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Full-length Research Article

Virtual placemaking: self-built environments and revisiting shared memories in virtual reality increase group cohesion

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Abstract

Using virtual reality (VR) to revisit the past is a pervasive theme in philosophy, fiction, and futurism. We conducted a longitudinal exploratory study ($N = 136$) investigating how collectively revisiting shared real-world social interactions differs from envisioning plausible interactions in VR, and how experiencing self-built virtual environments or those built by others influences psychological and behavioral outcomes. Participants who revisited, compared to those who envisioned, reported greater increases in group cohesion, as well as higher collective psychological ownership and liking of virtual environments. They also used more first-person plural pronouns and language related to affiliation and social behavior. Participants in self-built virtual environments, compared to those in other-built environments, stood closer to others and reported greater increases in group cohesion and higher collective psychological ownership of the virtual environment. We discuss theoretical advances and practical implications for using VR to revisit memories.

Lay Summary

This study explored how revisiting shared face-to-face social interactions in virtual reality (VR) can influence group closeness. Over four weeks, subjects participated in collaborative face-to-face activities, built virtual environments that replicated physical environments using Generative artificial intelligence and VR, and spent time immersed in the built virtual environments. Results showed that subjects who revisited face-to-face group social interactions reported greater increases in group cohesion and a higher sense of group ownership and liking toward the virtual environments, compared to subjects who envisioned plausible yet hypothetical social interactions. Linguistic differences also emerged, such that those who revisited used more first-person plural pronouns and language affiliated with group identity and consensus. Additionally, subjects who completed the revisiting or envisioning exercise in a virtual environment they built themselves reported greater increases in group cohesion and higher group ownership of the virtual environment they were immersed in, compared to those who completed the exercise in a virtual environment built by others. Overall, these findings suggest that using VR to revisit shared social interactions can alter social dynamics and enhance group cohesion.

Keywords: computer-mediated communication, episodic memory, group cohesion, nonverbal behavior, virtual reality

Picture a group of friends returning to their dorm lounge at their college reunion. The room feels familiar, but not quite the same. The green chalkboard once covered in scribbled notes has been replaced by a spotless whiteboard. The makeshift table they built together during orientation has been displaced by a bookshelf. But then they see it: the old half-stacked Jenga set, remnants of their favorite pastime. Laughter erupts over shared memories, and their emotional bonds feel as strong as ever. Emerging technologies hold the promise of recreating such moments easily and at scale, allowing people to step back into meaningful, detailed places and revisit memories with the very people who co-created them.

One process illustrated in this vignette is place memory, the transformation of neutral *spaces* into personal *places* through memory associations (Othman et al., 2013). A house is just a house until a family fills it with memories and calls it home. This embedding of memories into spaces is central to placemaking, the social process of constructing meaningful places by linking symbolic and functional value to them (Cilliers & Timmermans, 2014). Placemaking emphasizes that places are not found, but built through collective actions. These actions foster a sense of belonging and collective identity (Butterworth, 2000; Cilliers & Timmermans, 2014) and can occur throughout the process of constructing a place, beginning with collaborative planning, and continuing into their implementations with individuals placing objects into shared spaces (Cilliers & Timmermans, 2014). While placemaking research has primarily focused on physical places, the concept also applies to virtual settings. Despite recent technical developments that enable virtual placemaking using virtual reality (VR) and generative artificial intelligence (AI) (Kobenova et al., 2024), empirical research on this topic remains limited.

Another dimension highlighted by the reunion vignette is how shared memories are enriched by the surrounding social and spatial cues. Seeing a once-frequented dorm lounge alongside familiar faces vividly awakens past experiences. This process is informed by situated social cognition, which posits that how we think, feel, and recall is shaped by the spaces we inhabit and the people we inhabit them with (Smith & Semin, 2007). Although this form of memory engagement shares cognitive similarities with other forms of

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mental simulation, such as envisioning future events, their experiential qualities differ (Stephan & Sedikides, 2024). While remembering is rooted in lived experiences rich in sensory and emotional detail, envisioning relies more on generalized knowledge.

VR complicates this distinction by enabling individuals to experience richly detailed environments with high presence and emotional engagement (Lombard & Ditton, 1997; Makransky & Mayer, 2022), regardless of whether the environments are rooted in memory or imagination. This raises an important theoretical question: In VR, does reflecting on experiences rooted in memories offer distinct psychological benefits compared to those based on plausible yet unrealized interactions? This study addresses this question by comparing how revisiting shared memories in VR shapes group experiences differently from envisioning plausible interactions. Here, *revisiting* refers to recalling memories in virtual replicas of the environments where these memories were formed. Over four weeks, participants ($N = 136$) engaged in face-to-face collaborative activities, built virtual replicas of those physical environments, and reentered the virtual environments to either collectively revisit their shared memories or envision plausible interactions. To examine placemaking, we varied whether participants revisited or envisioned in a virtual replica built by themselves or by others. By analyzing how these experiences influence self-reported outcomes and group behaviors, this study advances the theoretical understanding of revisiting shared memories as a socially situated process through placemaking in immersive environments.

Mental time travel as an individual and social process

Mental time travel is linked to the perception of interpersonal relationships and encompasses remembering past experiences and envisioning future ones (Stephan & Sedikides, 2024). One concept relevant to how remembering the past connects to social closeness is "we-ness," defined as a sense of "interdependence, connection, and mutual influence" (Alea et al., 2015, p. 164), and operationalized as the use of first-person plural pronouns during memory reflection. When individuals in marital relationships wrote about relationship-defining events, "we-ness" positively correlated with relationship satisfaction (Alea et al., 2015). The benefits of reflecting on sentimental memories are further illustrated by Jiang et al. (2021), who found that individuals who wrote about nostalgic memories, rather than memories emphasizing rumination or analysis, reported higher intimacy maintenance and social connectedness. When individuals reflect on extraordinary group experiences, compared to ordinary ones, they foster greater group cohesion (Jurewicz et al., 2024). Reflecting on the past with others elicits similar effects. Reminiscing as a couple increased feelings of closeness (Mroz et al., 2022), while sharing autobiographical memories, rather than general ones, yielded greater relationship closeness (Guan & Wang, 2022). These results emphasize that relationships are built through personal memories and that social closeness can be enhanced by priming relationship-focused memories.

While research on how envisioning alters social relationships is relatively nascent, existing works suggest that their effects resemble those of remembering the past. For example, Fowler et al. (2024) found that collectively imagining a shared future across novel dyads fostered greater social connection compared to doing so individually or engaging in shared experiences of puzzle-solving or describing pictures. Adıgüzel et al. (2024) further demonstrated that during the pandemic, thinking about the future led to greater increases in social and emotional regulation functions. These studies highlight how past and future thinking differentially shape social connectedness: while remembering is rooted in memories carrying rich emotional, sensory, and spatial details, envisioning is effective because it allows individuals to construct idealized possible futures and positive self-perceptions (Stephan & Sedikides, 2024).

This difference is especially relevant in social VR, as it provides perceptual experiences to enrich mental time travel. When individuals are immersed in realistic virtual environments with others, spatial and social cues can facilitate recollections of shared pasts (e.g., seeing replicas of meaningful places) or establish common ground that aligns envisioned futures. The theory of situated social cognition contextualizes these possibilities by positing that social cognition is shaped by both the physical environment and the social agents within it (Smith & Semin, 2007). It notes that social-cognitive representations are constructed in context rather than retrieved as fixed entities, suggesting that VR can function as an environmental scaffold for reconstructing memory traces in more vivid and socially-anchored ways. The theory also argues that communicative contexts regulate what is foregrounded in recall, meaning that the presence of other VR users during mental time travel can shape how memories are articulated and synchronized. Finally, the theory emphasizes that cognition is socially distributed across interaction partners, implying that joint engagement in VR can reinforce a collaborative representation of their shared experiences. Situated social cognition, therefore, invites a reexamination of how mental time travel occurs in VR. Grounded in past research highlighting how remembering the past and envisioning the future strengthen interpersonal relationships, this study investigates how collective *revisiting* (i.e., spatially-anchored remembering) and envisioning differentially foster social closeness in VR.

RQ1a. How do collectively revisiting shared memory and envisioning plausible social interactions in VR differ in their effects on group cohesion?

Revisiting the past through immersive environments

Scholars have built systems for reconstructing face-to-face and virtual scenes to allow for revisiting hypothetical virtual scenarios, engaging with social interactions they missed, and reexperiencing memories. Technical systems that enable individuals to repeatedly revisit past virtual scenarios shaped opinions on topics such as moral dilemmas (Friedman et al., 2014) and vaccine efficacy (Lee et al., 2023), while those that allow individuals to engage with interactions they missed can alter workplace interactions (Fender & Holz, 2022) and social attention (Wang et al., 2024).

