Figure 1: Screenshots from the Participants’ View in the VR Modules (Top) and Layout of the Main VR Environment (Bottom).
ABSTRACT
Virtual reality (VR) is increasingly used as a platform for social interaction, including as a means for elders to maintain engagement. However, not many empirical studies have been conducted to examine features of social VR that are most relevant to elders’ experiences. The current study qualitatively analyzed the behavior of older adults in a collaborative VR environment and evaluated aspects of design that affected their engagement outcomes. We paired 36 participants over the age of 60 from three diverse geographic locations to interact in collaborative VR modules. Video-based observation methods and thematic analyses were used to study their interactions. The results indicated a strong link between conversations about personal lives in VR and social engagement, highlighting the need for social VR to encourage users to create their own stories and share their life experiences. The study provides new insights into design guidelines that could improve social VR for older adults.

CCS CONCEPTS
• Human-centered computing → Interaction design: Collaborative and social computing.

KEYWORDS
virtual reality, social VR, older adults, social Engagement

1 INTRODUCTION
There is a growing body of research investigating applications of immersive virtual reality (VR) for older adults. Some of this work includes using VR to assist older adults with developing their physical capabilities, such as rehabilitation and gait function [1, 19, 40, 51, 56, 62]. Additional research has been oriented toward helping older adults with mental illness [75] and cognitive training [18, 25]. One of the more novel areas of study, which has grown particularly relevant during the COVID-19 pandemic, is the use of VR as a means for promoting social interaction and interpersonal engagement among older adults.

Social isolation, defined as having few social relationships or infrequent social contact with others, is a significant concern for older adults worldwide [83]. For many people such isolation can have adverse impacts on mental and physical health [17, 43, 53, 83]. A systematic review of studies on social isolation and loneliness found that older adults are one of the populations most at risk of experiencing these conditions, in part due to declines in mental and physical abilities leading to social withdrawal [37]. Age is also associated with reductions in social network size [82], which in turn predicts greater risk for cognitive impairment [63] and decreased wellbeing [60]. In contrast, many studies show that active social activities and meaningful engagement with others are an integral part of successful aging, and that the benefits of such engagement are substantial, including better cognitive health, physical and emotional health, and life satisfaction, among others [58, 81].

Researchers have found that many older adults wish to remain actively engaged in society and involved in meaningful collaborative activities [29, 37, 73]. Understanding how to best support this goal and enhance opportunities for social engagement among older adults is an important challenge, and it is one that is increasingly being taken up by the medical and social services communities. A recent review found that interventions to promote social support for older adults can effectively improve outcomes such as perceptions of loneliness and disengagement [19]. Unfortunately, such interventions confront significant obstacles, such as life changes associated with retirement, mobility challenges, illnesses, and ageism in the broader society [43]. This is especially true for older adults who are of lower socio-economic status or who are part of minoritized and marginalized groups [26].

One of the advantages of VR interventions is that they can allow older adults who would otherwise have limited opportunities to meet with other people to do so from the safety and comfort of their own residences. The popularity of “virtual travel” has grown tremendously during the COVID-19 era, as a way for individuals to “leave” their immediate environment and take part in new experiences and social engagement in a safe fashion [41, 72, 74, 78]. Today’s VR systems are able to provide a highly immersive and realistic impression of being “present” in a digitally rendered or filmed environment, which enhances cognitive engagement [66]. When such experiences are designed to include a social component, they can become a valuable means of connecting with others, either through engaging in shared activities or through simple conversation. Studies have found that interactions in VR spaces are perceived as being more “realistic” or more similar to in-person interactions when compared against other types of digital communications [40]. The emergence of VR as a technology can be traced back to long-standing aspirations toward the creation of truly realistic collaborative spaces that erase geographic distance [10].

The current study was conducted to analyze the social interaction behavior of older adults during a social VR program and to relate that behavior to program design features. Baumeister and colleagues [9] called for more observational study in this field, arguing that such approaches can provide greater insights than the self-reports, hypothetical scenarios, and questionnaire ratings that are commonly used. The current study was not designed to manipulate specific environmental variables; rather, we drew from prior research to try to optimize spatial presence and embodiment in various VR modules, and then evaluated the responses of participants who interacted with those different environments and activities. Another important aspect of the study is that it paired
older adults from different geographic locations and backgrounds, including both rural and urban study sites. Through this process, participants had the opportunity to meet other older adults whom they would generally not interact with in their everyday lives. To the best of the authors’ knowledge, no other studies on social VR with older adults have incorporated this level of diversity in regard to the geographic location of participants.

The study makes two main contributions to knowledge about social VR use by older adults. First, drawing on our observations and thematic analysis of the social interactions, we identified features of the VR environment that appeared to promote or discourage social engagement in the older adult population. Second, we identified which types of interaction activities led to more positive experiences in the VR environment. The results provide insights into an understudied area and help to identify important and sometimes overlooked aspects of older adults’ VR experiences, which merit strong consideration as the technology becomes more widespread.

Two primary research questions shaped the directions of our observation and analysis: How will VR content design affect social engagement behavior among older adults in social VR? What technical issues will the older adults have with the VR system in a social VR application?

2 RELATED WORK

Relevant prior work on VR socialization has tended to fall within three broad areas: specific studies about use of VR by older adults, studies about the technological design of VR as it contributes to social interaction, and studies of online games.

2.1 Social VR and Older Adults

Several prior studies have evaluated the usability, feasibility, and acceptability of VR by older adults, and have found respectable levels of positive response, engagement, and comfort with the technology when it was carefully introduced to participants [1, 20, 31, 34]. However, knowledge in this area is still preliminary, since there have not been many design studies evaluating the specific features of the technology that are most relevant to an older population. This is particularly true when it comes to social VR, where research into the mediated interactions that take place on such platforms has focused mostly on younger adults. Such research includes a great deal of work on design strategies for enhancing virtual social engagement in general [32, 49, 70], analyses of communication modes and the dynamics of interactive activities in VR [4, 24, 44, 50, 51], engagement strategies for long-distance couples and families [45, 46, 87], and the psychology of VR self-presentation and avatars [11], among others. However, to the best of the current researchers’ knowledge, the existing literature on engagement in social VR has not specifically focused on design issues relevant to the older adult population, and the participant diversity and depth of analysis regarding older adults has been very limited. The current study was conducted to help fill these gaps by providing qualitative observation of older adults meeting and collaborating in an immersive VR environment, and evaluating their reactions to content design strategies.

