Being a Child Again: Investigating the Role of Self-Avatar in Virtual Reality-Based Reminiscence Therapy

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Fig. 1. Exploring the Role of Self-Avatars in VR-Based Reminiscence Therapy: Across two experiments, this study demonstrates how embodying self-avatars, particularly child-like avatars, in immersive VR environments significantly enhances memory recall and facilitates reminiscing, offering a novel approach to engaging older adults in meaningful memory retrieval.

The growing older adult population underscores the need for innovative approaches to addressing mental health challenges, particularly those related to cognitive function, emotional health, and psychological well-being. Reminiscence therapy (RT), a widely used intervention that encourages individuals to recall past experiences, has proven effective in addressing these challenges effectively. Virtual reality (VR) enhances the benefits of RT by creating immersive environments that deepen engagement with personal memories. However, most previous studies have focused on the effects of virtual scenery, leaving the potential impact of self-avatars -known to significantly influence users' experiences in VR- largely unexplored. This study addresses this gap by investigating the role of self-avatars in VR-based RT (VR-RT) through two experiments. In both experiments, adults aged 65 years and older recalled past events while immersed in virtual environments depicting mid-20th-century Japanese landscapes, corresponding to their childhood period. Experiment 1 investigated the effect of the presence of self-avatars, revealing that participants with self-avatars showed a marginally significant improvement in event specificity and significantly greater enhancements in cognitive function compared with those without the avatars. Experiment 2 explored the influence of self-avatar age by comparing child-like and older adult avatars. Participants using child-like avatars recalled events with significantly greater specificity. These findings demonstrate that VR-RT, enhanced by self-avatars and its age design, may serve as a powerful tool for improving the mental health of older adults.

CCS Concepts: • **Human-centered computing** → **Virtual reality**; *Laboratory experiments*; *Empirical studies in HCI*.

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1 Introduction

The global population is experiencing unprecedented demographic aging. According to a 2024 United Nations report, adults aged 65 and older currently represent approximately 10 % of the total population and are projected to outnumber children under 18 by 2080 [1]. Japan, exemplifies this demographic transformation, with individuals aged 65 and older constituting 29.3 % of its population as of September 2024, the highest proportion worldwide [2]. This significant demographic shift necessitates urgent attention to mental health challenges affecting older adults, including cognitive decline [74] and diminished psychological well-being [4, 12, 74]. Addressing these challenges is crucial, as promoting the mental health among older adults not only enhances individual quality of life but also reduces societal burdens through decreased healthcare costs and alleviated caregiver stress [21].

Reminiscence therapy (RT), a psychological intervention encouraging individuals to recall and share past experiences [15, 104], has emerged as a promising approach for improving mental health in older adults. This therapeutic approach typically incorporates external stimuli, such as photographs and music, to facilitate memory recall [104]. Research has demonstrated RT's effectiveness in enhancing multiple dimensions of mental health including cognitive function [18, 108], emotional well-being [51, 62, 83], and psychological stability [47, 93]. Recent innovations have integrated virtual reality (VR) technology into RT as a memory-triggering stimulus. Studies indicate that VR's immersive capabilities significantly enhance mental health outcomes for elderly individuals and dementia patients [34, 56, 106], showing superior efficacy compared to conventional RT approaches [96].

While previous studies have clarified the effects of VR scenery, a critical gap remains: the effects of self-avatars have not been thoroughly investigated. Among the components of VR, self-avatars are known to play a crucial role during VR experiences. For example, the presence of self-avatars is known to enhance immersion in VR experiences [85, 99] and influence users' perception [53] and cognition [13, 14, 60, 87]. Furthermore, child-like avatars have been suggested to evoke a sense of youthfulness [91], which may facilitate reminiscing and enrich RT outcomes. These effects suggest that incorporating self-avatars into VR-RT could amplify its therapeutic benefits by fostering deeper emotional engagement and facilitating richer reminiscing experiences. Bridging this gap is therefore crucial for advancing the effectiveness of VR-RT.

This study addresses this gap by investigating the influence of self-avatars on VR-RT. We conducted two experiments with older adults. The first experiment (Experiment 1) investigated whether the presence of self-avatars promotes reminiscing and enhances the effectiveness of VR-RT by comparing conditions with and without self-avatars. Subsequently, another experiment (Experiment 2) examined the effect of the age of self-avatars on VR-RT, through a comparison between conditions embodying a child avatar and an older adult avatar.

The primary contributions of this study are (1) demonstrating that the presence of self-avatars can enhance the effectiveness of VR-RT and (2) showing that embodiment in child-like self-avatars within VR promotes reminiscing,

[1] https://population.un.org/wpp/
[2] https://www.stat.go.jp/data/topics/topi1420.html

compared to using those resembling older adults. By shedding light on the role of self-avatars in VR-RT, this study provides insights into designing more effective interventions for improving the mental health of older adults.

2 Related Work

2.1 Reminiscence Therapy

Autobiographical memory (AM) is a specific type of episodic memory that involves recalling events and experiences from an individual's life [65]. Episodic memory captures events within temporal and spatial contexts [98]; however, AM extends this by incorporating self-related meanings, emotions, and the significance of events in the individual's life [17, 29]. For example, rather than simply recalling the episode of seeing the sea during a trip, AM encompasses subjective elements such as the happiness felt at that moment or the importance of time spent with family. Recalling AM has several important effects, such as facilitating self-understanding [35] and identity formation [17], aiding emotional processing and regulation [9, 37, 71], influencing self-perception [24, 36] and behavior [27, 82], and enhancing social interactions [89].