Most relevant to our research are works on reexperiencing memories. Wang et al. (2020) compared dyads reliving past virtual gameplay in VR to co-watching 360-degree videos and found that participants who relived reported greater immersion, social presence, and stronger understandings of their past experience. Moreover, Danry et al. (2025) introduced a system that allowed individual users to navigate immersive environments

constructed from video recordings. They found that these experiences, compared to directly watching the videos, yielded greater memory vividness, emotional intensity, and a sense of traveling back in time. These studies suggest that engaging with memories immersively enhances virtual experiences and understanding of memories.

The present work extends these works in several ways. First, we move beyond media comparison and focus on psychological mechanisms impacting immersive experiences, such as placemaking and mental time travel. We achieved this through a longitudinal method of having groups create physical environments, build replicas of them in VR, and finally revisit them in VR. Another contribution is our examination of revisiting and envisioning across group sizes, which contrasts with studies with singular users or dyads (Danry et al., 2025; Wang et al., 2020). This variation is important to consider empirically, as collective remembering occurs across a range of group sizes in everyday life, from intimate gatherings to large reunions. Although sociologists and memory scholars have studied remembering in large groups, most empirical works have focused on objective recall of memories (Barber et al., 2012; Harris et al., 2008). We build on this foundation by analyzing the psychological and behavioral effects of revisiting memories in groups of various sizes.

The psychological effects of physical and virtual context

Ellery and Ellery (2019) posit that placemaking elicits psychological benefits through community involvement: collaboratively shaping a space's role and features enhances wellbeing and fosters personal and collective identities, and a sense of belonging to physical locations (Butterworth, 2000; Cilliers & Timmermans, 2014). Placemaking also develops social capital by engendering an "optimistic and positive experience that engages thoughtfulness and feelings and supports personal growth" (Corcoran et al., 2018, p. 13). While much research has focused on physical places, less is known about the psychological implications of immersive placemaking. For one, VR and physical-world interactions are similar, as virtual environments elicit realistic responses and strong presence (Makransky & Mayer, 2022; Maloney et al., 2020). Virtual environments are also increasingly realistic and personalizable, due to the rise of generative AI and networked platforms. This capability also differentiates the two, as co-creating places in VR requires less technical expertise and resources compared to doing so in the physical world. VR holds the promise of facilitating placemaking more easily and at scale, yet its effects on the perception of environments and social others remain underexplored.

One mechanism that could inform this relationship is psychological ownership. Defined as "the possessive feeling that some object is mine or ours" (Van Dyne & Pierce, 2004, p. 439), psychological ownership is enhanced through increasing control, knowledge, and personal investment toward the object (Van Dyne & Pierce, 2004). This sense of ownership and one's bond to their environment are positively associated with contribution quality (Lee & Suh, 2015) and one's sense of community and psychological comfort (Scannell & Gifford, 2017). We therefore propose that placemaking in VR, an activity that increases control and investment in one's virtual environment, may serve as a pathway to psychological ownership of virtual environments, in turn shaping social outcomes such as group cohesion.

The present study investigates these relationships by having participants build virtual environments and varying whether participants were later immersed in the replica built by themselves (i.e., self-built) or another group (i.e., other-built). This allowed us to investigate how placemaking influences group cohesion and psychological ownership in VR.

RQ1b. During the VR revisiting or envisioning exercise, how does being in a self-built versus other-built virtual replica affect group cohesion differently?

RQ2a–b. How do individuals revisiting and envisioning in VR differ in their psychological ownership of the virtual environment (a)? Furthermore, how does being in self-built versus other-built virtual environments influence these measures (b)?

To complement our exploration of psychological ownership, we considered liking of spatial environments as an affective measure that may explain how immersive experiences shape group cohesion and social dynamics. The mere exposure effect offers a useful lens here, positing that repeated exposure to stimuli elicits stronger memories and higher familiarity, which in turn increases liking (Zajonc, 2001). Research revealed that individuals prefer familiar locations and regions, often reporting higher positive affect when in known environments (Mangone et al., 2021; Oishi et al., 2011). Drawing from these works, we make the following hypotheses regarding how familiarity established through shared memory and placemaking shapes individuals' evaluation of spatial environments[1]:

H1a–b. Individuals who experienced virtual replicas of previously shared physical environments will report greater liking for both the virtual replica (a) and the corresponding physical environment (b) compared to those who experienced virtual replicas of unfamiliar environments.

H2a–b. Individuals immersed in self-built virtual environments will report greater virtual environment liking than those in other-built environments (a). This higher familiarity of virtual replicas that are self-built rather than other-built will also enhance liking for the original physical environment (b).

In contrast, there is less evidence on how repeated exposure to virtual replicas of physical environments influences sentiments toward the memories associated with the replicated physical environments, which is reflected below:

RQ3. How does interacting with a virtual replica of a previously shared physical environment in VR influence liking toward the shared memory?

Psychological interpretations of nonverbal and verbal behavior in VR

Researchers have leveraged behavioral data in VR to understand social and psychological processes based on our understanding of face-to-face interactions (Wang & Bailenson, 2024).

Two widely studied nonverbal behaviors are interpersonal distance and gaze. Interpersonal distance reflects social context and group membership in face-to-face settings (Hall, 1966; Wei et al., 2024) and is used to interpret immersive social dynamics (Kim & Sung, 2024). Gaze is associated with social closeness and attention in non-immersive settings (Cui et al., 2019) and is similarly used in VR contexts (Kim & Lee, 2025; Miller et al., 2023). It is worth noting that nonverbal behaviors are particularly well-suited for studying social contexts beyond dyads. For example, eye contact tends to be high during dyadic interactions, but can become more variable in larger groups and signal attention and coordination in complex social settings.

Language also reflects psychological processes underlying social dynamics. Particularly, first-person plural pronouns are associated with "we-ness" and one's focus on joint identity (Alea et al., 2015; Horn & Meier, 2022), while affiliation-associated words signal group identity and feelings of connectedness (Ashokkumar & Pennebaker, 2022). First-person pronoun usage is further positively associated with social and spatial presence in VR (DeVeaux et al., 2024). The number of words spoken reflects effort and investments in social relationships (Huang & Hancock, 2022). As verbal and nonverbal behaviors can reveal psychological states, we analyze how they manifest across revisiting and envisioning experiences.

RQ4a–b. How do individuals collectively revisiting and envisioning in VR differ in their nonverbal and verbal behavior (a)? How does being immersed in self-built virtual environments, compared to other-built environments, influence nonverbal and verbal behavior (b)?

Methods

To examine the hypotheses and explore the research questions, a 2 (activity type: revisit vs. envision) x 2 (environment type: self-built vs. other-built) between-subjects randomized controlled experiment was conducted. We use *environment* to refer to spatial contexts, as it is unclear whether participants experienced their surroundings as meaningful places or merely as spaces. Participants were first organized into groups to collaborate on face-to-face activities. Groups were then divided into subgroups that either revisited their face-to-face memory in a virtual replica of the original physical environment or envisioned plausible interactions in a virtual replica of an unfamiliar physical environment. Virtual environments were either built by the participants themselves or by another subgroup. We analyzed how these factors influenced self-report responses and behaviors.

Participants

We recruited participants through a university course about VR. The study was approved by the university's Institutional Review Board. To ensure students received the same pedagogical experience, the teaching staff and researchers were blind to the consenting status until the completion of the course. A total of 177 students participated in the real-world activities, of whom 161 consented. We dropped individuals who were not present at all subsequent activities, or if the group activity was completed by only one participant, resulting in a sample size of 136. The dropout ratio and procedure for excluding participants are comparable to other longitudinal VR studies (Han et al., 2023; Khojasteh & Won, 2021).

Participants (F = 68, M = 64, non-binary/third gender = 2, decline to answer = 2) were of age 18 to 32 [mean (M) = 20.78, standard deviation (SD) = 1.83] and self-identified as Asian or Asian-American ($N = 56$), Caucasian ($N = 37$), Hispanic or Latinx ($N = 10$), African, African-American, or Black ($N = 9$), Middle Eastern ($N = 4$), Hawaiian or other Pacific Island ($N = 1$), multiracial ($N = 17$), or declined to disclose their ethnicity ($N = 2$). Participants varied in prior XR experiences (no experience = 24, one to two times = 57, three to five times = 25, at least six times = 30) and design experiences (no experience = 76, under a year = 33, one to three years = 19, over three years = 8).