2.2 Presence, Non-Verbal Communication, and Avatar Design

Social VR provides a unique form of engagement compared with other types of computer-mediated interactions. One important aspect of this experience is the high level of spatial presence, which is defined as a subjective feeling of “being there” within a virtual environment [57, 79]. The degree of spatial presence is related to numerous design factors, including visual resolution and sensory immersiveness, the sophistication and appeal of the content, and user’s ability to “act there,” which is to say, the fluid translation of commands into the environment [21, 61]. Beyond this issue of spatial presence, researchers have also discussed “social presence,” defined as the sense that other humans are there along with the user in the virtual space [16]. Studies have found that higher reported social presence in VR was associated with emotional responses that are more similar to those experienced in real-world interactions [14, 51, 68]. Additionally, social presence has been positively correlated to enjoyment and trust in the VR environment [56].

Despite the recognized impact of maximizing social presence in VR experiences, design guidelines for the process have been relatively under-explored. Parsons and colleagues provided a psychological model to describe various levels of social presence, ranging from simply noticing the existence of other persons in the environment to actively engaging with those individuals [59]. Oh and colleagues developed this work further by examining factors that affected the sense of social presence, divided into a variety of immersive, contextual, and psychological variables [56]. In another study, the researchers found that social presence was affected by the sense of self-embodiment, proxemics (location and distance between participants), symmetric vs. asymmetric interactions, the presence of non-verbal avatar cues (gaze, facial expression, gesture), and the types of activities that participants were engaged in [84]. Beyond these few studies, however, design factors related to the production of social presence have remained somewhat vague and tenuous, with little robust empirical grounding.

In social VR, users can convey both verbal and non-verbal cues via their avatars while maintaining a level of anonymity and privacy, a phenomenon that has sometimes been described as “Avatar-mediated communication” [36, 69]. However, the fluidity and sense of social presence provided by this experience depends on high-quality avatar design and other technological factors. Williamson and colleagues [80] found that avatar realism can have a strong effect in enabling positive social experiences, by mediating activities such as group formation and the sense of personal space during interactions. When socialization is the primary goal of a VR environment, it also becomes extremely important to incorporate functions for body language—the ability of avatars to fluidly convey the user’s gestures, facial expressions, gaze direction, and other fundamental aspects of non-verbal communication [47]. When compared to other forms of computer-mediated communication, VR tends to allow a greater sense of “inhabiting” one’s avatar and thus creates a rich presentation of experiences that are closely akin to those people enjoy face-to-face, such as standing next to each other and interacting with the same object [40], or the exchange of objects among users [4].
Data from prior studies has given us a preliminary understanding of important features of VR environments that may affect social outcomes; however, the majority of these design studies have relied on participant samples that skew toward younger adults, and it is imperative to collect more information about how factors such as embodiment, presence, and engagement are experienced by older users of social VR. The limited work in this area suggests that older adults may have different interests and needs in this regard. For example, older adults have been found to prefer “realistic engagement” scenarios in VR that reflect ordinary environments, rather than “gamified” scenarios that bestow users with superhuman abilities to meet challenging tasks [24, 44]. In one notable study, Baker and colleagues [5] conducted workshops with older adults and found that the key drivers of VR technology’s acceptance in this population were behavioral anthropomorphism (“the embodied avatars’ ability to speak, move, and act in a human-like manner”) and translational factors (“how VR technology translates the movements of the ageing body into the virtual environment”). Thus, the careful design of these environments and especially avatars is likely to be crucial in meeting the specific engagement needs of older populations, which in some respects may diverge from broader gamified development trajectories in the industry. The current study contributes to our knowledge in this area by providing additional data about what design factors are most relevant to older adults’ responses to social VR.

2.3 Social Interactions in Digital Games

Online platforms and virtual worlds intended for social interaction have existed decades before the emergence of modern VR devices. They can be traced back to 1970s under the term “artificial reality” as discussed by Myron Kreuger [12]. One of the most famous and influential platforms is Second Life, a virtual world that was inspired by the creator’s project on virtual reality interfaces in 1995 [42]. This platform started its beta test two decades ago in 2002, and went live in 2003 [65]. Some studies have utilized Second Life to facilitate social engagement among older adults, but have reported a relatively low success rate in establishing relationships. This may be due to challenges such as ignorance or lack of positive responses toward older adults from other platform users, which was perceived by study participants as a form of rejection [55].

Second Life is generally associated with the much larger terrain of online video games, especially those described as massively multiplayer online role-playing games (MMORPGs). Existing older players of online games were found to frequently use them as a means of obtaining social interactions and a sense of connectedness though the researchers did not evaluate the presence of obstacles or difficulties faced by older players in achieving such social ends [39]. For players in general, social interaction has been a main focus of many if not most MMORPGs. Previous studies about players of online digital games have identified interest in social interaction to be a player type, a dimension of some players’ motivation, or an important aspect of the fun in the game for some players [27]. Perhaps most foundationally, the prominent game researcher Richard Bartle described “socializers,” one type of player of online interactive games, as being focused strongly on using the game platform as a means of chatting and building relationships [7, 8].

In other research, factor analysis of survey data also found socializing to be an important motivation of online game players [85, 86], which sometimes involves the creation or maintenance of real-life friendships via shared gaming [67].

