIARITY (HIGH VE OR LOW VE). $*** = P < .001$, $** = P < .01$

Code	Description & Example	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. *e.g., A3 said to B3's Low Ava. "Why do you look like this? This is completely different from you."*	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. *e.g., B18 stared at photos of trips with A18 on High VE wall.*	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. *e.g., after A9 and B9 ended a conversation and they began to explore the VE separately.*	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 together. *e.g., A15 found a volleyball in VE and played with B15.*	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?" *e.g., A16 told B16 about his child's recent life.*	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. *e.g., A21 and B21 reminisced about their past after-school activity class and shared their favorite memories.*	29 (36%)	11 (14%)	28 (35%)	13 (16%)	81
Silence	Both participants became silent for over 5 seconds. *e.g., A8 and B8 became silent after saying hello in VE.*	22 (33%)	23 (35%)	10 (15%)	11 (17%)	66

Likert scale, where 1 indicated strongly disagree, and 5 indicated strongly agree.

4) Behavior Analysis by Video Coding: In addition to the self-report measures, we used the VR and camera to record the interactions between dyads. By analyzing the recorded video, we were able to identify and categorize various behaviors based on their social intentions. Video coding has proven to be an effective method for capturing and understanding users' high-level behaviors that are difficult to detect automatically [63], [64]. Additionally, the temporal nature of the recorded video allowed us to obtain video codes that were tailored to our research questions. We utilized the process of inductive open coding to analyze recorded video, following conventional content analysis guidelines [65]. First, we aligned the videos of A and B in the same dyad according to the timeline, then two authors gradually confirmed the content of the videos and marked different actions (e.g., A comments on B's Avatar, A is distracted, etc). Next, the two authors categorized different actions into several codes and integrated codes to generate the final list of codes. For example, A commenting on B's avatar or B commenting on A's avatar were both coded as one count of "Comment on Avatar." Table I provides a comprehensive list of code examples along with their respective descriptions.

5) Semi-Structured Interviews: In order to explore the underlying reasons for their quantitative feedback and behaviors, we designed and conducted semi-structured interviews with each participant after the experiment. The interview outlines are listed in Table V in the supplementary material.

F. Data Analysis

To analyze the questionnaire responses, we conducted repeated-measure two-way mixed ANOVA to analyze the main effects of two factors (avatar similarity × VE familiarity) and Tukey HSD for post-hoc pairwise comparison.

Regarding analyzing video recordings, two authors coded the video recordings following the process mentioned in Section III-E4 and generated the counts of each code shown in Table I. The two authors achieved an inter-rater agreement validity of Cohen's kappa equal to 0.855. For the statistical analysis, we also conducted repeated-measure two-way mixed ANOVA to analyze the main effects of two factors (avatar similarity × VE familiarity) on the counts of video-coded behaviors using Tukey HSD for post-hoc pairwise comparison. We also transcribed the participants' conversation in each condition to analyze their verbal interaction, since the prior research showed that the metrics of verbal interaction and linguistic features could reveal the social dynamics and engagements between dyads [66].

For the qualitative data, we implemented thematic analysis [67] to examine the interviews, aiming to comprehend the participants' experiences during interactions with their dormant ties under each condition. After the interview data of the 48 participants were transcribed, two authors identified an initial set of codes by browsing all the interview transcripts and separately creating codes associated with each statement. Then, they jointly arranged these codes into broader themes within the context of our research questions. 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.

IV. RESULT

A. Questionnaire Results

Fig. 4 displays the ratings given by participants for the subscales of interaction quality (QoI), presence/immersion (PI), and

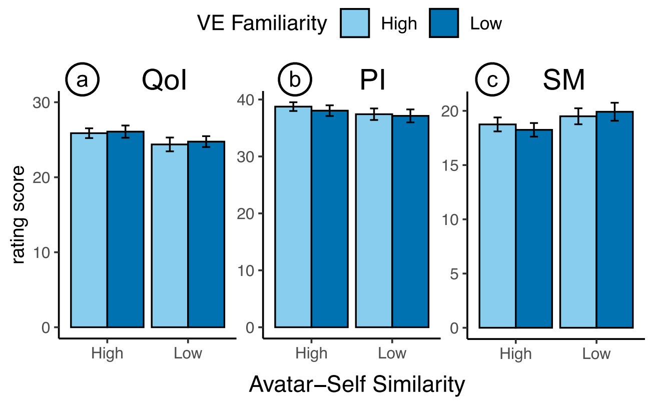

Fig. 4. Results of the self-report questionnaire. (a) shows the rating result for interaction quality (QoI), (b) shows the result for presence/immersion (PI), and (c) shows the result for social meaning (SM). The error bars represent the standard error.