After accounting for participants' availabilities, we randomly assigned participants to groups of 13 to 19. Those who missed the real-world activities were excluded from subsequent procedures, resulting in group sizes between seven and 18 (M = 12.92, SD = 3.58). The study employed a 2 × 2 between-subjects design, so groups were randomly split into four subgroups of roughly equal size.[2] Assigning different conditions to participants within the same group prevented confounding face-to-face activity with conditions and enhanced engagement during VR activities with smaller groups. The final subgroup size ranged between two to seven (M = 3.68, SD = 1.34). A researcher not part of the teaching or research team performed group assignments based on participant availability and consent status.

Study setup and equipment

For creating virtual environments, participants used MeshyAI's text-to-3D tool to generate 3D models. For VR activities, participants used Meta Quest 2 headsets and hand-held controllers. We used ENGAGE, a social VR platform, to facilitate immersive experiences and allowed participants to smoothly translate (i.e., continuous movement using joysticks) and teleport (i.e., instant movement using controllers) within virtual environments. We recorded the VR sessions using ENGAGE's recording tool.

Conditions

The study follows a 2 × 2 between-subjects design (Figure 1).[3] The first independent variable is activity type. In the revisit condition (**RE**), participants collectively recalled their shared face-to-face activity in a virtual replica of the physical environment they shared during the group activity. In the envision condition (**EN**), participants envisioned plausible group activities that could occur with their entire group in the physical environment represented by a virtual replica that the group did not share physically.

The second independent variable is environment type. In the self-built condition (**S**), during revisiting or envisioning, participants are placed in virtual replicas they built previously. In the other-built condition (**O**), participants are placed in virtual replicas built by another subgroup. Specifically, subgroups **RE-O** and **EN-O** are immersed in replicas built by subgroups **RE-S** and **EN-S** from the same group, respectively.

Procedure

Pre-study and face-to-face activity

Participants first completed a pre-study questionnaire on demographics and individual differences (Figure 2A). In week one, participants gathered with their groups in a large indoor

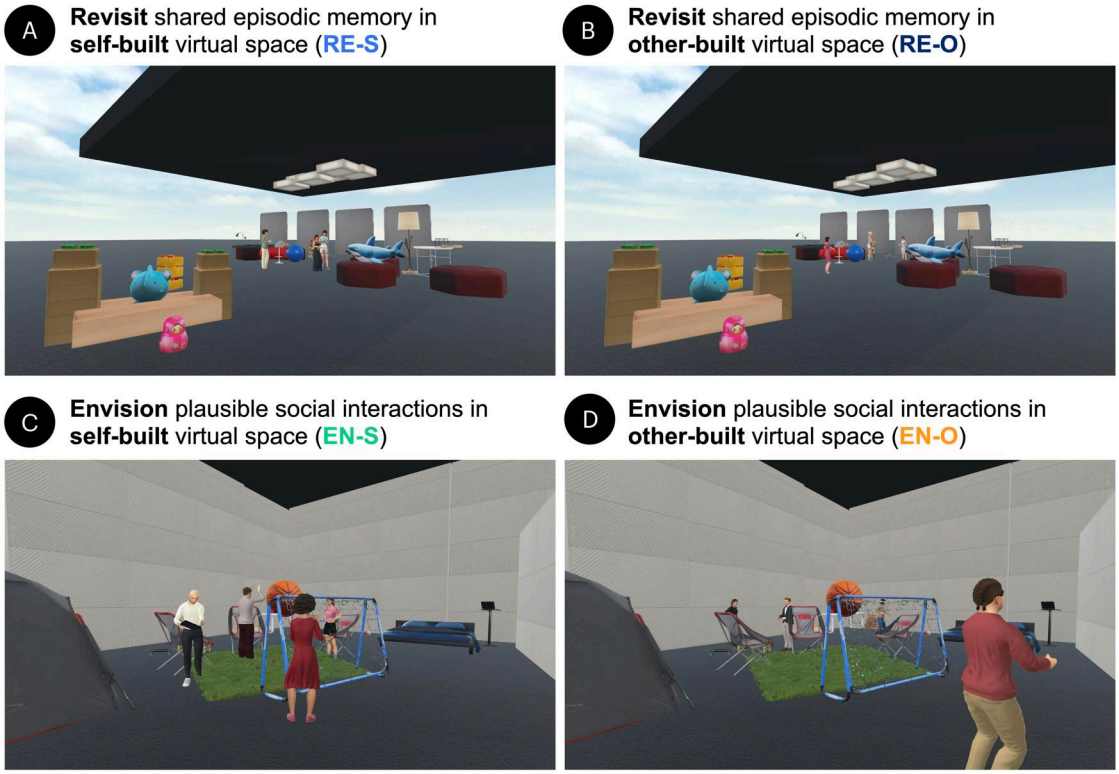

Figure 1. ENGAGE screenshots of the revisiting and envisioning exercise. Subfigures show subgroups from the same face-to-face activity group across conditions. This group built a relaxation space face-to-face. RE-S revisited the virtual replica they built of their shared physical space, while RE-O revisited the same space built by RE-S. EN-S was immersed in the virtual replica they built of a physical space they did not share physically, while EN-O was placed in the same space built by EN-S.

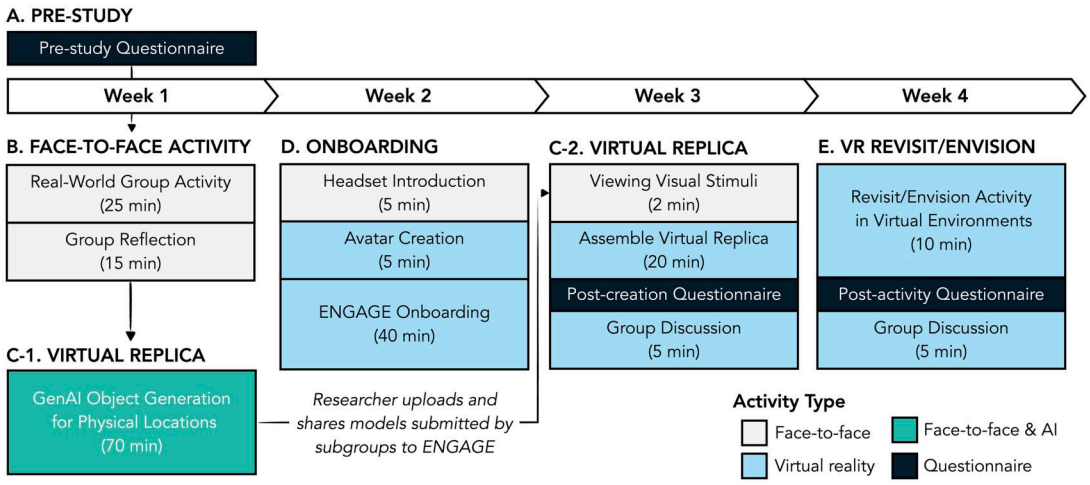

Figure 2. Study procedure overview.

event space (10 m × 7 m) and completed a 40-minute group activity, building either a recreation or relaxation space from around 25 objects (Figure 2B), which was counterbalanced across groups. There was no overlap in objects between the two spaces. Objects and room configuration are detailed in the online supplementary material. For the activity, each group spent five minutes discussing what recreation or relaxation spaces mean to them, 10 minutes building the space using the objects provided, 10 minutes interacting with the space, and 15 minutes reflecting on their shared experience. A 360-degree photo of the built environment was captured (Figure 3) and used as a guide when later constructing virtual replicas.

We formulated this space-building activity because it brings together several central elements of placemaking and mental time travel. First, it helps participants form memory associations with their spatial environment, which is key to altering how environments are perceived through placemaking (Othman et al., 2013). This allows us to generate socially meaningful environments shaped by shared group

Figure 3. Built physical environments examples. Image insets show 360-degree photos with rectangular overlays indicating the zoomed-in regions. The top environment in Panel A is built by the group shown in Figures 2 and 4. The top environment in Panel B is used by the subgroups assigned to virtually replicate a physical environment not shared by their group, referenced in Figure 4.

experiences experimentally. Additionally, the activity necessitates communication and collaboration, marking also the beginning of the group's relationship. As suggested by research on mental time travel, these relationship-defining interactions are especially relevant for changing how participants view their group when revisiting shared memories. With this activity serving as the foundation for later exercises, participants who revisit are not simply returning to a generic environment, but a place they built together during their first group interaction.