In addition to goals and tasks, one fundamental feature of digital games, in contrast to other social platforms, is emergent narrative: stories or experiences that are created by users as a product of their interactions with the game systems and other players, that can produce social presence during gameplay, even with limited physical presence [2, 77]. Similar ideas were found in other frameworks for understanding digital games, such as the “dynamics” aspect that includes interaction between players in the Mechanics, Dynamics, and Aesthetics (MAD) framework of game design [30], or in research focused on the fictional world-building aspects as opposed to the tangible rules imposed in the games [33]. Promoting emergent narratives has been used as an intentional design strategy to increase older users’ engagement in digital skills-training activities [71]. In the current study, we did not intentionally design for emergent narratives, but we did look to evaluate their organic presence as a user response and their relationship to perceived social presence and engagement.

3 METHODS

3.1 VR Task Design

Based on our research questions and literature review, we designed our social VR platform specifically to enable our older adult users to meet with other members of their age group and to experience collaborative activities that would prompt social interaction. For the activities, we referred to the McGrath task circumplex, which, drawing on decades of research on group dynamics and team interaction, categorizes diverse types of collaborative tasks and their components [48]. Each module of the experiment was designed with a different type of McGrath task classification in mind to ensure a wide range of tasks and group dynamics was included in the study. The first two modules, in which participants worked together to create a shared travel itinerary and then travel together, were based on “Type I planning” and “Type II intellective” tasks. After a brief training session to learn the VR controls, the participants entered a room in the virtual world that contained a large map of the Earth, where they met with their assigned partner. They were told that they would be going on a “trip” together, and were asked to introduce themselves (their name, where they are from, etc.). They were then asked to discuss which locations shown on the map they would like to visit for the upcoming Travel and Conversation portion of the experiment. For participants who had difficulty choosing, they were offered an opportunity to visit adjacent rooms, which had images of representative landmarks for each of the available locations.

After agreeing on an itinerary, the participants entered the Travel and Conversation module, which involved viewing immersive virtual videos of their selected locations. Moderators accompanied the participants on this tour and prompted them if needed to engage in conversation with each other, for example by asking them to discuss what they thought was the most interesting landmark at the site. Due to the nature of the surround-video technology, the
participants were not able to change their position within the environment, but they were able to look around in different directions from their fixed position.

In the final module the participants were brought into a VR gallery space where they were instructed to work together to identify which of the photos on the gallery wall were landmarks that they saw during their VR tour, and remove the pictures of places they had not visited (they were not graded on accuracy in this task). The participants were then asked to collaboratively rearrange the remaining photos into a collage, by adjusting their size and positioning on the wall, to create an artistic documentation of their “travels.” These tasks were regarded as “Type III cognitive conflict tasks” and “Type IV psychomotor tasks” under the McGrath system.

Figure 1 shows some of the virtual environments that the participants encountered during these modules. Before conducting the primary study, we ran some informal pilot tests with older adults to obtain feedback about potential shortcoming of the VR environment and equipment, and used this feedback to enhance some aspects of the VR content prior to the experiment. For the final version, we developed our module 1 and 3 on the Spatial platform v.6.19 (www.spatial.io), and our module 2 on Alcove v.1.194 (www.alcovevz.com), both running on the Meta Quest 2 headset with 1832x1920 resolution per eye and 90 Hz refresh rate.

3.2 Participants

Twelve participants were recruited at each of our three study sites (Ithaca, NY; Tallahassee, FL; and New York City, NY), resulting in a total of 36 participants. We used a convenience sampling method, primarily through the e-mail lists of the participating local institutions including Cornell University at Ithaca, NY, Florida State University at Tallahassee, FL, and Weill Cornell Medicine at the New York City site.

Each potential participant was engaged personally by the researchers to discuss the study goals, compensation, and potential risks. Participants were informed that they would be asked to engage with another person virtually and to complete collaborative tasks in VR. The inclusion criteria were: (a) at least 60 years of age; (b) able to readily understand written and spoken English; and (c) not already a regular user of VR technology. The requirement limiting the study to novice VR users was intended to promote parity in technological knowledge, which could otherwise become a source of dominance in social interaction (i.e., limiting the engagement of less knowledgeable participants). Interested individuals who met the eligibility criteria were provided with an informed-consent document and a demographic questionnaire, which they filled out prior to arriving at their site for the VR session. For the VR social interactions, we paired each participant with a partner at one of the other sites based on matching availability in their personal time-schedules (for a total of 18 pairings, six between each site).

The average age of the participants was 71 (Standard Deviation = 5.2). The overall sample skewed toward Female (72%) and White (81%). A wide range of educational backgrounds were represented; more than half of the participants had a professional degree (n=19, 53%), while 5 (14%) had some college education, 10 (28%) had a four-year college degree, and 2 (6%) had a doctoral degree. Proficiency with information technology was assessed in the initial demographic instrument using two scales: the Computer Self-efficacy Scale [6] and the Mobile Device Proficiency Questionnaire [64]. The first scale focuses on confidence levels in relation to information technology, while the second evaluates proficiency with using various mobile devices (tablet computers and smartphones). Both use 5-point Likert scales, with higher scores indicating greater proficiency. The average score was 27.22 (SD=2.94, range 6–30) on the Computer Proficiency Scale and 33.47 (SD=6.63, range 8–40) on the Mobile Proficiency Scale, both of which indicate a high level of familiarity with information technology.

Immediately prior to the VR sessions, participants’ cognitive abilities were evaluated using the Montreal Cognitive Assessment (MoCA) [52], administered by a MoCA-certified researcher. This instrument was used to divide the participants into those with a likely mild cognitive impairment and those without, using a threshold score of lower than 26 on the instrument as likely-impaired. The MoCA is a screening instrument rather than a diagnosis, but it is commonly used to identify and refer individuals who may have aging-related declines in memory and thinking skills [52]. The average MoCA score was 26.75 (SD=2.57, range 0–30), with 9 (25%) participants scoring below the threshold.