RT is a clinical intervention that leverages the multifaceted benefits of AM recall by encouraging individuals to recall and share past experiences [100, 105]. It reduces depressive symptoms [51, 62, 83] and improves psychological well-being [47, 93] and cognitive functions [18, 108], rendering it a promising approach to promote healthy aging [73].

RT is generally conducted in groups or individually [80]. Group RT fosters social connections through shared memories, reducing depressive symptoms and enhancing communication skills [33, 41, 90]. Conversely, individual RT, conducted one-on-one, is associated with deeper self-understanding and positive effects on cognitive functions [16, 31, 38, 88]. Both approaches often utilize external cues, such as music, photos, and videos, to enhance memory vividness and facilitate recall [104].

Visual cues are particularly effective in facilitating AM recall. Specifically, detailed and vivid visual stimuli, such as images or drawings, provide rich perceptual details that align closely with stored memories, enhancing recall more effectively than verbal descriptions [23, 67, 78]. This underscores the importance of visual processing in AM recall and suggests that increasing the amount of visual information can promote vivid memory recall and emotional arousal [17, 28, 70]. From this perspective, VR, which enables multi-dimensional visual presentation, has garnered attention [6, 22]. VR enhances RT by enabling users to virtually experience past scenes in immersive environments, thereby improving cognitive functions and psychological well-being [26, 42]. Indeed, Tominari et al. [96] demonstrated that VR-RT using panoramic images led to greater improvements in subjective well-being compared with traditional methods using static pictures. Ng et al. [55] reviewed VR-RT and highlighted its benefits, including reductions in anxiety [56] and depressive symptoms [34], improved life satisfaction [76], and maintenance or enhancement of cognitive function [34, 66, 75, 96].

VR has been widely introduced in RT; however, the use of self-avatars - a crucial component of the VR experience (as described in Section 2.2)- in VR-RT remains underexplored. Existing studies utilizing avatars in VR-RT [2, 6] have been conducted in group settings, where participants often focus their attention on others' avatars rather than theirs [72], potentially diminishing the individual impact of self-avatar embodiment. In contrast, individual RT eliminates such distractions, creating conditions where self-avatars can maximize their positive effects on cognitive and perceptual processes. This study addresses these gaps by exploring the effects of self-avatars in individual RT, thereby advancing our understanding of their potential to enhance VR-RT practices.

2.2 Self-Avatar in VR

Prior research on VR has extensively examined how embodying self-avatars can alter users' perception and cognition. For example, the sense of presence in VR experiences is enhanced when self-avatars are displayed and synchronized with the users' movements [85, 99]. Additionally, the presence of self-avatars can improve spatial proximity accuracy [53] and memory recall by reducing cognitive load and promoting natural interactions [13, 14, 60, 87]. These findings suggest that using self-avatars enhances the sense of presence and facilitates cognitive processes, providing a solid foundation for examining self-representation in VR. Building on this foundation, Experiment 1 investigated the effect of self-avatars on VR-RT by comparing conditions with and without self-avatars, attempting to prove the hypothesis that the presence of self-avatars would promote the effectiveness of VR-RT.

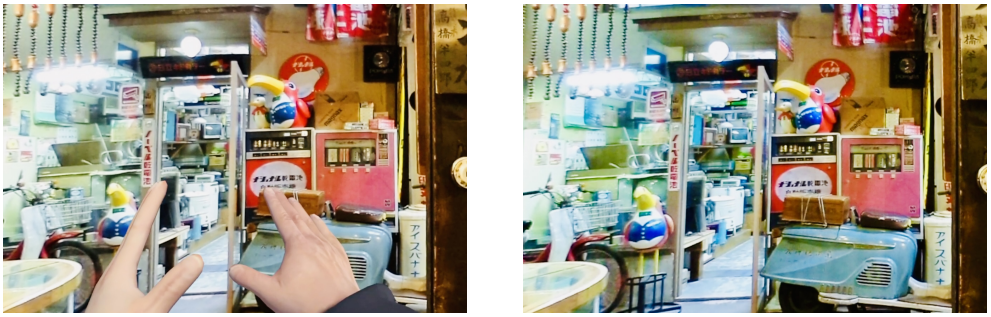
Furthermore, the appearance of self-avatars can influence users' cognition and behavior based on associated stereotypes or traits, a phenomenon known as the *Proteus effect* This effect posits that users adapt their attitudes and actions to align with the perceived characteristics of their avatars [107]. For instance, taller or attractive self-avatars increase users' confidence and assertiveness [107]. Similarly, embodying an Einstein-like avatar enhances cognitive task performance compared to embodying avatars resembling peers [8].

An intriguing factor among the various avatar attributes is the age of the self-avatars, which has been manipulated in some studies. For example, Liu & Xu [94] demonstrated that older adults embodying younger avatars during VR-based exercises reported increased motivation and physical activity levels. Conversely, Reinhard et al. [64] discovered that adult participants embodied with elderly avatars exhibited slower walking speeds, suggesting that avatar age can directly influence physical behavior. Beyond these behavioral outcomes, manipulating an avatar's age can yield noticeable cognitive and perceptual changes in adult participants. Banakou et al.[7] reported that adults who embody child avatars experience perceptual and cognitive shifts. Similarly, Tajadura-Jimenez et al. [91] reported that adult participants felt younger and experienced more positive emotions when using child avatars, particularly when their voices matched the avatars' appearance. These findings underscore the multifaceted impact of avatar age on user experience, encompassing immediate behavioral responses and underlying cognitive processes.