Onboarding

In week two (Figure 2D), participants completed an onboarding session of ENGAGE. After hardware introduction, participants spent five minutes creating an avatar that looked and felt like them (Wang et al., 2024), which they embodied throughout the study. Participants used the platform's avatar creation tool, which allowed them to customize avatars by toggling between physical traits (e.g., hairstyle) and outfits (e.g., accessories). Finally, participants spent 40 minutes learning the software (e.g., virtual locomotion, creating and manipulating objects).

Building virtual replicas

Figure 4 shows the procedure overview for building virtual replicas. Following the face-to-face activities, each group was divided into four subgroups (Figure 4A). Half of the group (i.e., subgroups who will revisit memories) was assigned to recreate the physical environment they shared during the face-to-face activity. The remaining half (i.e., subgroups who will envision plausible interactions) was assigned to recreate a physical environment shared by another group. To ensure that the envisioning half do not unintentionally revisit their shared face-to-face memories, they recreated physical environments built by groups assigned to a different face-to-face activity.

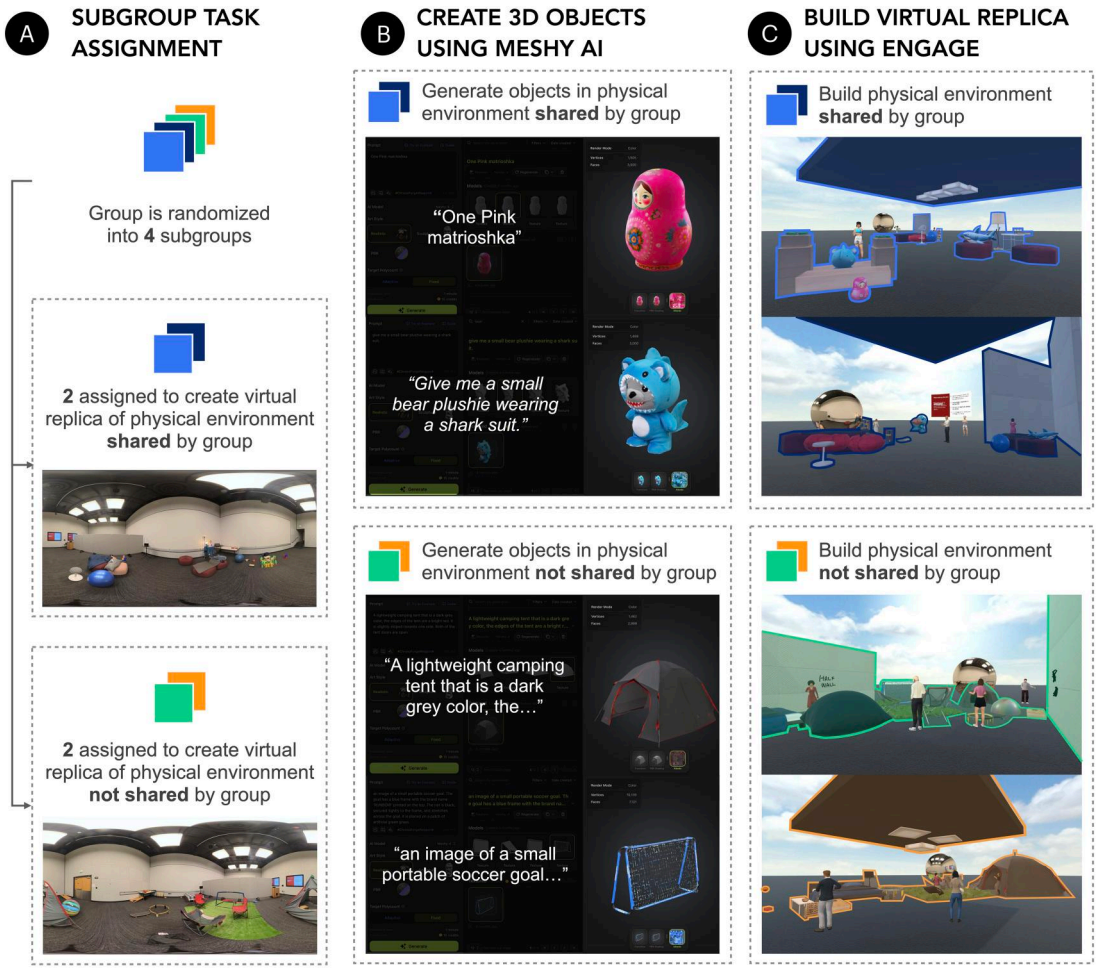

Figure 4. Overview of procedure for building virtual replicas. Panel A shows task assignment. Panel B shows objects generated using MeshyAI, with prompts overlaid on screenshots. Panel C shows built virtual replicas, with participant-created objects highlighted with colored lines. The group and subgroups are the same as in Figure 1: the top two screenshots in Panel C show the building process of subgroups RE-S (Figure 1A) and RE-O (Figure 1B), and the bottom two screenshots show that of subgroups EN-S (Figure 1C) and EN-O (Figure 1D), respectively.

Following subgroup formation, individuals worked with their subgroups in a workshop to generate 3D objects using Meshy AI's text-to-3D tool (Figure 2C-1). During the workshop, a researcher demoed the tool and provided subgroups with links to interactive 360-degree photos of the physical environments they were assigned to recreate. Due to logistical constraints, the two subgroups from each group that were assigned to recreate the same physical environment created and shared the same set of 3D objects. Subgroups spent 70 minutes creating 3D models and were asked to upload 20 models to a shared folder (Figure 4B). In practice, subgroups submitted between 18 and 25 objects ($M = 21.71$, $SD = 1.60$), which a researcher uploaded to ENGAGE and shared with subgroup members.

In week three, participants gathered with their subgroups to build virtual replicas (Figure 2C-2). After spending two minutes observing the target 360-degree photo on non-immersive devices, participants joined an ENGAGE session instantiated as an empty creator space, where the 360-degree photo was imported as a virtual sphere (see Figure 4C for examples of spheres). Each subgroup spent 20 minutes collaboratively creating the virtual replica. Participants were allowed to import and manipulate 3D objects from their submitted models and the platform library and draw using 3D pens (Figure 4C). Participants then exited VR to complete the post-creation questionnaire, which served as baseline measures (henceforth referenced as pre-activity). Finally, participants returned to VR and completed a five-minute class-related discussion in a virtual gathering room.

VR revisit or envision exercise

In week four, subgroups completed the revisiting or envisioning exercise (Figure 2E). Each subgroup joined their ENGAGE session, instantiated with the appropriate virtual replica, and spent three minutes discussing any observations they had of the replica. Then, participants were instructed to spend seven minutes either collectively revisiting their shared memory or envisioning plausible social interactions. We adopted instructions from the co-imagining script from Fowler et al. (2024) and presented them in the online supplementary material. We modeled activity durations based on past works (Jiang et al., 2021; Mroz et al., 2022) and adjusted for larger groups with longer durations. Following this, participants exited VR and completed the post-activity questionnaire (henceforth referenced as post-activity). Finally, participants returned to VR and completed a five-minute class-related discussion in the same gathering room from week three. These discussions enabled us to explore

whether changes in social dynamics persisted from revisiting and envisioning into subsequent interactions.

Measures

Self-report measures

Demographics

The pre-study questionnaire collected information on gender, age, previous XR, and design experiences, and vividness of visual imagery. Vividness of visual imagery assesses one's mental ability to visualize hypothetical scenarios and can signal how well individuals conjure up memory details (Marks, 1995).

Group entitativity

To capture group cohesion, the tendency for groups to remain together and united toward common goals (Carron & Spink, 1995), we employed two complementary measures. The first is entitativity, which captures the level of common intentions and behaviors toward shared goals (Hamilton et al., 2002). Participants rated entitativity toward their subgroups using an 8-item construct adapted for classroom VR (Han et al., 2023). Sample items include "How motivated are members of your group to achieve its goals?" and "How strongly bonded do you think the members of your group are?" Items were rated on a 7-point Likert scale (1 = *Strongly disagree*, 7 = *Strongly agree*). The items had high reliability (α =0.88), so were averaged into a composite score. To account for existing relationships, we collected measurements pre- and post-activity.

Inclusion of other in the self

The second measure of group cohesion, inclusion of other in the self (IOS), reflects the subjective relationship closeness (Gächter et al., 2015). Following Aron et al. (1992), participants reported their level of self-other overlap with their subgroup by selecting from seven drawings depicting increasingly overlapping circles (1 = *non-overlapping*, 7 = *almost fully overlapping*). We measured IOS pre- and post-activity.