3.3 Procedure

Prior to arriving at the study site, participants were asked to provide informed consent and complete an online demographic survey. When participants arrived for their experiment session, the supervising researcher first administrated the MoCA, and then fitted each participant with the VR equipment and provided instruction about its use. During this time the session moderators, who were research assistants at each study site, created virtual avatars for each participant. The avatars were designed to model the participant’s real-life appearance and dress, and were confirmed with the participant to be appealing prior to the start of the experiment. The participants then entered the social VR environment and completed the three content modules (as discussed in 3.1). Between each of the modules, participants were asked to remove the VR equipment and take a short break. Upon completion of the final module, each participant completed an exit survey and interview about their VR experience and was given a $50 gift card as compensation for their research contribution.

Each site had two moderators present during the experiment sessions: one monitored the VR experience of the participant and the other monitored the physical safety of the participant. All sites used a consumer edition of the Oculus Quest 2 head-mounted display and its accompanying handheld controllers, a Blue Yeti USB microphone, and a Sony SRS-RA3000 speaker to hear the audio from the other site. Continuous video of each participant’s VR experience was recorded using the Open Broadcaster Software (OBS). The respective Institutional Review Boards for each of the three institutions involved in this research approved all study procedures and surveys prior to the start of research activities.
3.4 Measures

The current analysis focused primarily on the researchers’ observation of the video data from each participant’s VR interactions, as well as data from the post-experiment surveys and interviews, which were intended to capture participants’ experiences of social interaction. Experiences of physical discomfort with the VR environment were quantified in the exit survey using the Simulator Sickness Questionnaire (SSQ), which consists of 16 items on a 4-point Likert scale, with higher numbers indicating greater experiences of sickness [35]. The four-item Usability Metric allowed participants to rate the usability of the system using sliders from 0–100, where higher numbers indicate greater usability [23]. The level of participants’ Engagement in the VR Experience was measured during the exit survey using a 3-item, 5-point Likert scale developed by the current researchers (“I found today’s experience to be engaging”; “The experience I shared with my virtual partner today was meaningful”; “The experience I shared with my partner today allowed me to express creativity”), with higher scores indicating greater perceived engagement. Cronbach’s Alpha was calculated for this instrument and was found to be 0.81, indicating a high level of internal consistency. To further investigate the usability of the social VR system, the exit survey also included the NASA Task Load Index (six subscales each rated on a 5-point Likert algorithm in Adobe Premiere, with manual cleansing and correction. Some markers, including participants’ laughing moments, participant digital proximities, and changes in the VR content, were annotated in table format. Participant conversations were coded independently by two researchers, using the following labels: “Conversations related to the virtual reality platform and overall VR experience” (V); “Talking with the moderator” (M); “Commenting on the task assigned and/or the VR content” (E); “Experiences from the participants’ lives” (L); “Decision-making processes, either asking or answering” (D); “Positive emotional expression” (P); “Comments about non-verbal cues and avatar positioning” (N); “Technical issues and challenges” (T); and “Unintelligible segments” (C). Examples of each label are shown in Table 1. A third researcher, after watching the recordings and reading the transcripts, went through the labels and refined them together with the two original coders. Finally, a thematic analysis approach [15] was used by all three researchers working together, to identify emerging themes in each label category as relevant to the study’s research questions.

4 RESULTS

4.1 Descriptive Statistics

The quantitative measurements indicated that on average participants reported low rates of simulator sickness (M=21.82 out of 235.62; SD=26.69), as well as high usability (M=67.01 out of 100; SD=20.73) and low task workload (M=2.86 out of 7; SD=1.17). Ratings were moderately high for spatial presence (possible actions: M=3.70 out of 5; SD=1.17; self-location: M=3.76 out of 5; SD=1.27) and for engagement (M=4.18 out of 5.00; SD=0.91). Participants also reported moderately high perceptions of social presence (M=61.21 out of 100; SD=22.00) and likeliness to reconnect with their virtual partner (M=3.69 out of 5; SD=0.79). Table 2 shows the percentages of conversation that were assigned to each topical category. Detailed results of all participants can be found in Table 4.

4.2 Relationship between Conversation Topics and Social Engagement

We calculated the correlation between the frequencies of different conversation topics (in categories M, V, E, etc. as described in Table 1) and the measures of spatial presence, engagement, and likeness to reconnect per pair (Table 3). The most important factor found here was conversation about life experiences (L), which were strongly correlated with engagement (r=0.37) and likeness to reconnect (r=0.61). In the qualitative analysis of the life experiences category, three main topics emerged. The most common was past experiences, including memories about participants’ earlier lives and places they had lived (“I grew up in New York City”) or previously visited (“I’ve been to San Francisco a number of times”). The second topic in this category was current hobbies and interests (“I’m in a book club . . . we have a book each month”). The third topic was future plans, especially those relevant to traveling due to the theme of our program (“So we were actually coming to Florida on Saturday”).

We also found that comments about the VR content (E) were somewhat correlated with engagement (r=0.29), social presence (r=0.27) and with spatial presence (r=0.51). The conversation topics in this area were almost all related to the appearance or design of virtual areas (“The room is extremely modern, which is fantastic”) or to the collaborative accomplishment of specific tasks (“You can take the frame [of the picture] away”). Perhaps unsurprisingly, communication with the moderator was somewhat correlated with a decrease in all three factors of spatial presence, engagement, and willingness to reconnect (r=-0.26, -0.34, and -0.35, respectively). Most of these communications were associated with participants experiencing technical issues, or with moderators interrupting the experience due to safety concerns (participants moving too violently in real-life, or too close to the physical “safe area” borders), both of which would logically tend to decrease immersion and virtual socializing. The total number of words spoken by participants
Table 1: Categorical labels used in the analysis of participant conversations

| Labels | Description | Example |
|--------|-------------|---------|
| V      | Discussing the VR platform and VR experience. | I’m afraid of heights, so I can’t look down. |
| M      | Talking to the moderator. | How long are we supposed to do this? |
| E      | Commenting on the task assigned and the VR content. | I’m going to suggest Madrid. Beautiful. Looks like cherry blossoms. I’m making this one bigger. |
| L      | Experiences from participants’ lives. | I went to a Lutheran school. I don’t recall this picture. |
| D      | Decision-making process, either asking or answering. | Do you want to delete it, or should I delete it? Wow. Blown away by the cherry blossoms. Can you hear me? |
| P      | Positive emotion. | I’m right in front of you now. I’m bad with this joystick. I just can’t seem to do it right. |
| N      | Comments about non-verbal cues and avatar positioning. | | |
| T      | Technical issues and challenges. | | |
| C      | Unintelligible segments. | | |