These studies on avatar age manipulation have often compared avatars matching a participant's actual age with those that are noticeably younger or older, examining how such manipulations influence users' cognition and behavior. Based on this framework, Experiment 2 in this research also employed and compared two avatar conditions for older adults: an avatar representing their current age and another embodying a child to evoke their childhood . By examining these contrasting conditions, this study aimed to investigate the effect of embodying a child avatar on the outcome of VR-RT.

3 Experiment 1

Experiment 1 investigated the effect of the presence of self-avatars on the outcome of VR-RT. Participants engaged in tasks designed to recall past events in childhood environments rendered in VR across three separate sessions, either with or without the presence of self-avatars. Previous studies have revealed that embodiment through self-avatars can enhance memory recall in VR spaces [13, 14, 60, 87]. Thus, we hypothesized that the presence of a self-avatar promotes reminiscence and amplifies its emotional, cognitive, and psychological benefits. The local ethics committee approved this study.



(a) Avatar condition (b) Non-Avatar condition

Fig. 2. Conditions in Experiment 1. In the Avatar condition, a self-avatar of the same sex as the participant was displayed within the VE, whereas in the Non-Avatar condition, only the VE was displayed. The VEs wee created using 360-degree images depicting mid-20th-century Japanese landscapes, corresponding to the participants' childhood period.

3.1 Design

This experiment was conducted using a between-participants design with one factor and two levels. Participants were assigned to either the *Avatar condition* (five men and seven women aged 73.8 ± 4.26 (*SD*) years) or the *Non-Avatar condition* (six men and six women aged 73.4 ± 5.30 (*SD*) years). The Avatar condition included a self-avatar with tracked head and hand movements displayed within the virtual environment (VE), whereas the Non-Avatar condition featured only the VE without any avatar representation (Figure 2).

3.2 System

The experimental apparatus comprised a Windows computer and a Meta Quest 3 for the virtual experiences. We implemented the VR system using Unity [3] (version: 2021.9.3f1).

We selected 360-degree images for the VE from the Takayama Showa Museum website [4] with permission, following the methodology of Tominari et al. [96]. These images depicted mid-20th-century Japanese landscapes corresponding to the participants' childhood period, including scenes such as a school classroom, clinic, and shopping street. The order of the VEs was randomized and counterbalanced across participants to avoid order effects.

We used two self-avatars representing typical young Japanese men [5] and women [6], sold by Atelier Brown Co. Each participant was assigned a same-sex avatar to eliminate the potential cognitive effects of using avatars of different sexes [10]. Additionally, participants' head and hand movements were tracked and reflected in the movements of their self-avatars within the VR to enhance their sense of embodiment and immersion [32].

3.3 Participants

This experiment included 24 participants (11 men and 13 women aged 73.6 ± 4.71 (*SD*) years), recruited through a local senior human resource center. They were required to be Japanese-speaking individuals aged 65 years or older to ensure familiarity with the mid-20th-century Japanese landscapes used in the experiment. They were also required

[3] https://unity.com/ja
[4] https://showakan.jp/gallery/360degree/
[5] https://ddd.pink/product/064_syun-2/
[6] https://ddd.pink/product/002_rika-2/

to have no significant cognitive impairments or severe visual/hearing disabilities as determined by the Mini-Mental State Examination (MMSE) and a pre-experimental behavioral assessment. Furthermore, participants must not have undergone RT in the past three months to maintain experimental control and avoid potential confounding effects, .

3.4 Measurements and Hypotheses

3.4.1 Cognitive Characteristics. Participants' cognitive characteristics were assessed using the MMSE [25]. The MMSE scores range from 0 to 30, with higher scores indicating better cognitive function. Scores below 23 suggest possible dementia [3, 25], and scores below 27 indicate suspected mild cognitive impairment [39, 77, 95]. As the MMSE is not designed to detect short-term changes, we used it to assess participants' baseline cognitive characteristics in this study.

3.4.2 Reminiscence. The specificity of reminiscence was evaluated using the Test épisodique de mémoire du passé autobiographique (TEMPau) Scale [11, 43, 63]. Each retrieved event was rated from zero to four points: zero points for no memory or only general information, one point for repeated or extended events, two points for events situated in time or space, three points for specific events lasting less than 24 hours and situated in time and space, four points for specific events situated in time and space enriched with phenomenological details, such as emotions, thoughts, and visual imagery. Consequently, the maximum possible score for each condition is 12 points (four points × three events). Based on prior studies demonstrating that self-avatars within VR enhance the sense of presence [85, 99] and memory recall [13, 14, 60, 87], we proposed the following hypothesis:

H1-1 TEMPau scores will be higher in the Avatar condition than in the Non-Avatar condition.

3.4.3 Reminiscence Therapy Effects. The effects of RT were assessed using three key measures: the Self-Assessment Manikin (SAM) [102], Paced Auditory Serial Addition Test (PASAT) [30], and Revised PGC Morale Scale [45].

First, we assessed emotional states using the SAM, which includes two indices: *Valence*, representing the positivity or negativity of emotions, and *Arousal*, indicating the intensity of emotions. Participants rated their current state by selecting an illustration on a scale of 1 to 9 that best matched their feelings. Higher Valence scores indicated more positive emotions, and higher Arousal scores reflected more intense emotions.

Next, we employed the PASAT to measure comprehensive cognitive functions, including attention, processing speed, and working memory. Participants listened to sequences of 60 numbers presented at fixed intervals—either 2-second or 1-second intervals— and were required to provide the sum of the last two numbers immediately. Practice sessions were conducted before the tests to ensure familiarity with the task and minimize learning effects.