Psychological ownership

Participants reported psychological ownership of the virtual environment used for revisiting or envisioning. We measured both collective ("the environment is ours") and individual psychological ownership ("the environment is mine"). Collective psychological ownership was included as it signals one's identification with their social group. Conversely, individual psychological ownership offers a meaningful lens for examining how placemaking may differentially influence individuals' connection to the space versus their sense of shared ownership (Pierce & Jussila, 2010). Individual psychological ownership was measured using a 4-item, 5-point Likert scale (1 = *Not at all*, 5 = *Extremely*) (Dyne & Pierce, 2004). Collective psychological ownership items are generated through swapping possessive pronouns (e.g., "my" to "our") (Wang et al., 2023). Constructs had high reliability (collective: α =0.87; individual: α =0.75), so were averaged into composite scores. Measures were collected post-activity.

Liking

Participants rated their liking toward their face-to-face group experience, the original physical environment, and virtual environment during revisiting or envisioning. Following Mrkva and Boven (2020), liking was measured using a single-item 7-point Likert scale (−3 = *Dislike*, 0 = *Neutral*, 3 = *Like*). We measured liking post-activity.

Nonverbal behavior

We collected nonverbal behaviors using ENGAGE's recording features. The recordings captured the position (i.e., x, y, z) and rotation (i.e., pitch, yaw, roll) of headsets and controllers at 30Hz, from which we extracted three behavioral measures. We analyzed these measures because they can be automatically extracted to study social dynamics in VR (Kim & Sung, 2024; Miller et al., 2023). Specifically, interpersonal distance reflects social context, while gaze signals social attention and connection (Cui et al., 2019; Miller et al., 2023).

Interpersonal distance

We calculated the pairwise distance in meters between each user pair (Miller et al., 2023). Since virtual locomotion (e.g., teleportation, users joining and spawning in the same locations) can result in users standing unintentionally close to others, we computed the *n*th smallest distance for each user pair. Like Miller et al. (2023), we chose $N = 150$, effectively dropping five seconds of tracked motion.

Direct and mutual gaze

We defined direct gaze as moments when a user's head orientation is within 15-degree pitch and yaw of at least one other user's head position (Miller et al., 2023) and mutual gaze as those when two users are engaging in direct gaze with each other. We report gaze as the percentage of time users maintain direct and mutual gaze in VR. We downsampled the raw data to 3Hz to reduce the computational load.

Verbal behavior

We collected verbal behavior during revisiting and envisioning. We extracted MP3 files from the recordings and generated initial transcripts using Otter.ai. A researcher cleaned and created speaker labels by replaying the ENGAGE recordings. Transcripts with fewer than 25 words were excluded (DeVeaux et al., 2024). We processed the transcripts using Linguistic Inquiry and Word Count (LIWC) (Tausczik & Pennebaker, 2010), which calculated feature scores as percentages of total words matching a given category (e.g., counting "I" and "me" for first-person singular pronoun). We examined scores for *first-person pronoun* and *affiliation-related* language to study group identity (Ashokkumar & Pennebaker, 2022; Horn & Meier, 2022) and presence (DeVeaux et al., 2024).[4] To understand how individuals reference social behaviors and thinking processes, we extracted *social behavior* scores, which capture language associated with communication and interpersonal dynamics (Boyd et al., 2022). *Word count* was used to assess exercise investment and self-disclosure (Huang & Hancock, 2022). Language related to *memory* (e.g., "remember") was analyzed as a manipulation check for activity type.

Data analysis

We built repeated-measure mixed-effects models to account for baseline differences in group cohesion and linear mixed-effects models for the remaining measures. Across all models, we modeled activity type and environment type as fixed effects. Subgroup size was included as a control variable as it significantly predicted a considerable number of outcome variables. Other variables were initially included (e.g., face-to-face activity) but were dropped since none significantly predicted a considerable number of outcomes. We tested interactions and omitted them in the final models as none

were significant. We set pre-activity measures, envision, and other-built environments as reference levels. All models were built using R's lme package, with significance evaluated at $\alpha = .05$. We report significant post-hoc contrasts, adjusting for multiple hypothesis testing using Tukey's method.

For group cohesion, we built repeated-measure mixed-effect models using pre- and post-activity measurements. The individual outcome for student i in group g at time t was modeled as

$$outcome_{tgi} = \beta_{0gi} + \beta_{1gi}(time_{tgi}) + e_{tgi}$$

where $outcome_{tgi}$ is modeled as a function of a person-specific intercept, β_{0gi}, a person-specific slope, β_{1gi}, and residual error, e_{tgi}. The person-specific intercepts and slopes are modeled as

$$\beta_{0gi} = \beta_{00} + \beta_{10}(activity\ type_{gi}) + \beta_{20}(environment\ type_{gi}) + \beta_{30}(subgroup\ size_{gi}) + v_{0g0} + u_{0gi}$$

$$\beta_{1gi} = \beta_{01} + \beta_{11}(activity\ type_{gi}) + \beta_{21}(environment\ type_{gi}) + \beta_{31}(subgroup\ size_{gi}) + v_{1g0} + u_{1gi}$$

where β_{00}, β_{10}, β_{20} and β_{30} describe the prototypical individual's initial value; the interaction terms of β_{11}, β_{21}, and β_{31} represent how activity type, environment type, and subgroup sizes influence the changes in outcomes after the exercise. Random effects v_{0g0}, u_{0gi}, v_{1g0}, and u_{1gi} are residual unexplained differences assumed to be multivariate normal.

For other individual- or dyadic-level measures, we built linear mixed-effects models. We log-transformed nonverbal data, as most models violated normality assumptions. We added an initial offset of 0.1% to mutual gaze to avoid undefined values. We log-transformed the memory scores as the original model violated normality assumptions and added a 0.1 offset to avoid log-transforming zeros.

Results

Manipulation check for activity type

Participants who revisited scored higher on memory scores than those who envisioned ($\beta = 1.21$, standard error [SE] $= 0.17$, $p < .001$). Those in larger subgroups exhibited lower scores ($\beta = -0.19$, $SE = 0.065$, $p = .0044$), while environment type was nonsignificant ($\beta = 0.13$, $SE = 0.17$, $p = .44$). There were significant contrasts between **EN-O** and **RE-O** ($\beta = 1.29$, $SE = 0.26$, $p < .001$), **EN-O** and **RE-S** ($\beta = 1.35$, $SE = 0.24$, $p < .001$), **EN-S** and **RE-O** ($\beta = 1.08$, $SE = 0.25$, $p < .001$), and **EN-S** and **RE-S** ($\beta = 1.14$, $SE = 0.23$, $p < .001$), with **RE** scoring higher than **EN**. This confirms that activity type was successfully manipulated.

Group cohesion

We analyzed group entitativity and IOS (**RQ1a–b**). Figure 5 visualizes model parameters, and Table 1 presents summary statistics.

Group entitativity

The prototypical individual had a starting group entitativity of 2.56 ($SE = 0.22$, $p < .001$) and grew for a nonsignificant amount of 0.028 ($SE = 0.15$, $p = .85$). Larger subgroups began with higher levels than smaller ones ($\beta = 0.12$, $SE = 0.046$, $p = .012$). Those who revisited reported nonsignificant lower initial values than those who envisioned ($\beta = -0.049$, $SE = 0.11$, $p = .67$). Those in self-built environments reported nonsignificant lower entitativity than those in other-built environments ($\beta = -0.0063$, $SE = 0.11$, $p = .96$).

More importantly, answering **RQ1a**, participants who revisited reported greater increases in entitativity than those who envisioned ($\beta = 0.23$, $SE = 0.080$, $p = .0041$). Addressing **RQ1b**, those in self-built environments reported greater increases than those in other-built environments ($\beta = 0.17$, $SE = 0.080$, $p = .035$). The interaction between time and subgroup size was nonsignificant ($\beta = -0.043$, $SE = 0.031$, $p = .16$).

Inclusion of the other in the self

The prototypical individual had a starting IOS of 2.95 ($SE = 0.49$, $p < .001$) and grew for a nonsignificant amount of 0.085 ($SE = 0.31$; $p = .78$). Larger groups reported higher initial starting values ($\beta = 0.25$, $SE = 0.10$, $p = .018$). Participants who revisited reported nonsignificant lower pre-activity values than those who envisioned ($\beta = -0.40$, $SE = 0.26$, $p = .12$). Those in self-built environments reported nonsignificant lower initial values than those in other-built environments ($\beta = -0.048$, $SE = 0.26$, $p = .085$).