Table 2: Mean and standard deviation of number of words and percentage in each categorical label per pair.

| Category | M  | V  | E  | L  | D  | P  | N  | T  | Total |
|----------|----|----|----|----|----|----|----|----|-------|
| Number of Words | 251.89 (377.99) | 56.39 (49.59) | 2420.56 (737.34) | 341.83 (273.29) | 1301.06 (596.73) | 206.44 (246.87) | 89.61 (143.40) | 279.17 (215.10) | 3967.81 (825.13) |
| Percentage (%) | 6.58 (10.45) | 1.36 (1.15) | 60.42 (11.58) | 8.40 (6.25) | 32.05 (11.61) | 4.97 (3.80) | 7.03 (5.3) | 100 | |

Note: Mean(SD). Descriptions of labels can be found in Table 1. Total: Total number of words, including those from moderators. Percentage = Number of words per category / Total number of words.

was somewhat correlated with spatial presence (r=0.42), engagement (r=0.25), and willingness to reconnect (r=0.25). In addition, engagement was highly correlated with willingness to reconnect (r=0.84), less so with spatial presence (r=0.48), and social presence (r=0.38).

4.3 The Effects of VR Content Design on Social Engagement

Analysis of the conversation data indicated that much of the participants’ discourse during the experiment, nearly two-thirds of all words, was about the VR contents. The topics of these conversations varied according to the modules. In Module 1, conversations were mainly about choosing the destination of the virtual travel. In Module 2, conversations were often triggered by the changes of scenes in the videos. The comments here ranged from simple appreciation (“Beautiful pool”) to descriptive (“It’s bright and sunny here”) to affective responses to the environment (“Makes me really want to go sunbathing”). In Module 3, conversations mainly focused on the assigned tasks, including confirmations about accurate responses (what images had been seen during the prior travel videos), discussions of personal preferences regarding the design of the collage, and informing partners about what actions the speaker was about to take. Overall, this finding indicated that VR design factors and content had a large impact on the direction of participants’ conversations, though such interactions were also localized to the times when participants were interacting with specific content elements.

These conversations reflected participants’ overall spatial presence and hence engagement.

The second most important type of discourse was related to the participants’ personal lives (label L), which can be regarded as emerging narratives. These topics usually started to appear at the very beginning of Module 1, mostly likely because the moderators prompted participants to introduce themselves at that time. These conversations tended to become more prominent if the participant pairs discovered shared experiences or areas of interest, such as both growing up in New York City. Additional topics related to personal life experiences continued to crop up throughout the modules, for example during Module 2 some participants began to compare the destination videos with other places they had previously visited in real life. In a few cases, conversations emerged that had little relation at all to the VR content, such as participants talking about their interest in literature and book club experiences. They followed a different trajectory compared to discussions of the VR content, as the conversations tended to last longer and continue across the modules and tasks, even if the initial VR content that had prompted the topic changed (Figure 2).

While the emerging narratives in the experiment had little impact on successfully accomplishing tasks within the VR environment, they were associated with social connections between participants and willingness to reconnect after the experience (“I don’t know if they [experimenters] are going to get mad at me for this, but I want to give you my email address.”). Below is an example of such
Table 3: Correlation between frequencies of different conversation labels, engagement, and likeness to reconnect

| Variables          | M   | V   | E   | L   | D   | P   | N   | T   | Total |
|--------------------|-----|-----|-----|-----|-----|-----|-----|-----|-------|
| Social Presence    | -0.13 | 0.08 | 0.27 | 0.06 | -0.23 | 0.14 | 0.25 | 0.2  | 0.05  |
| Spatial Presence*  | -0.26 | 0    | 0.51 | 0.25 | 0.12  | 0.22 | -0.02 | 0.15 | 0.42  |
| Engagement         | -0.34 | 0.03 | 0.29 | 0.37 | 0.14  | 0.03 | -0.23 | -0.15 | 0.25  |
| Reconnect          | -0.35 | 0.15 | 0.2  | 0.61 | 0.14  | 0.09 | -0.12 | -0.28 | 0.25  |

Note: Descriptions of labels can be found in Table 1. Total: Total number of words, including moderators’. *: Both dimensions of Spatial Presence were added together for an overall score.

A conversation from the participant pair (P6), which started with references to the travel site they were “visiting” and then continued beyond the on-screen content, covering multiple aspects of lives:

[D007] Yeah, exactly. Well, it’s funny because we’ve been there [San Francisco] a different time. So when we were with our son, when he was young, you know, you do a certain...
[F017] Yeah, yeah. Exactly.
[D007] And then we’ve been back as older adults, and we do different things.
[F017] Yeah. Yeah. When I was like I was there like sixties thereabouts and you could actually ride on the cable cars to get places.
[D007] Wow.
...
[D007] How did you … is Florida … a retirement in Florida or have you been there a while?
[F017] I’ve been here for 30 years. I moved here when I retired from the Army because my mom and dad, my brother were here.
[D007] Gotcha.
[F017] You don’t sound like New York.
[D007] [laugh] Upstate, if that makes a difference. Yes.
[F017] It does make a difference.
[D007] Yeah. Okay. Yeah, it’s where [the research institute] is and that I’m one of those professor brats. But my dad died young and then I just stayed. And then after college moved south. I never thought I’d be back [here] but I am.