social meaning (SM). The two-way ANOVA conducted showed that there was no main effect of avatar-self similarity and VE familiarity on QoI (avatar-self similarity: $F(1, 46) = 1.91$, $p = .17$; VE familiarity: $F(1, 46) = .47$, $p = .49$), PI (avatar-self similarity: $F(1, 46) = .78$, $p = .38$; VE familiarity: $F(1, 46) = .92$, $p = .34$), and SM (avatar-self similarity: $F(1, 46) = 1.79$, $p = .19$; VE familiarity: $F(1, 46) = .01$, $p = .93$). Moreover, there was no significant interaction effect among them on all three subscales (QoI: $F(1, 46) = .04$, $p = .85$; PI: $F(1, 46) = .16$, $p = .69$; SM: $F(1, 46) = 1.04$, $p = .31$). These results indicate that neither avatar-self similarity, VE familiarity, nor their combination had any significant impact on the participants' self-reported perceptions regarding interaction quality, social presence, and social meaning.

B. Video Coding Results

According to the results presented in Table I, we observed that dyads using low-similarity avatars commented more frequently on their partner's avatar, as indicated by higher counts for *"Comments on Avatar"* compared to those using high-similarity avatars ($F(1, 22) = 7.65$, $p < .05$). For instance, A3 said to B3's low-similarity avatar "Why do you look like this? This is completely different from you." This finding suggests that the more alien appearance of avatars triggered more conversation topics around their appearance between the dyads. Additionally, we found that in VEs with high familiarity, the counts for *"Attracted by Objects in the VE"* ($F(1, 22) = 6.44$, $p < .05$) and *"Conversation About Nostalgic and Shared Memory"* ($F(1, 22) = 6.35$, $p < .05$) were higher than low familiarity VEs. For instance, B18 saw the photos of previous trips with A18 hanging on the wall in high familiarity VE ("Attracted by Objects in the VE"). Then, A18 also looked at the photos and chatted about the memory of the trips with B18 ("Conversation About Nostalgic and Shared Memory"). This finding indicates that the VEs that look familiar to dormant ties can trigger more attention to virtual objects and elicit more nostalgic conversations.

C. Conversational Results

We first examined if there was any effect of avatar-self similarity and VE familiarity on the amount of turn-taking, which indicated participants' engagement [68], during the conversation based on the verbal data. By referring to [68], [69], we defined turn-taking as the sequential exchange of speaking roles between two speakers in a conversation. A turn is considered taken when one speaker begins speaking after the other has finished. If a speaker continues speaking across multiple turns without interruption or response from the other speaker, it is not counted as a new turn-taking instance in the current setting. Turn-taking occurs only when the speaking role shifts from one speaker to the other. For example, if Speaker 1 asks, "Where do you live now?", and Speaker 2 responds, "I'm still living in Tainan.", this constitutes one turn-taking instance because the speaking role has shifted from Speaker 1 to Speaker 2. The result of two-way ANOVA showed that there was no main effect of avatar-self similarity and VE familiarity on the number of turn-taking (avatar-self similarity: $F(1, 22) = 0.038$, $p = .85$; VE familiarity: $F(1, 22) = 1.02$, $p = .33$).

We further examined whether avatar-self similarity and VE familiarity influenced the overall communication accommodation behavior in terms of word choice during the conversation using cosine similarity. Cosine similarity measures how similar two conversation data points are by calculating the cosine of the angle between their vector representations. This method has been used widely for evaluating lexical and semantic synchrony [70], [71], [72]. We first tokenized the transcripts from each speaker and then calculated the cosine similarity between the dyads. The result of two-way ANOVA showed that there was no main effect of avatar-self similarity and VE familiarity on the cosine similarity between the conversation of the dyads (avatar-self similarity: $F(1, 22) = 0.069$, $p = .80$; VE familiarity: $F(1, 22) = 0.38$, $p = .54$). The descriptive statistics of the Number of turn-taking and cosine similarity are provided in Table VI and Table VII of the supplementary material.