Continuing with **RQ1a**, participants who revisited reported higher increases in IOS than those who envisioned ($\beta = 0.43$, $SE = 0.17$, $p = .012$). With respect to **RQ1b**, those in self-built environments yielded higher increases in IOS than those in other-built environments ($\beta = 0.38$, $SE = 0.17$, $p = .025$). The interaction between time and subgroup size was nonsignificant ($\beta = -0.035$, $SE = 0.065$, $p = .059$).

Psychological ownership

Figure 6 summarizes our psychological ownership findings (**RQ2a–b**). For individual psychological ownership, and to address **RQ2a**, activity type was nonsignificant ($\beta = 0.27$, $SE = 0.15$, $p = .067$). Concerning **RQ2b**, participants in self-built environments reported higher values than those in other-built environments ($\beta = 0.63$, $SE = 0.15$, $p < .001$). Subgroup size ($\beta = -0.019$, $SE = 0.058$, $p = .74$) was nonsignificant. There were significant differences between **EN-O** and **RE-S** ($\beta = 0.89$, $SE = 0.21$, $p < .001$), **EN-O** and **EN-S** ($\beta = 0.59$, $SE = 0.22$, $p = .037$), and **RE-O** and **RE-S** ($\beta = 0.66$, $SE = 0.20$, $p = .0070$), with **RE-S** and **EN-S** yielding higher values.

For collective psychological ownership, participants who revisited reported higher values than those who envisioned ($\beta = 0.37$, $SE = 0.15$, $p = .016$) (**RQ2a**), while those in self-built environments reported higher values than those in other-built environments ($\beta = 0.64$, $SE = 0.15$, $p < .001$) (**RQ2b**). Subgroup size was nonsignificant ($\beta = -0.046$, $SE = 0.062$, $p = .46$). There were significant contrasts between **EN-O** and **RE-S** ($\beta = 1.02$, $SE = 0.22$, $p < .001$), **EN-O** and **EN-S** ($\beta = 0.71$, $SE = 0.22$, $p = .0098$), and **RE-O** and **RE-S** ($\beta = 0.58$, $SE = 0.21$, $p = .031$), with participants in self-built environments reporting higher values.

Liking

Figure 7 summarizes findings on liking toward the virtual environment (**H1a, H2a**), physical environment (**H1b, H2b**), and face-to-face experience (**RQ3**). For virtual environment liking, participants who revisited reported higher liking than

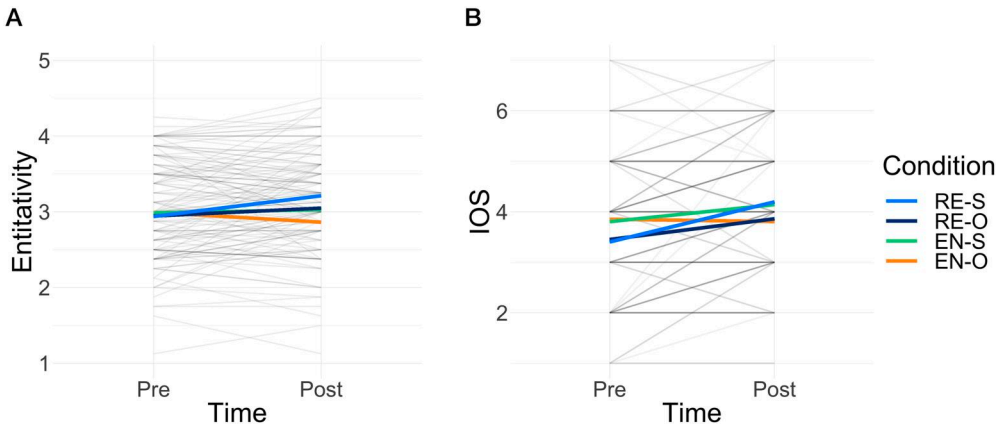

Figure 5. Self-report group cohesion. Individual changes over time are indicated by gray lines. Model-implied trajectories are overlaid using thicker colored lines, with subgroup size set to sample mean.

Table 1. Summary statistics of group cohesion measures.

Measure	Condition	Pre-activity	Post-activity
Entitativity	RE-S	3.08 (0.69)	3.31 (0.65)
	RE-O	3.04 (0.68)	3.11 (0.67)
	EN-S	3.02 (0.60)	3.02 (0.58)
	EN-O	3.04 (0.64)	2.90 (0.72)
IOS	RE-S	3.64 (1.40)	4.46 (1.30)
	RE-O	3.59 (1.48)	3.84 (1.48)
	EN-S	3.84 (1.67)	4.03 (1.38)
	EN-O	3.96 (1.53)	4.04 (1.53)

We report averages and standard deviations in parentheses.

those who envisioned ($\beta = 0.88$, $SE = 0.23$, $p < .001$), supporting **H1a**. **H2a** is not supported, as environment type did not significantly predict virtual environment liking ($\beta = 0.30$, $SE = 0.23$, $p = .20$). Subgroup size was nonsignificant in predicting virtual environment liking ($\beta = -0.13$, $SE = 0.095$, $p = .19$). There were significant contrasts between **EN-S** and **RE-S** ($\beta = 1.07$, $SE = 0.31$, $p = .0043$), and **EN-O** and **RE-S** ($\beta = 1.14$, $SE = 0.33$, $p = .0045$), with **RE-S** reporting higher values.′

Activity type was nonsignificant in predicting liking toward the face-to-face experience ($\beta = 0.17$, $SE = 0.18$, $p = .45$) and physical environment ($\beta = 0.048$, $SE = 0.19$, $p = .80$). Participants in self-built and other-built environments showed no significant difference in liking toward the face-to-face experience ($\beta = 0.011$, $SE = 0.18$, $p = .95$) and physical environment ($\beta = -0.043$, $SE = 0.19$, $p = .82$). **H1b** and **H2b** are not supported. Subgroup size was nonsignificant in predicting liking toward the virtual environment ($\beta = -0.13$, $SE = 0.95$, $p = .63$), face-to-face experience ($\beta = 0.055$, $SE = 0.073$, $p = .45$), and physical environment ($\beta = 0.052$, $SE = 0.075$, $p = .49$).

Nonverbal behavior

We analyzed nonverbal behavior during the main exercise and class-related discussion (**RQ4a–b**). Table 2 presents summary statistics.

Interpersonal distance

During revisiting and envisioning, activity type marginally predicted interpersonal distance ($\beta = -0.16$, $SE = 0.096$, $p = .095$) (**RQ4a**). Participant pairs in self-built environments

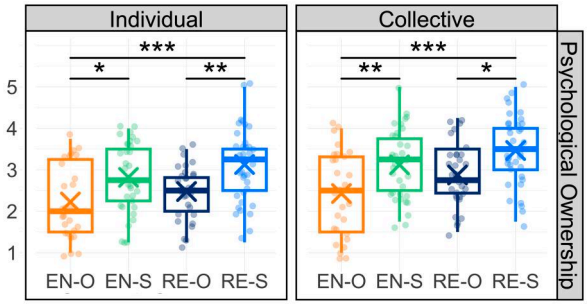

Figure 6. Individual and collective psychological ownership of virtual environments. Significant contrasts are shown (*$p \leq .05$, **$p \leq .01$, ***$p \leq .001$).

stood closer than those in other-built environments ($\beta = -0.19$, $SE = 0.094$, $p = .045$) (**RQ4b**). Subgroup size was nonsignificant ($\beta = -0.036$, $SE = 0.043$, $p = .41$). Post-hoc analysis showed no significant contrasts. For class-related discussions, activity type ($\beta = 0.13$, $SE = 0.13$, $p = 0.31$) and environment type($\beta = -0.047$, $SE = 0.12$, $p = 0.70$) were nonsignificant (**RQ4a-b**). Subgroup size was nonsignificant ($\beta = 0.090$, $SE = 0.059$, $p = 0.13$).

Direct and mutual gaze

Further addressing **RQ4a–b**, we found no main effect of activity ($\beta = 0.079$, $SE = 0.069$, $p = .26$) and environment type ($\beta = -0.011$, $SE = 0.070$, $p = .88$) for direct gaze during revisiting and envisioning. Activity ($\beta = -0.011$, $SE = 0.097$, $p = .91$) and environment type ($\beta = -0.028$, $SE = 0.098$, $p = .78$) were nonsignificant in predicting direct gaze during class-related discussions. The control variable of subgroup size significantly predicted direct gaze during revisiting and envisioning ($\beta = 0.20$, $SE = 0.026$, $p < .001$) and the discussion afterward ($\beta = 0.14$, $SE = 0.039$, $p < .001$).