Finally, the Revised PGC Morale Scale was used to evaluate the psychological well-being of older adults. This 11-item questionnaire, structured as a series of Yes/No questions, covers domains such as agitation, attitude toward aging, and dissatisfaction, with higher total scores reflecting greater levels of subjective well-being.

These three measurements were administered both before and after the experiment. Based on prior research demonstrating that VR-RT enhances emotion, cognitive functions, and psychological well-being [6, 22, 26, 42] and that self-avatars amplify VR effects [13, 14, 60, 87], we hypothesized that the presence of self-avatars would strengthen the effects of reminiscence therapy. Thus, the following hypotheses were proposed:

H1-2a Participants in the Avatar condition will report greater positive changes in Valence compared to those in the Non-Avatar condition.

H1-2b Participants in the Avatar condition will report greater positive changes in Arousal compared to those in the Non-Avatar condition.

H1-3a Cognitive performance improvements on PASAT with 2-second intervals will be greater in the Avatar condition compared to the Non-Avatar condition.

H1-3b Cognitive performance improvements on PASAT with 1-second intervals will be greater in the Avatar condition compared to the Non-Avatar condition.

H1-4 Participants in the Avatar condition will exhibit greater improvements in psychological well-being scores compared to those in the Non-Avatar condition.

3.4.4 VR Experience. The VR experience was evaluated using two 7-point Likert scales: the Igroup Presence Questionnaire (IPQ) [79] and the Virtual Embodiment Questionnaire (VEQ) [69]. The IPQ assessed the sense of presence within the VR after each VR session for both the Avatar and Non-Avatar conditions. Based on prior research demonstrating that self-avatars enhance the sense of presence in VR [85, 99], the following hypothesis was proposed:

H1-5 IPQ scores will be higher in the Avatar condition compared to the Non-Avatar condition.

We used the VEQ to evaluate the sense of embodiment with the self-avatar. It comprises three subscales: *Ownership*, which measured the extent to which participants felt the avatar was part of their body; *Control*, reflecting the perceived ability to control the avatar's movements; and *Change*, assessing any perceived transformation in the participant's bodily self-perception. The VEQ was administered only in the Avatar condition, as the absence of self-avatars in the Non-Avatar condition made it inapplicable. Based on prior research demonstrating that a higher sense of embodiment facilitates memory recall [50, 97], the following hypotheses were proposed:

H1-6a Scores on the Ownership subscale will positively correlate with the specificity of the retrieved events.

H1-6b Scores on the Control subscale will positively correlate with the specificity of the retrieved events.

H1-6c Scores on the Change subscale will positively correlate with the specificity of the retrieved events.

3.5 Procedures

Participants were provided with a detailed explanation of the experiment and gave their informed consent before proceeding. Subsequently, cognitive function was assessed using the MMSE. Participants scoring below the cutoff of 27 points, indicating a potential mild cognitive impairment, were to be excluded from the study; however, no participants met this exclusion criterion, as detailed later in Section 3.6.1. The participants then completed three assessments: the SAM, PASAT, and Revised PGC Morale Scale. Following the preliminary assessments, each participant performed three rounds of the reminiscence task under either the Avatar or Non-Avatar conditions.

At the start of each round, the participants donned the VR headset and spent 60 seconds looking around the VE, followed by a 30-seconds performing a reaching task in which they touched cubes that appeared sequentially in front of them. During this looking around and reaching period, a virtual mirror was displayed for participants in the Avatar condition, enabling them to observe their self-avatars. Subsequently, the mirror was removed to avoid disrupting the environment. Participants then engaged in a three-minute reminiscence task in which they recalled and described a specific, significant event from their life that lasted less than 24 hours as specifically and accurately as possible. A countdown timer was displayed throughout the VR session to indicate the remaining time. Upon completing the reminiscence task, participants removed the VR headset and completed the IPQ to assess their sense of presence. Participants in the Avatar condition also completed the VEQ to evaluate their sense of embodiment.

This sequence was repeated three times, with different VEs presented in each round. At the end of the experiment, participants completed the SAM, PASAT, and Revised PGC Morale Scale again and provided verbal feedback on the experiment.

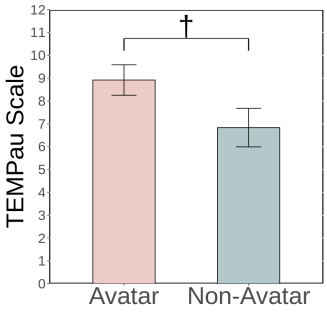
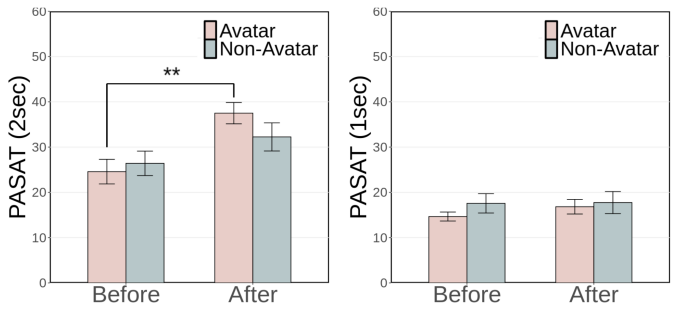


Fig. 3. Results of TEMPau Scale. There was a marginally significant trend where the TEMPau Scale score in the Avatar condition was higher than in the Non-Avatar condition. † : $p < .1$.