We found similar transition, or progression in other pairs with frequent conversations about life experiences, from content-related life experiences to more “personal” experiences: In P7, participants talked about where they have lived previously and why they live where they do now; in P14, participants realized that they were both familiar with the same neighborhood in New York City, even working in buildings that were close to each other, launched them into a conversation about their childhood and high schools. However, in P12 (Figure 2), the topic did not process after F013 talked about their book club experience as W013 did not actively respond. The reported willingness to reconnect levels were not consistent within the pair, with W013 reporting a very high willingness and F013 being neutral.

We then examined the balance, or dominance within pairs to better understand the effects of power dynamics and their effects on social interaction. We found three main types of social interactions in which participants exhibited social dominance, which we labeled as follows (Figure 3):

- **Task-oriented**, in which specific activity goals in the VR were linked to domineering conversations. Examples include: “We have to move these two photos”, “All right… Now we’re supposed to make like, a collage”; “I think it’s kind of cooler without the frames – what do you think?”.
- **Skill-oriented**, found in pairs where there were significant skill gaps in using the VR controls. Among these pairs, the more skilled participant would either take on the role of a dominant “teacher,” or would simply complete the tasks themselves with (at most) narration and verbal input from the less skilled participant. In one pair, the unskilled participant said to the skilled participant, “You do the heavy lifting,” demonstrating a relinquishing of control.
- **Content-oriented**, in which one participant dominated the conversation because of their prior familiarity with the VR environment’s content, or the on-going topic. This generally related to prior experience with the travel destinations, which resulted in one partner occupying a “tour guide” role and explaining the content to the other.

While such dominance was widespread enough in the experiment to be noticeable, they were all conditional. As we can see from the examples in figure 3, the power dynamics could change based on tasks at hand. Generally, participants were willing to ask for, listen to, and negotiate with their partners’ opinions when making decisions, and have been patient when partners were slower with controls. As a result, skill-oriented and task-oriented dominance, such as what we have found in P14, would not usually affect participants willingness to reconnect.

It is notable, however, that in a few pairs the partners did not seem to get along at all, and engaged in minimal conversation after
the initial introductions, which also resulted in content-oriented
dominance since most topics were from only one of the participants.
In exit interviews these participants tended to report lower levels
of perceived social engagement. Interestingly, however, these pairs
did not report lower levels of spatial presence, and were generally
positive about the technical aspects of the environment. One part-
icipant, in response to the question, “Which part could be most
improved and why?” replied: “Oh my partner. I don’t want to come
down hard on this guy because this is a personality thing and not
the project; hope he’s not sensitive . . . the lack of interaction was
very frustrating for me.” In most of these cases both paired partici-
pants attributed the poor social experience to a lack of compatibility,
and indicated that the platform would be more enjoyable with a
different partner.

4.4 Technical Issues with the VR System in a
Social VR Application

VR system mechanics issues primarily emerged in conversations be-
tween participants and moderators, as well as in the exit interviews.
A common issue was the lack of visual prompting in our system
about which controller button to press to undertake a particular
action in the VR. Since the Quest controllers have an abundance
of input possibilities (12 buttons plus two joysticks), and most of
our participants had never used the controllers before, they often
struggled to understand or remember how to enact their desired
input. This led to participants occasionally asking their interaction
partner for technical suggestions or, more commonly, asking the
site moderator for such help.

A variety of additional concerns were tied directly to the use of
the VR controllers. Some participants had trouble distinguishing
the joystick axis movements; that is, they would unintentionally
shift the joystick to the side (which was mapped to rotation in the
VR) while they were trying to push the joystick forward (mapped
to movement in the VR), or vice-versa. This led to problems with
the chaotic avatar movement. Better mapping of controller functions
would likely have fixed such issues. The input system that we used
also had an issue where it disallowed concurrent button presses,
so that holding one button down would result in presses on other
buttons being ignored. Many of the participants unintentionally
pressed the “grip” buttons on the handle of the controllers by hold-
ing them too tightly, which stopped the system from responding
to any other inputs. It took us several sessions to troubleshoot this
issue, as the researchers did not expect a modern commercial VR
system to disallow concurrent button presses.

In addition, one of the functions that we used in the collage-
making task turned out to be unnecessarily complicated. To change
the size of the pictures in the VR, participants were required to: (1)
point controllers on both hands at the picture steadily; (2) press
trigger buttons on both controllers at the same time; (3) move the
controllers closer to, or away from, each other while holding down
the trigger buttons; and (4) avoid triggering the grip buttons on the
handle during the entire process. Many of the participants reported
struggling with this function, and as a result, many of them simply
gave up on it and decided to leave the pictures at their original size.

All these technical issues created frustration for the participants
and tended to interrupt their conversations as they paused their
other activities to figure out the solution or ask the moderators for
help. Such technical issues are a major consideration as they can
eradicate the sense of fluid immersion and presence in the virtual
environment.

Finally, software issues related to avatar presentation sometimes
created stumbling blocks to participants’ fluid interactions and
sense of presence. Many participants established strong connections
to their avatars, even to the extent of declaring incongruously, “It’s
cold!” when they teleported themselves into a water area by mistake.
Concerns related to avatars were a common topic of conversation,
for example in comments related to the look of a partner’s virtual
clothes, or the distance between avatars (“Look, we are right next
to each other”). The VR system that we used (Spatial) did not present
avatar legs, a fact that was noticed and commented on by several
participants (“Oh my, she’s floating!”).

5 DISCUSSION

This paper reports a behavioral social interaction study of 18 pairs
of older adults (36 participants) who met each other for the first
time to interact and complete collaborative tasks in an immersive
social VR platform. Overall, the study found that the social VR
environment could create a positive experience for older adults. In
addition to high average ratings for self-reported engagement and
for willingness to reconnect with their social partner, a majority of
older participants in this study showed high levels of engagement
and low levels of simulator sickness and workload. One pair of

Figure 3: Examples of Content-oriented Dominance (Pair 01, upper) and Task-oriented Dominance (Pair 14, lower).
participants ended up voluntarily exchanging contact information, which the researchers had not anticipated. These outcomes support the positive findings of the limited number of previous studies that have evaluated older adult’s responses to social VR environments [2, 3, 51, 57].