Subgroup size significantly predicted mutual gaze during revisiting and envisioning ($\beta = 0.32$, $SE = 0.046$, $p < .001$), while the manipulated variables of activity type ($\beta = 0.15$, $SE = 0.12$, $p = .22$) and environment type ($\beta = 0.0048$, $SE = 0.12$, $p = .97$) did not. For class-related discussions, subgroup size was significant ($\beta = 0.13$, $SE = 0.061$, $p = .037$)

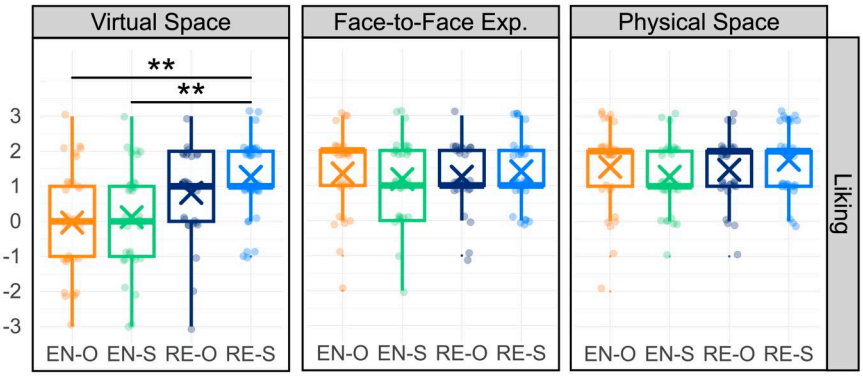

Figure 7. Liking toward the physical environment, face-to-face experience, and virtual environment. Significant contrasts are shown (*$p \leq .05$, **$p \leq .01$, ***$p \leq .001$).

while activity type ($\beta = -0.12$, $SE = 0.15$, $p = .43$) and environment type ($\beta = -0.12$, $SE = 0.15$, $p = .41$) were not.

Verbal behavior

First-person pronouns

We analyzed verbal behavior during revisiting and envisioning to continue examining **RQ4a–b** (Figures 8 and 9). For first-person singular pronouns, participants in self-built environments scored higher than those in other-built ones ($\beta = 0.97$, $SE = 0.38$, $p = .011$). There was a marginal effect of activity type ($\beta = 0.72$, $SE = 0.38$, $p = .058$) and a main effect of subgroup size as a control variable ($\beta = -0.44$, $SE = 0.15$, $p = .0043$). Participants in **EN-O** exhibited lower scores than those in **RE-S** ($\beta = 1.75$, $SE = 0.54$, $p = .0086$).

For first-person plural pronouns, those who revisited scored higher than those who envisioned ($\beta = 0.45$, $SE = 0.20$, $p = .027$). Those in self-built environments scored marginally higher than those in other-built environments ($\beta = 0.38$, $SE = 0.20$, $p = .061$). Subgroup size was nonsignificant ($\beta = 0.037$, $SE = 0.082$, $p = .66$). There were significant contrasts between **EN-O** and **RE-S** ($\beta = 0.90$, $SE = 0.29$, $p = .013$) and **EN-O** and **RE-O** ($\beta = 0.79$, $SE = 0.30$, $p = .047$), with **EN-O** yielding lower scores.

Word count, affiliation, and social behavior

For word count, participants in self-built environments spoke more than those in other-built environments ($\beta = 75.92$, $SE = 33.71$, $p = .026$), while activity type was nonsignificant ($\beta = 4.53$, $SE = 33.80$, $p = .89$). Those in larger subgroups spoke less ($\beta = -58.95$, $SE = 13.10$, $p < .001$). Participants in **RE-S** spoke more than those in **RE-O** ($\beta = 122.6$, $SE = 46.4$, $p = .045$).

For affiliation, participants who revisited scored higher than those who envisioned ($\beta = 0.48$, $SE = 0.20$, $p = .019$), while those in self-built and other-built environments did not differ significantly ($\beta = 0.29$, $SE = 0.21$, $p = .16$). Subgroup size ($\beta = -0.030$, $SE = 0.082$, $p = .72$) was also nonsignificant. Those in **RE-S** scored higher than those in **EN-O** ($\beta = 0.81$, $SE = 0.29$, $p = .034$).

For social behavior, participants who revisited scored higher than those who envisioned ($\beta = 0.42$, $SE = 0.14$, $p = .0033$), while environment type was nonsignificant ($\beta = -0.070$, $SE = 0.14$, $p = .62$). The control variable of subgroup size was significant ($\beta = -0.11$, $SE = 0.055$, $p = .050$). Participants in **RE-S** scored higher than those in **EN-S** ($\beta = 0.55$, $SE = 0.19$, $p = .022$).

Table 2. Summary statistics of nonverbal behavior measures.

Measure	Condition	Main exercise	Discussion
Interpersonal distance (m)	RE-S	0.99 (0.67)	3.53 (2.46)
	RE-O	1.20 (0.69)	3.34 (3.10)
	EN-S	1.29 (0.78)	2.98 (2.11)
	EN-O	1.28 (0.67)	2.77 (1.85)
Direct gaze (%)	RE-S	39.50 (15.77)	42.67 (24.02)
	RE-O	44.04 (18.76)	42.43 (19.82)
	EN-S	38.02 (14.20)	37.77 (13.27)
	EN-O	38.13 (17.45)	35.64 (19.05)
Mutual gaze (%)	RE-S	8.97 (4.90)	11.19 (9.51)
	RE-O	12.55 (7.56)	11.44 (10.21)
	EN-S	9.93 (6.26)	9.71 (8.51)
	EN-O	9.68 (6.66)	8.40 (7.10)

We report averages and standard deviations in parentheses.

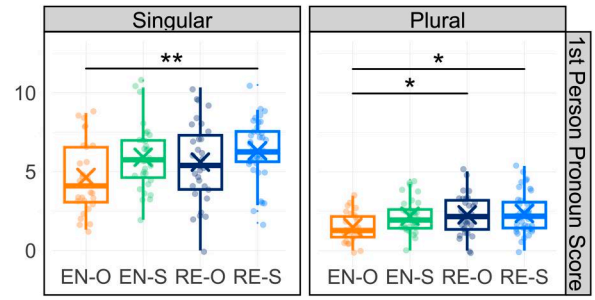

Figure 8. Linguistic inquiry and word count (LIWC) first-person pronoun scores. Significant contrasts are shown (*$p \leq .05$, **$p \leq .01$, ***$p \leq .001$).

Discussion

Psychological differences of collective revisiting and envisioning

We advance the understanding of revisiting memories as a socially situated process by showing that revisiting shared memories led to greater increases in group cohesion than envisioning plausible interactions (**RQ1a**). We posit that virtual replicas and social others serve as a double-edged sword during envisioning: while their rich spatial and social cues can help collective envisioning feel more vivid and grounded in shared perceptual references, they also constrain the envisioned activities, leaving little room for imagining positive and idealized interactions that facilitate psychological benefits (Stephan & Sedikides, 2024). This study shows that when envisioning is scaffolded by shared virtual replicas of physical

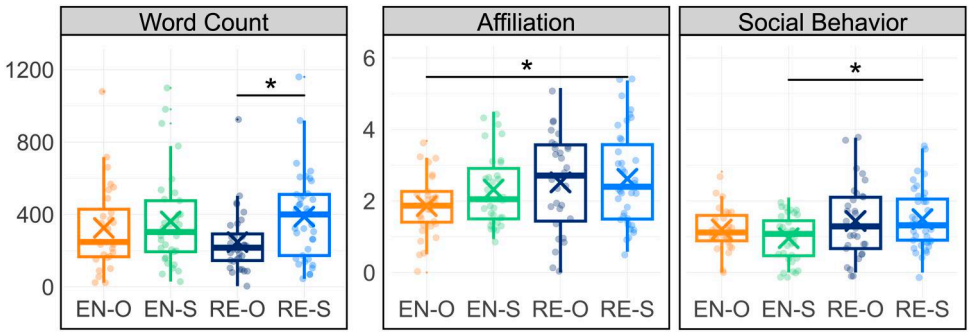

Figure 9. Word count and LIWC affiliation and social behavior scores. Significant contrasts are shown (*$p \leq .05$, **$p \leq .01$, ***$p \leq .001$).

environments, such that the virtual environments and thought-about activities are comparable between revisiting and envisioning, revisiting unites a social group more than envisioning.