(a) 2-sec interval (b) 1-sec interval

Fig. 4. Results of PASAT task. For the 2-second interval task (a), a main effect of Timing was observed, and post hoc analysis revealed that scores were significantly higher after the experiment compared to before only in the Avatar condition. No significant effects were found in the 1-second interval task (b). **: $p < .01$.

3.6 Results

3.6.1 Participants Characteristics. No significant differences in age were observed between the two conditions (Wilcoxon rank-sum test, $p = .79$). Regarding cognitive characteristics, the MMSE scores for both the Avatar and Non-Avatar conditions ranged from 29 to 30, with no participants scoring below the threshold of 27 points, which indicates mild cognitive impairment. Consequently, all 24 recruited participants were included in this experiment without exclusion. No significant differences in the MMSE scores were observed between the two conditions (Wilcoxon rank-sum test, $p = .38$).

3.6.2 Reminiscence. Figure 3 illustrates the specificity of the retrieved events as measured by the TEMPau Scale. A Wilcoxon rank-sum test revealed a marginally significant trend, with scores in the Avatar condition being higher than those in the Non-Avatar condition ($p = .074$, Cohen's $r = 0.36$).

3.6.3 Reminiscence Therapy Effects. The effects of VR-RT were analyzed using a two-way ANOVA with factors of *Condition* (Avatar, Non-Avatar) and *Timing* (Before, After). When normality was violated (Shapiro-Wilk test, $p < .05$), the aligned rank transform (ART) [103] was applied before analysis.

First, Valence and Arousal were measured using the SAM. Regarding Valence, the main effect of the Condition was not significant (F (1, 22) = 0.67, $p = .42$, $\eta_p{}^2 = 0.030$); however, the main effect of the Timing was significant (F (1, 22) = 5.51, $p = .028$, $\eta_p{}^2 = 0.20$), indicating higher score after the experiment compared to before. The interaction effect was not significant (F (1, 22) = 0.48, $p = .50$, $\eta_p{}^2 = 0.021$). Arousal exhibited no significant effects for the Condition (F (1, 22) = 0.71, $p = .41$, $\eta_p{}^2 = 0.03$), Timing (F (1, 22) = 1.65, $p = .21$, $\eta_p{}^2 = 0.070$) or their interaction (F (1, 22) = 0.99, $p = .33$, $\eta_p{}^2 = 0.04$).

Second, the results of the PASAT task are illustrated in Figure 4. In the 2-second interval task, the main effect of the Condition was not significant(F (1, 22) = 0.24, $p = .63$, $\eta_p{}^2 = 0.011$). However, the main effect of Timing (F (1, 22) = 33.1, $p < .001$, $\eta_p{}^2 = 0.60$) and the interaction effect (F (1, 22) = 4.73, $p = .041$, $\eta_p{}^2 = 0.18$) were significant. Subsequently, post hoc tests were conducted to examine the simple main effects. For the Condition factor, no significant differences were observed between the Avatar and Non-Avatar conditions at both Timings (Before: $p = .64$, Cohen's $r = 0.10$; After:

p = .28, Cohen's r = 0.22). For the Timing factor, Wilcoxon rank-sum tests revealed no significant differences for the Non-Avatar condition (p = .22, Cohen's r = 0.25), whereas, in the Avatar condition, scores were significantly higher after the reminiscence tasks than before (p = .0017, Cohen's r = 0.64). In the 1-second interval task, none of the main effects for Condition, Timing, or their interaction were significant.

Finally, the total score of the Revised PGC Morale Scale exhibited no significant main effects for Condition (F (1, 22) = 0.17, p = .68, $\eta_p{}^2$ = 0.01) or interaction effect (F (1, 22) = 0.88, p = .36, $\eta_p{}^2$ = 0.04). However, a marginally significant main effect of Timing was observed (F (1, 22) = 3.52, p = .074, $\eta_p{}^2$ = 0.13), suggesting a trend toward higher scores after the tasks compared to before.

3.6.4 VR Experience. Wilcoxon rank-sum tests revealed no significant differences in the IPQ Presence scores between the two conditions (p = .14, Cohen's r = 0.17). Additionally, Pearson's correlation analyses revealed no correlations between the reminiscence scores and the scores of the VEQ subscales for Ownership (p = .21, r = 0.21), Control (p = .49, r = 0.12), and Change (p = .27, r = 0.19).

3.7 Discussion

3.7.1 Reminiscence. The specificity of retrieved events, measured by the TEMPau Scale, demonstrated a marginally significant trend, with higher scores in the Avatar condition than in the Non-Avatar condition, partially supporting H1-1. This trend suggests that the presence of self-avatars may have enhanced AM retrieval, aligning with prior studies demonstrating that self-avatars within VR facilitate memory recall [13, 14, 60, 87]. One potential explanation for this outcome is that the self-avatars may have activated self-referential processing, a mechanism by which individuals deeply process self-related information and integrate it into thier memory [58, 101]. The alignment of participants' movements with their self-avatars likely facilitated this process, enhancing detailed recall. This is reflected in participants' remarks, such as, *"It felt like I was stepping into the past landscape with the body, and memories started to resurface"*. Another explanation is that the use of self-avatars may have enhanced participants' psychological safety through increased anonymity. Qualitative studies have demonstrated that self-avatars in VR experiences can reduce anxiety about being observed and encourage greater self-expression [20, 59]. In this experiment, participants in the Avatar condition engaged in reminiscence tasks using their self-avatars, which may have helped reduce psychological barriers and facilitated more open and expressive verbalizations.