D. Qualitative Findings

1) Similar Avatar and Familiar VE Induced Nostalgia and Related Emotion on Dormant Interactions: Our participants reported that high-similarity avatars and high-familiarity VEs evoked their shared memories and contributed to nostalgia. Moreover, these senses of connecting the avatar to the physical self and their dormant-tie partners or the VE to the past memory make participants feel secure. For the dyads assigned to the high-similarity avatar group ($N = 24$), nearly half of the participants ($N = 11$) reported that high-similarity avatars helped them rapidly and intuitively associate with their partner's appearance based on characteristics such as the avatar's facial features, hairstyle, and dressing. As mentioned by B1: *"His avatar's stubble matches his actual appearance closely, just as the same as the one in my memory."* Moreover, participants with avatars resembling themselves reported feeling more secure and calm because they felt the avatars could represent themselves accurately ($N = 7$).

For the effect of high-familiarity VEs, A18 described how the virtual classroom, which is a highly familiar VE for A18 and B18, affected the reconnection process with B18: *"The photo of us in childhood I prepared amazed her when she found it in the virtual classroom. She was surprised that 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 for triggering our shared memory."* Furthermore, the high familiarity VE evoked emotional resonance in dormant dyads by recalling past events and people. This finding was supported by the experiences of A11 and B11, who were placed in a VE of a classroom they were familiar with: *"My dormant tie said our teachers in our junior high school have been bedridden now. This overwhelmed us with complicated sentiments."* The familiar VE triggered a conversation about their shared past. We also noticed that eight participants who were already familiar with the VE were able to engage in conversations and were attentive to each other. For instance, B12 noted, *"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 to each other"*.

2) Dissimilar Avatar Could Provide Social Mask and Unfamiliar VE Provide Novelty: Compared to high-similarity avatars, avatars with low similarity were more difficult for participants to identify and associate with the past images of their dormant ties ($N = 11$). For example, B3 described this situation as follows: *"His [B3's dormant tie's] avatar looks totally different from what I can remember. Though I was aware of who he is, I felt incongruent with my memory and deviated from reality."* Moreover, some participants given low-similarity avatars struggled and were uncomfortable when interacting with their dormant ties because they felt the avatars did not accurately represent them ($N = 11$).

In contrast, our study also found that avatars with low similarity can be beneficial for individuals who are not comfortable with their current physical appearance in the real world, especially for the senior participants. In this case, the avatar can act as a social mask, allowing people to conceal certain aspects of themselves and feel more confident in interacting with their dormant ties. B16 (age: 54; A16's age: 58) with the low-similarity avatar stated: *"Sometimes, physical appearance and barriers make face-to-face interactions awkward. After years of not seeing each other, we have become old and ugly. That's why I prefer to stay away from him if we meet physically. But in virtual reality, I feel comfortable sharing anything with my dormant tie using my avatar. Potential sources of embarrassment, such as body odor or aging, are no longer a concern."*

For the effect of the VEs with low familiarity, participants ($N = 9$) who were assigned low-familiarity VEs with their dormant ties leveraged the novelty of objects and scenes they saw in the VEs to facilitate their interactions. For example, B22 reported, *"We used to be in those fixed workplaces and had no chance to reach different places together. The virtual museum was fresh and interesting to us, and we took selfies and explored the scene together. It's like we went through an adventure together."* 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: *"Growing up in the city, we rarely had the opportunity to experience nature. However, I was surprised to discover that our current shared interest is camping. Thanks to this common interest, our conversation revolved around our outdoor activities."*

Additionally, some participants ($N = 3$) reported that the nature of the VE would dominate the atmosphere of the dormant-reconnecting process: *"Although this virtual villa is not the environment we were familiar with in the past, I think the atmosphere here is more relaxed than the classroom, which makes me feel very stressed, so I also find it easier to chat here."* (A12). Some participants ($N = 8$) also highlighted the high- and low-familiarity VEs could be used in different stages during the reconnection 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 shared memory. After being reconnected, I think something new in the low-similarity VE can be brought to us for further interaction and discussion."*

3) VR-Enabled Co-Located and Embodied Experience Faciliate Reconnection: In addition to the primary themes we intended to explore to answer research questions, we discovered that VR's embodied nature is a suitable means for reconnecting dormant relationships. Some participants ($N = 6$) depicted how the VR-embodied experience strengthened their relationship during the study: *"Wandering in the VE can provide an experience similar to 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 dormant tie'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 VR 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 language. I really fear my clumsy movements"* (A10).