Participants who revisited reported greater liking toward the virtual environment than those who envisioned (**H1a**), aligning with the mere exposure effect and studies on spatial context (Mangone et al., 2021; Zajonc, 2001). This pattern was not observed for the physical environment (**H1b**) or associated memory (**RQ3**). Drawing on situated social cognition, virtual environments likely served as perceptually salient targets of evaluation, consistent with Zajonc's (2001) view that the mere exposure effect warrants direct sensory exposure. While we expected immersion in virtual replicas to elicit mechanisms similar to direct exposure to the physical environments, our results suggest otherwise. The lack of evaluative differences for the physical environment and associated memory may be due to the virtual environments being perceived indirectly, as they are not exact replicas of the physical environments. Participants who revisited reported higher collective psychological ownership of the virtual environment than those who envisioned, though not for individual psychological ownership (**RQ2a**). It is possible that revisiting reminded participants of their collective shared control, intimate knowing, and investment during the face-to-face activity (Pierce & Jussila, 2010). Compared to envisioning, revisiting may have more strongly reinforced the virtual environment as a product of collaborative placemaking, thereby evoking a sense of joint effort rather than an individual one.

Revisiting and envisioning yielded no differences in interpersonal distance and eye contact (**RQ4a**). While this contrasts with research correlating the two with social closeness (Cui et al., 2019; Hall, 1966), one explanation is the wide distribution of subgroup size from two to seven. Such variability may have introduced nonlinear effects on behavioral markers of social closeness that our models were not fit to capture, overwhelming the observation of subtle behavioral differences. Finally, compared to envisioning, revisiting resulted in more first-person plural pronoun usage and language related to affiliation and social behavior (**RQ4b**). This corroborates the group cohesion finding and suggests that those who revisited experienced greater "we-ness" and group connectedness (Alea et al., 2015; Ashokkumar & Pennebaker, 2022) and heightened presence (DeVeaux et al., 2024) compared to envisioning.

Placemaking through self-built virtual environments

Compared to participants in other-built environments, those in self-built environments reported greater increases in group cohesion (**RQ1b**) and higher individual and collective psychological ownership of virtual environments (**RQ2b**). This is reasonable, as participants likely felt more individual and collective control as well as investment in self-built environments (Pierce & Jussila, 2010). These findings extend placemaking research by demonstrating that immersion in self-built environments enhances a group's sense of rootedness and collective identity. It is also possible that environments built by others introduced greater cognitive load for processing and referencing in social groups, increasing communicative overhead in aligning and articulating past memories or envisioned activities, and limiting the formation of meaningful bonds. Being in self-built versus other-built environments did not affect liking of the virtual environment (**H2a**), shared memory (**RQ3**), or associated physical environment (**H2b**). The more prominent influence of placemaking on interpersonal relationships and psychological ownership may stem from these constructs being closely tied to how individuals reflect on shared contributions and derive meaning from their immediate contexts.

During revisiting and envisioning, participant pairs in self-built environments stood closer together and spoke more than in other-built environments (**RQ4b**). The interpersonal distance finding corroborates our group cohesion finding, as smaller interpersonal distances reflect closer relationships (Heshka & Nelson, 1972) and more personal situations (Hall, 1966). This effect was not observed in class-related discussions, suggesting that interpersonal distance was shaped more by the immediate virtual context. The word count finding reveals that levels of investment and self-disclosure could be related to the self-report differences (Huang & Hancock, 2022). Finally, participants in self-built environments used more first-person singular pronouns than in other-built environments, suggesting that self-built environments felt more socially and spatially engaging (DeVeaux et al., 2024).

Group size shaping social dynamics

Our findings underscore how group size can influence social dynamics. Notably, larger subgroups reported higher initial group cohesion, contrasting with research suggesting that cohesion decreases with larger groups (Akcaoglu & Lee, 2016). One explanation is that our face-to-face interaction acted as

a team-building exercise, which offset the differences in cohesiveness across group sizes (Carron & Spink, 1995). As our VR groups were smaller than those in previous works, additional members may have instead amplified group identity. Furthermore, we found that individuals in larger subgroups engaged in more eye contact and used language such as first-person singular pronouns less frequently. While these patterns may reflect basic statistical probabilities, they could signal subtle differences in how group size shapes placemaking and mental time travel.

For example, larger subgroups may have experienced reduced communication efficiency and heightened isolation (Saqr et al., 2019). Conversely, aligned with situated social cognition, the presence of more individuals could heighten the salience of past interactions, reinforce social presence, and amplify the emotional intensity of immersive experiences. The effects of group size may also hinge on individual differences, group composition, and the type of memory being recalled, such as whether it occurred in a public or intimate setting. These nuances highlight the importance of considering group size not only as a control variable but also as a meaningful factor shaping how individuals connect with people and environments.

Practical implications

For VR practitioners aiming to foster cohesion within novel groups, it may be beneficial to incorporate revisiting shared experiences into group-building exercises. When groups share relationship-defining face-to-face experiences, immersing them in self-built replicas of shared physical environments can enhance psychological ownership and social cohesion. Exploratory analyses (see online supplementary material) showed that nonverbal behaviors such as gaze correlated with group cohesion, highlighting the practicality of leveraging behaviors to understand psychological states. As our subgroup sizes varied, these guidelines are broadly applicable to small-group interactions. Finally, our protocol for creating virtual replicas and revisiting memories offers a methodology that practitioners can adapt beyond the scope of this study. For example, families could collaboratively reconstruct and revisit meaningful places, and therapists could guide patients through recollections in immersive environments constructed by the patients themselves.

Limitations and future work

This study has several limitations. For one, our sample consisted of university students engaging in space-building activities. Researchers should investigate other demographics and activities differing in mobility and spatial relevance. While we expect our findings on revisiting face-to-face memories to extend to memories that occur virtually, research should study the generalizability and nuances of our observed psychological and behavioral effects. For example, when virtual environments are automatically saved and reloaded, the effects of placemaking may be obscured, while the high replication fidelity may further shape reliving and envisioning. As memory characteristics can shape psychological processes (Jiang et al., 2021), scholars should investigate revisiting different types of memories (e.g., positively versus negatively valenced). It is also important to understand whether aspects of immersive experiences, such as presence and quality of interaction, alter these dynamics (see online supplementary material for analyses on psychological benefits and personal significance).

Researchers should consider individual and group differences and alternative study procedures, and supplement our behavioral analyses with finer-grained examinations of moment-to-moment gestures and movement patterns. For example, analyses presented in the online supplementary material revealed differences in head and hand synchrony, suggesting synchrony as a sensitive marker of social dynamics in these contexts. In this study, participants were allotted around an hour to create and engage with virtual replicas and completed questionnaires immediately afterward. Researchers should study longer experiences and the longitudinal effects of reliving and envisioning, and compare VR to nonimmersive settings (e.g., videos, mental imagery). Finally, research can vary the VR exercises, for example, by having participants envision scenarios without constraining their spatial context.

Conclusions

We studied how collectively revisiting shared memories and envisioning plausible interactions in VR differentially impact psychological and behavioral outcomes. Compared to envisioning, revisiting increased group cohesion, collective psychological ownership, and liking of virtual environments. Experiencing self-built virtual replicas during revisiting or envisioning, compared to other-built replicas, increased group cohesion and collective psychological ownership of virtual environments. Behaviorally, individuals who revisited used more first-person plural pronouns and language related to association and social behavior than those who envisioned. Our findings highlight the potential of revisiting shared memories in self-built immersive environments for fostering group cohesion and eliciting behavioral change. As we move toward a future in which we can reexperience meaningful places from our past with great fidelity, emerging technology may continue to redefine what it means to revisit shared memories.

Supplementary material

Supplementary material is available at *Journal of Computer-Mediated Communication* online.

Data availability

The data cannot be shared publicly due to privacy concerns, but will be shared on reasonable request to the corresponding author.

Funding

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Conflicts of interest

None declared.

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reviewers for their valuable feedback during the revision process.

Open science framework badges

Open Materials
The components of the research methodology needed to reproduce the reported procedure and analysis are publicly available for this article.

Preregistered
Research design was preregistered.

Notes

1. Hypotheses were preregistered through OSF (https://osf.io/8bac7/).
2. We divided the two smaller groups into two subgroups and assigned them the self-built conditions.
3. The preregistration detailed building and experiencing virtual replicas. We focus on the latter due to space constraints.
4. For thoroughness, we present results on third-person pronoun in the online supplementary material.

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