However, the results did not reach conventional levels of statistical significance, warranting cautious interpretation. The moderate effect size (Cohen's r = 0.36) suggests a potentially meaningful effect; however, several factors may explain the lack of significance. One possible explanation is the insufficient impact of self-avatars on participants' sense of presence, as measured by the IPQ (H1-5: unsupported). As the sense of presence has been linked to improved memory recall [40, 46], the absence of a notable increase in presence in the Avatar condition could have attenuated its impact on memory retrieval. The lack of significant differences in presence scores contrasts with prior research demonstrating that self-avatars enhance the sense of presence in VR [85, 99], indicating that the design or implementation of self-avatars in this study may not have been as impactful as anticipated. Notably, only three out of 12 participants in the Avatar condition reported paying attention to their self-avatars, particularly during the reminiscing phase, where the virtual mirror was not shown. This lack of focus on their self-avatars likely further diminished their potential to enhance their sense of presence. Furthermore, the VEQ results also offer insights into the limited effects of the self-avatars. Although the VEQ was administered only in the Avatar condition, the lack of significant correlations between the subscales (Ownership, Control, and Change) and the TEMPau Scale scores (H1-6a, H1-6b, H1-6c) suggests that the sense

of embodiment with the self-avatars might not have been sufficiently robust to substantially enhance memory recall. Participant's feedback supports this interpretation, with one remarking, *"It felt like the avatar was someone mimicking my movements,"* and referring to it as "that person" (not "me"), highlighting a lack of identification with the self-avatar. This detachment likely limited the degree to which self-referential processing was activated, reducing its effect on detailed memory retrieval.

3.7.2 Reminiscence Therapy Effects. The PASAT result for the 2-second interval task revealed that participants in the Avatar condition demonstrated greater improvement in cognitive performance than those in the Non-Avatar condition, supporting H1-3a. This suggests that the presence of self-avatars facilitated the effects of VR-RT on cognitive functions [34, 66, 75, 96]. As discussed earlier, the display of self-avatars likely enhanced the self-referential processing [14, 87], enabling efficient cognitive resource allocation by prioritizing self-related information, effectively activating neural networks [58, 101]. This process may have transformed the reminiscence task into a form of cognitive training exercise, enhancing attentional flexibility and information processing, thereby enhancing cognitive performance. The difficulty of the 2-second interval task may also have influenced the results. Compared with the 1-second intervals, where no significant differences were observed (H1-3b unsupported), the cognitive demands of the 2-second intervals were moderate, providing an opportunity to efficiently utilize the cognitive resources activated by the reminiscence task. This likely made the cognitive enhancement effects of self-avatars more detectable.

However, no such differences were observed in the measures of emotion (SAM) or psychological well-being (Revised PGC Morale Scale); this observation failed to support H1-2a, H1-2b, and H1-4. This result might be because the reminiscence task itself had a strong overall effect [9, 37, 81], as evidenced by the significant (for Valence) or a marginally significant (for the Revised PGC Morale Scale) main effects of Timing. This general effectiveness likely left minimal scope for additional effects from the presence of the self-avatar, as both conditions benefitted from the inherently evocative nature of recalling past memories.

4 Experiment 2

Experiment 2 investigated the effect of self-avatar age on VR-RT. Participants engaged in reminiscence tasks while embodying a self-avatar, represented as either a child or an older adult. Building on prior research indicating that embodying a child self-avatar can evoke a sense of being younger and enhance emotional, cognitive, and psychological outcomes [7, 91], we hypothesized that using a child self-avatar in VR-RT would foster more detailed reminiscence and enhance the emotional, cognitive, and psychological effects of RT compared to an older adult self-avatar. The local ethics committee also approved this experiment.

4.1 Design

The experiment used a between-subjects design with one factor and two levels. Participants were assigned to either the *Child Avatar condition* (six men and six women aged 74.4 ± 2.75 (*SD*) years), where the self-avatar was represented as a child, or the *Old Avatar condition* (six men and six women aged 74.5 ± 2.43 (*SD*) years), where the self-avatar was represented as an older adult (Figure 5). The assignment was balanced to ensure similar distributions of age and sex across conditions, and the participants performed reminiscence tasks.

(a) Child Avatar condition (b) Old Avatar condition

Fig. 5. Conditions in the Experimental 2. In the Child Avatar condition, the self-avatar was represented as a child, while in the Old Avatar condition, it was represented as an older adult. A virtual mirror was always displayed in front of the participants, allowing them to observe their self-avatars.

4.2 Participants

This experiment included 24 participants (12 men and 12 women, aged 74.5 ± 2.54 (*SD*) years), recruited through a local senior human resource center. In addition to the eligibility criteria in Experiment 1, participants were required not to have participated in Experiment 1 to prevent behavioral bias due to prior knowledge.

4.3 Method

The procedures, measurements, and VR system used in Experiment 2 were largely identical to those used in Experiment 1. We hypothesized that the specificity of retrieved memories and the effects of RT on emotion, cognitive function, and psychological well-being, and the sense of presence in the Child Avatar condition would be greater than those in the Old Avatar condition:

H2-1 TEMPau scores will be higher in the Child Avatar condition than in the Old Avatar condition.

H2-2a Participants in the Child Avatar condition will report greater positive changes in Valence compared to those in the Old Avatar condition.

H2-2b Participants in the Child Avatar condition will report greater positive changes in Arousal compared to those in the Old Avatar condition.