Drawing on our observation and thematic analysis of the interaction of different pairs, we identified features of the VR content design that promoted and hindered social engagement among the older adult participants. Self-introductions as part of the tasks in module 1 allowed our participants to discover their shared experiences or interests, which would lead to more conversations about their personal lives later in the more relaxed and “passive” video tours in module 2, sometimes even in module 3 where most participants had a lot of conversations about the assigned tasks. These findings are significant in that they indicate the diverse way content may impact the direction of interactions: task-oriented content tended to produce more immediate engagement, but most participants seemed to prioritize the broader conversations that emerged around and beyond the tasks. Conversations related to personal life experiences were more strongly associated with social connections and willingness to reconnect, as compared to conversations about the task content. This observation resembles the experiences of “socializers” or similar concepts in the online gaming literature [7, 8, 38], in describing the meaningful connections formed when people focus more on the other participants who share the space rather than focusing purely on the content. These findings support the importance of providing ample space and time in the VR content design for participants to engage with each other conversationally and to develop emerging narratives with their partners in a free-form fashion.

We paired our participants based on their personal schedules instead of personal characteristics, which resulted in pairs with various levels of similarities and differences. While not exhaustive, this approach allowed us to observe the effects of different strategies of pairing, an important aspect design of any social platform, on social interactions. Social dominance has been spotted among some of the participant pairs, where one participant led the activity and the other took a relatively passive role. While task-oriented and skill-oriented dominance was limited to the tasks at hand and unlikely to affect the social connections between our participants, content-oriented “dominance” where one participant talked, or tried to talk more than the other may result in frustration due to the lack of response, or (perceived) interest. The finding suggested the importance of pairing users based on their desired types or levels of social interaction: while some users prefer collaborative tasks in social VR, others may prefer idle conversations with more freedom.

In terms of technical features, we found that participants often expressed delight in the richness of the immersive world, and that they demonstrated a strong sense of spatial presence and identification with their avatars (e.g., by expressing a fear of heights in the VR, or a feeling of being “cold” when immersed in virtual water). There were, however, some important technical challenges that occurred during the study, in relation to both the hardware and software components. Many participants experienced frustrations with the unfamiliar, complex controllers. We recommend that a universal design approach to all aspects of VR equipment would be helpful to address these issues and make the experience more accessible. On the bright side, the older adult participants in our study were often able to help each other to overcome the technological challenges, which in some cases promoted social engagement. As one participant said, “We can get lost together.”

5.1 Design Implication

Based on our observations of older adult participants during the experiment, we suggest the following guidelines for future social VR designs. First, systems should encourage users to create their own stories and share their life experiences. Users should be given more flexibility to set aside or skip tasks when they want to focus on conversation (i.e., users can finish the task when they, not an algorithm, decide to do so). Open-ended or sandbox environments, similar to Second Life or even Minecraft could be more suited to promoting social interaction, as they allow users to interact with, explore, and discover the environment together instead of being fed pre-defined stories or experiences. Designers should continue to focus on the fidelity and customizability of avatars, so that they can properly convey facial expression, body language, and so forth as desired by users.

Second, systems should minimize confusing controls or other factors that could potentially distract or hinder users from social interaction. This includes adopting intuitive control schemes with quick learning curves, providing on-screen prompts for controller button use, establish input formats that can handle inadvertent button presses, and avoid complex actions that require multiple steps to perform. Simplistic controls as used in Journey and Book of Travels also have the potential to support and promote social interactions. Additional steps that VR technologies can take to improve social environments for older adults include adding support for adaptive/universal controllers, including options to increase font size, image contrast, and other accessibility functions, and developing lighter-weight head-mounted displays.

Finally, social VR systems should respect the characteristics of individual users. Pairing needs to be included as part of the design. Matching users according to interests, skill levels, and desired interaction styles can lead to better outcomes. While meeting diverse strangers may be considered an inherent good, users should have the ability to tailor these settings and convey what kind of social experiences they are interested in exploring at a given time. Designers should also acknowledge that some users have different means of relating to others (e.g., some individuals may only be interested in sharing VR experiences with people they already know in real-life, others may only be interested in shared activities rather than open-ended conversations, and so forth). Increasing the range of modules or available social formats can help in accommodating these diverse user needs.

5.2 Limitations and Future Work

One limitation of the study was in the sound-design of the environment—we did not decrease the volume of participants’ speech in relation to the distance between their avatars in the virtual environment. This design was an intentional choice, as we were concerned about potential hearing issues among our older adult population (and indeed, some participants asked us to turn up the volume on
the speaker to an extent that was uncomfortably loud for the research team). However, integrating distance-scaled sound might assist in promoting greater immersion and sense of presence in the VR [59]. More research is needed to evaluate how various features of VR technology may be adapted to physical impairments that are common among older adults, including various forms of hearing and vision loss as well as restricted mobility.

Another limitation of the study was the participant demographics. Our study skewed strongly toward female, White, and highly educated participants. Furthermore, while we included participants from several diverse cities, all of these sites were located within the United States, and we required participants to be fluent speakers of English. The impact of variables such as gender, nationality, and socioeconomic status (SES) on older adults’ VR socialization cannot really be known without more detailed work to address those factors. Future studies with more extensive participant samples may be able to address such demographic differences and analyze their effects. It would also be interesting to evaluate the effectiveness of VR technology for mediating social interactions and exchange among widely different individuals, such as older adults and younger adults, or between people who do not speak the same language.

The extent of moderation in VR social activities is another important variable. Our study used a relatively heavily moderated approach, particularly in the first two modules. Participants were assigned to a social partner by the researchers (based on matching schedules) and did not have a choice in this matter, and the moderating researcher was often strongly involved in initiating the introductory conversations. While a more open-ended social design might be preferable in some ways, it is important to proceed with caution and to evaluate the impact of such changes, especially when working with potentially vulnerable populations such as older adults. There is clearly a great deal of prospective research to carry out in this area to determine the optimal means of balancing user autonomy against potential risks (not to mention moderator fatigue) in the service of achieving the social program’s stated goals.