V. Discussion

By triangulating the results, we discuss the knowledge gained from our experiment, the links to prior works, and the general discussion of avatar and VE selections for future works in reconnecting dormant ties in social VR platforms.

A. Effects of Avatar Similarity in Dormant Ties Interaction

Our experiment found that using high-similarity avatars during the reconnection process can have a positive impact. These avatars make it easier to have engaging conversations and increase self-presence, which can aid in the reconnection process. Previous research [29] has also shown that using an avatar that is similar to oneself can increase the sense of security and willingness to open up to others. By using a high-similarity avatar to connect with dormant ties, people were able to initiate conversations more easily. It has shown that thinking of reconnecting with dormant ties can sometimes be anxious to people [73]. In line with previous literature, our qualitative findings suggest that using high-similarity avatars may help with reducing such anxiety since participants felt a stronger connection to high-similarity avatars, which in turn created a sense of security. Additionally, the dyads using high self-similarity found it easy to associate the avatars of their dormant-tie partners with their actual appearance, evoking feelings of nostalgia and facilitating reconnection with their dormant ties. This finding is consistent with previous research [29], [74], which demonstrated that high-similarity avatars can increase self-identification and the desire to share personal topics with others, rather than induce fear of exposure.

Turning to low-similarity avatars, our qualitative findings show that using low-similarity avatars caused some participants to detach from reality due to the lack of self-identification. As a result, using low-similarity avatars made them feel mentally distant from their partners. Furthermore, the feeling of incongruency between the avatar of their dormant ties and the memorized appearance in the low-similarity avatar condition also made the reconnection more difficult. However, low-similarity avatars can sometimes be helpful in terms of serving as conversation starters between dormant ties. This is evidenced by our video coding results, which showed that the participants made significantly more comments related to the avatar appearance when using the low-similarity avatar (see Table I). Moreover, the use of avatars by senior participants to interact with dormant ties provided them with a balanced distance to maintain physical proximity without worrying about body odor or showing their wrinkles when meeting in person. This has important implications for social VR platforms such as VRChat and Mozilla Hubs, which can be used to facilitate dormant ties to connect with each other. These platforms offer users a wide range of avatar options before interacting with each other. To maintain the benefits of avatars in VR and prevent discomfort that may arise from using unfamiliar avatars, we suggest that social VR platforms offer users the option to select avatars that resemble themselves when reconnecting with dormant ties and allow for flexibility to change avatars based on the conversation's progression.

B. Effects of VE With Different Levels of Familiarity

Our research findings suggest that high-familiarity virtual environments (VEs) can be effective in eliciting feelings of nostalgia and facilitating conversations through shared memories, leading to the reconnection of dormant ties. The memory cues in familiar VEs can play a crucial role in reconstructing friendships by providing dyads with opportunities to recall their past shared memories. Prior works have also indicated that experiencing nostalgia can be an effective strategy for acquiring spiritual resources by reliving pleasant memories [75]. Moreover, this empathetic immersion can result in stronger bonds between dyads [75]. Our qualitative analysis further supports the idea that VEs that resemble the places in memories can reduce stress and enhance conversation quality by serving as icebreakers and increasing interpersonal attention [25]. Additionally, the video coding results show that there was a higher frequency of conversations about nostalgic and shared memories in conditions with high VE familiarity, validating previous suggestions that projecting more individual memories into the virtual environment can aid reminiscence [16]. On the other hand, when participants were placed in low-familiarity VEs, they lacked memory cues and had to explore the space to become familiar with it. Despite the absence of memory cues triggering conversations or interactions, our qualitative findings show that participants were able to use novel objects in the VE as conversation starters, leading to enriched interactions.

Based on the findings about the impact of VEs with different familiarity levels on dormant tie reconnection, we agree with some participants' suggestion that reconnecting with a dormant tie by talking about old memories in high-familiarity VEs is better. After discussing old memories, the VE can be transitioned to a low-familiarity one to induce more novel conversation topics. This strategy aligns with the requirements of dormant ties proposed by prior research. If dormant ties only discuss memories instead of reciprocating novelty, they will only prevent the decay of dormant ties but not achieve successful reconnection or further development [3], [73]. Moreover, our qualitative results show that certain VEs have a dominant influence on the atmosphere during the process of reconnection, which can alleviate the social anxiety experienced by dormant-tie dyads and provide comfort in social situations. This is consistent with previous studies that have shown how different features of places can lead to different social expectations and emotions [25], [39], such as the need for silence in a museum, a feeling of freedom in the countryside, or a tendency to relax in the atmosphere of a villa, as demonstrated in our research.