H2-3a Cognitive performance improvements on PASAT with 2-second intervals will be greater in the Child Avatar condition compared to the Old Avatar condition.

H2-3b Cognitive performance improvements on PASAT with 1-second intervals will be greater in the Child Avatar condition compared to the Old Avatar condition.

H2-4 Participants in the Child Avatar condition will exhibit greater improvements in psychological well-being scores compared to those in the Old Avatar condition.

H2-5 IPQ scores will be higher in the Child Avatar condition compared to the Old Avatar condition.

However, four key differences were introduced compared to Experiment 1. First, in this experiment, we used four 3D models provided by Atelier Brown Co. as self-avatars: child-male [7], child-female [8], old-male [9], and old-female avatar [10].

Second, although the virtual mirror was hidden during the reminiscence tasks in Experiment 1, it remained visible throughout the entire VR experience in Experiment 2. This change was implemented because feedback from Experiment 1 indicated that the participants did not pay sufficient attention to their self-avatars during reminiscence.

Third, the VEQ was administered in both conditions to evaluate the participants' perceived sense of embodiment. Plausibility,which emerges from the congruency between cues and the VR experience, has been suggested to influence the sense of embodiment [44]. In this experiment, the congruency between the Child Avatar and the VR experience, with reminiscence tasks within childhood landscapes, was hypothesized to enhance plausibility and thereby strengthen the sense of embodiment.

H2-6a Scores on the Ownership subscale will be higher in the Child Avatar condition compared to the Old Avatar condition.

H2-6b Scores on the Control subscale will be higher in the Child Avatar condition compared to the Old Avatar condition.

H2-6c Scores on the Change subscale will be higher in the Child Avatar condition compared to the Old Avatar condition.

Finally, participants additionally responded to two questions—*"I felt as though I became **older** through the experiment"* and *"I felt as though I age became **younger** through the experiment"*—using a 7-point Likert scale ranging from 1 (Strongly disagree) to 7 (Strongly agree). These questions were included to assess the psychological impact of the experimental conditions on participants' subjective age perceptions. Building on previous research suggesting that embodying a child avatar induces a sense of rejuvenation [91], we hypothesized that participants in the Child Avatar condition would feel significantly younger and less older compared to those in the Old Avatar condition:

H2-7a Participants in the Old Avatar condition would feel significantly older than those in the Child Avatar condition.

H2-7b Participants in the Child Avatar condition would feel significantly younger than those in the Old Avatar condition.

4.4 Results

4.4.1 Participants Characteristics. No significant differences in age were observed between the Child and Old Avatar conditions (Wilcoxon rank-sum test, $p = .79$). Regarding cognitive characteristics, no significant differences existed in the MMSE scores between the two conditions (Wilcoxon rank-sum test, $p = .38$).

4.4.2 Reminiscence. The results of the TEMPau Scale, which evaluates the specificity of the retrieved events, are presented in Figure 6. A Wilcoxon rank-sum test revealed that the scores were significantly higher in the Child Avatar condition compared to the Old Avatar condition ($p = .0095$, Cohen's $r = 0.53$).

4.4.3 Reminiscence Therapy Effects. For the three measures assessing the effects of VR-RT, a two-way ANOVA was conducted using factors: Condition (Child Avatar, Old Avatar) and Timing (Before, After). When normality was violated (Shapiro-Wilk test, $p < .05$), the aligned rank transform (ART) [103] was applied prior to analysis.

[7] https://ddd.pink/product/228_rui-k/
[8] https://ddd.pink/product/245_emi/
[9] https://ddd.pink/product/048_ken-2/
[10] https://ddd.pink/product/197_uta/

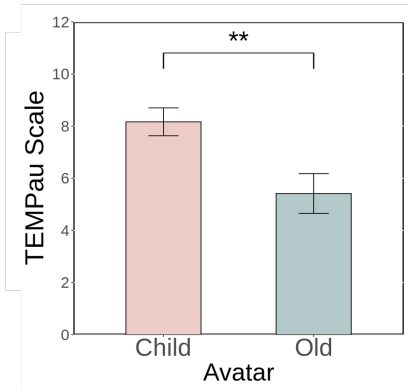


Fig. 6. TEMPau Scale results. Specificity scores of retrieved events were significantly higher in the Child Avatar condition than in the Old Avatar condition. (** : $p < .01$).

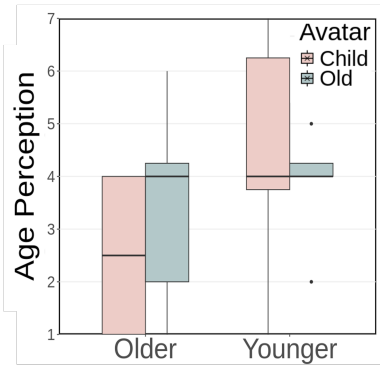
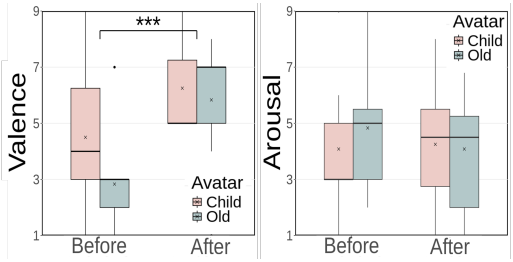
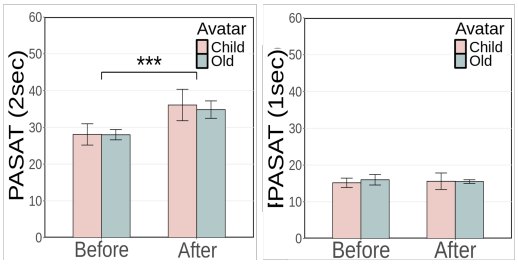


Fig. 7. Results of questions assessing participants' subjective age perception (Older and Younger). No significant differences were observed between the Child and Old Avatar conditions for either measure.