The order of activities undertaken after meeting a new partner might also be considered an important design factor. Our VR program design moved from a light introductory task (selecting a destination) to a “passive” video-based experience, and then to a more intensive memory and collage task. It would be interesting to explore the possibility of more fully interlacing passive and active material, or otherwise adjusting the order. Starting with an intensive task could potentially allow some initial bonds of cooperation to be established before giving participants more “breathing room” to introduce themselves and chat in an open-ended fashion. Furthermore, our modules included one with high interactivity and a clear goal (the memory/collage module), and another with low interactivity and no clear goal (the video module), but these are not the only possible activity designs. It would be interesting to examine additional possibilities, such as scenarios with high environmental interactivity but no clearly specified goal.

Finally, another factor to consider when designing VR applications is the period of use. Our environment was designed as a one-time experience, where users were able to meet new people, make introductions, and accomplish one simple task together in less than one hour. Such environments can potentially forge social connections that last after the experience, but duration is not built into the design. More persistent environments to which users can regularly return open a much broader array of social design possibilities, such as long-term collaborative tasks and achievements or the creation of clubs/guilds. Future experiments in this area might be conducted in a field-study manner, with initial training sessions with researchers followed by ongoing participant engagement with minimal supervision at home or in community centers. Such longitudinal studies would provide many additional insights about the ways long-term online VR interactions affect older adults’ social skills, feelings of connectedness, mental health, and overall quality of life.

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A DETAILED RESULTS OF ALL THE PARTICIPANTS

Figure 4: Occurrences of E, L, and M Labels over Time per Pair.
Table 4: Descriptive statistics for social interactions

| Pair | ID    | Number of Words | Engagement | Likeliness to Reconnect | Social Presence | Spatial Presence | Duration of Interaction (min) |
|------|-------|-----------------|------------|-------------------------|-----------------|------------------|-----------------------------|
| P1   | D001  | 1997            | 2          | 2.3                     | 47.7            | 9.3              | 29                          |
|      | W028  | 570             | 3.3        | 3                       | 56              | 9                |                             |
| P2   | D002  | 971             | 4.3        | 3.4                     | 37.7            | 5.8              | 27                          |
|      | F022  | 1174            | 4.3        | 3.6                     | 44.7            | 5.3              |                             |
| P3   | D003  | 2282            | 2.3        | 2.8                     | 56.8            | 4                | 29                          |
|      | W022  | 830             | 4          | 3.3                     | 92.8            | 9                |                             |
| P4   | D004  | 983             | 4.7        | 3.8                     | 98.7            | 10               | 29                          |
|      | F018  | 2643            | 5          | 4.5                     | 59.8            | 7.8              |                             |
| P5   | D006  | 1440            | 4.3        | 3.5                     | 64.7            | 8.3              | 34                          |
|      | F004  | 1604            | 4.7        | 4.5                     | 79.2            | 10               |                             |
| P6   | D007  | 2397            | 4.3        | 4.1                     | 54.2            | 8                | 41                          |
|      | F017  | 2072            | 5          | 4.5                     | 51.7            | 6.8              |                             |
| P7   | D008  | 1296            | 4.3        | 4.1                     | 90.5            | 8.8              | 36                          |
|      | F014  | 1656            | 4.3        | 4.3                     | 78.2            | 7                |                             |
| P8   | D013  | 2048            | 4.7        | 2.8                     | 81.7            | 9.3              | 56                          |
|      | W008  | 1437            | 5          | 5                       | 84.3            | 10               |                             |
| P9   | D015  | 642             | 3          | 3.3                     | 51.5            | 8                | 33                          |
|      | W011  | 1230            | 5          | 4.1                     | 50              | 10               |                             |
| P10  | D016  | 1337            | 3.7        | 3.5                     | 56.2            | 2.8              | 31                          |
|      | F009  | 1309            | 5          | 4.3                     | 86.5            | 8.3              |                             |
| P11  | F010  | 1066            | 4          | 2.8                     | 36.5            | 5                | 25                          |
|      | W012  | 1397            | 5          | 4.3                     | 76              | 9                |                             |
| P12  | F013  | 1661            | 2.7        | 3.1                     | 11.2            | 2                | 42                          |
|      | W013  | 2237            | 4.7        | 4.8                     | 46.8            | 8.5              |                             |
| P13  | W003  | 1000            | 4          | 4                       | 60.8            | 4                | 26                          |
|      | F005  | 1002            | 4          | 4.1                     | 52.7            | 5                |                             |
| P14  | W006  | 1344            | 5          | 4.4                     | 88              | 10               | 36                          |
|      | D005  | 2879            | 4.7        | 4.5                     | 71              | 9                |                             |
| P15  | W009  | 2114            | 4          | 3.6                     | 74.7            | 7.8              | 31                          |
|      | F016  | 1605            | 5          | 4.5                     | 79.3            | 8.8              |                             |
| P16  | W010  | 1822            | 2.3        | 2.3                     | 62              | 2.3              | 38                          |
|      | F008  | 1604            | 2.3        | 2                       | 37.7            | 5.8              |                             |
| P17  | W021  | 2761            | 4.7        | 3.1                     | 26.5            | 8.5              | 38                          |
|      | F012  | 921             | 5          | 3.9                     | 75.2            | 9.5              |                             |
| P18  | W024  | 797             | 5          | 5                       | 7.2             | 10               | 56                          |
|      | D010  | 3499            | 4          | 3                       | 75.5            | 6.8              |                             |
| Mean |       | 1600            | 4.2        | 3.7                     | 61.2            | 7.5              | 35                          |
| (SD) | (681) | (0.9)           | (0.8)      | (22.0)                  | (2.4)           | (9)               |                             |

Note: Possible Action and Self-Location sub-dimensions of Spatial Presence were added together for an overall score of Spatial Presence with a theoretical range of 2 to 10.