Overall, our study has found that VE with varying levels of familiarity can effectively assist in the process of reconnecting dormant relationships by facilitating shared memories or initiating new conversations. It is important to consider factors such as the reconnection phase of the dormant tie and the anxiety levels of the individuals involved when deciding on the VE familiarity to use. Future research could explore how to adjust VE familiarity to facilitate reconnections between individuals with dormant ties, taking into account their unique interactions and differences.

C. General Discussion and Implications

After analyzing the multifaceted results and discussion, we identified design and research implications that could be useful for VR applications aimed at reconnecting dormant-tie dyads in various scenarios.

1) Making Virtual Environment and Avatar Responsive to User Contexts: Our findings indicate that during dyadic interactions between dormant ties, social interaction can rapidly change due to conversation content, empathy, and triggers of nostalgia. To strengthen the effect of reconnecting with dormant ties in VR, we recommend future works to exploit context-awareness VR components, such as VE and avatar, to adapt the dyadic interaction in VR according to the conversation flow. For example, a VR system 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 [14], [19], [76]. 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 reconnecting dormant ties.

2) Facilitate Reconnection Using Similar Avatar and Familiar VE: A lack of understanding of a dormant tie's recent history often leads to an overestimation of the awkwardness of the reconnection [77]. Because of such awkwardness, it might be difficult for dormant-tie dyads to start a conversation once they meet in VR. Our qualitative results indicate that using avatars relatively similar to the physical self may help them adapt to the reconnection process initially due to a much higher degree of security and self-identification. Additionally, using VEs with a high level of familiarity may trigger more nostalgia-inspired conversation starters. Therefore, we anticipate that using high-familiar VE could trigger the conversation about the past, reconnecting the dormant ties and expanding new topics moving forward.

3) Establish Future Reconnection Using Unfamiliar VE: During this study, we observed that participants were satisfied with the chat when they revealed information about their recent lives, as shown in the qualitative results about the low-familiar VE. 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 [3], [73]. Based on the results of our study, low-familiarity VEs can provide novelty triggers for a pair of dormant ties to focus on new topics about unfamiliar contexts for each other. Dormant ties could disclose more about themselves to find more in common and facilitate future reconnection.

VI. Limitations and Future Work

First, reconnecting 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 [3]. Since we did not conduct a follow-up survey to assess their relationship status after the study, we are unable to determine the long-term effects of reconnection in VR on the dormant-tie dyads' social interactions over time. Based on the current findings, future work could observe the influence of VR on the development of dormant ties in the long run, such as conducting field studies to observe how or how often dormant ties use social VR with their partners or enable them with several options of avatars and VEs to observe how they utilize them during the reconnection process.

Second, our study showed that manipulating avatar-self similarity and virtual environment (VE) familiarity had a significant impact on video-coded behaviors and interview data. However, we did not observe similar significant results in the three subscales of the questionnaire (interaction quality (QoI), presence/immersion (PI), and social meaning (SM)) and conversational results. It is possible that meeting with dormant ties may have provided participants with a positive interaction experience and motivation to engage in the conversation with each other, as indicated by the relatively high questionnaire scores (Fig. 4) and frequent amount of turn-taking (Table VI). The relationship of dormant dyads may also influence the similarity of their conversations, which future studies could take into consideration. Moreover, the existing data we had did not enable us to observe behavioral synchronization among dyads. Previous research suggests that behavioral synchronization is crucial for achieving common ground between remote parties [78], [79], [80], [81]. Future research could further investigate how avatar similarity and VE familiarity affect behavioral synchronization and influence participants' perceptions of social interactions in VR.

VII. Conclusion

This research presented key insights into the two key features of VR, avatar and VE, in rekindling dormant ties. Our study demonstrated that avatar design and VEs of VR significantly influenced the reconnection process among 24 dormant dyads. We found that avatars resembling real-life appearances increased social closeness and comfort, facilitating the re-establishment of connections. Likewise, the choice of VEs impacted the dyadic interactions. Familiar settings evoked shared memories, while novel environments encouraged diverse conversations. Not only do these findings contribute to understanding VR in social contexts, but they also have practical implications for VR platform design that emphasize the importance of personalization in avatars and environment design for social reconnection. This study highlights VR's potential to bridge emotional and physical distances among dormant ties, providing the initial empirical evidence for future research in the field of VR and social relationships.

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