(a) Valence (b) Arousal

Fig. 8. SAM results. Error bars indicate standard errors. A main effect of Timing (Before, After) was observed for Valence (***: $p < .001$).



(a) 2-sec Interval (b) 1-sec Interval

Fig. 9. PASAT results. Error bars indicate standard errors. A main effect of Timing (Before, After) was observed for the 2-second interval task (***: $p < .001$).

First, Figure 8 illustrates the emotional results measured by the SAM, with Valence and Arousal indices. For Valence, the main effect of Condition was not significant (F (1, 22) = 0.99, p = .33, $\eta_p{}^2$ = 0.043), whereas the main effect of Timing was significant (F (1, 22) = 27.7, $p < .001$, $\eta_p{}^2$ = 0.56), indicating that scores were significantly higher after the experiment than before. The interaction effect exhibited a marginally significant trend (F (1, 22) = 3.56, p = .072, $\eta_p{}^2$ = 0.14). For Arousal, none of the main effects of Condition (F (1, 22) = 0.34, p = .56, $\eta_p{}^2$ = 0.015) and Timing (F (1, 22) = 0.51, p = .48, $\eta_p{}^2$ = 0.023) nor the interaction effect (F (1, 22) = 0.51, p = .48, $\eta_p{}^2$ = 0.023) were significant.

Second, Figure 9 presents the results of the PASAT task. For the 2-second interval task, the main effect of Timing was significant (F (1, 22) = 660.1, $p < .001$, $\eta_p{}^2$ = 0.51), indicating that scores were significantly higher after the experiment than before. However, neither the main effect of Condition (F (1, 22) = 0.030, p = .86, $\eta_p{}^2$ = 0.001) nor the interaction effect (F (1, 22) = 0.14, p = .71, $\eta_p{}^2$ = 0.006) was significant. For the 1-second interval task, no significant main effects or interactions were observed (Condition: F (1, 22) = 0.040, p = .84, $\eta_p{}^2$ = 0.00; Timing: F (1, 22) = 0.000, p = .97, $\eta_p{}^2$ = 0.000; Interaction: F (1, 22) = 0.23, p = .64, $\eta_p{}^2$ = 0.002).

Finally, the results of the Revised PGC Morale Scale were analyzed. Neither the main effects of Condition ($F(1, 22) = 0.012$, $p = .91$, $\eta_p{}^2 = 0.00$) nor Timing ($F(1, 22) = 0.15$, $p = .70$, $\eta_p{}^2 = 0.00$) were significant. The interaction effect showed a marginally significant trend ($F(1, 22) = 3.87$, $p = .062$, $\eta_p{}^2 = 0.15$).

4.4.4 VR Experience. The Presence scores from the IPQ and the subscale scores of the VEQ were analyzed using the Wilcoxon rank-sum tests. No significant differences were observed between the two conditions in either the IPQ Presence score ($p = .37$, Cohen's $r = 0.18$) or any of the three VEQ subscales: Ownership ($p = .79$, Cohen's $r = 0.05$), Control ($p = .33$ Cohen's $r = 0.20$), and Change ($p = .56$, Cohen's $r = 0.12$).

4.4.5 Subjective Age Perception. Regarding the questions assessing participants' subjective age perception (Older and Younger), Wilcoxon rank-sum tests revealed no significant differences between the Child and Old Avatar conditions (Older: $p = .20$, Cohen's $r = 0.26$; Younger: $p = .75$, Cohen's $r = 0.06$), as shown in Figure 7.

4.5 Discussion

4.5.1 Reminiscence. The specificity of the retrieved events, measured using the TEMPau Scale, was significantly higher in the Child Avatar condition than in the Old Avatar condition, supporting H2-1. This result underscores how the age design of self-avatars can influence the VR-RT process, with child avatars, in particular, facilitating more detailed recollections. One possible explanation is that the Child Avatar alignes with participants' mental image of their younger selves, fostering a stronger psychological connection to their past and enabling richer recollections of specific details. This can be explained by the inherent nature of human memory, which is linked to surrounding information, or the environmental context. Based on this phenomenon, memory retrieval is enhanced in the same environmental context in which the information is initially learned [86]. Notably, self-related bodily information has been shown to function as an environmental context, influencing memory processes [52] In this study, the Child Avatar may have served as an environmental context, reconnecting participants with their childhood experiences and facilitating the retrieval of past events. This interpretation is reinforced by feedback from post-experiment interviews; for example, one participant in the Child Avatar condition noted, *"Immersing myself in the childhood landscapes while embodying a younger self brought back memories from that time."*

These observations illustrate how the Child Avatar helped the participants reconnect with their childhood identity, enhancing the vividness and specificity of their recollections. Conversely, the Old Avatar likely introduced a mismatch of temporal and physical context, disrupting the alignment between the avatar's representation and the memories being accessed. This misalignment was evident in participants' feedback, such as *"Recalling my past while having an old man's body felt strange,"* indicating how the incongruence disrupted their focus on reminiscing.

4.5.2 Reminiscence Therapy Effects. The results for the RT effects revealed no significant differences between the conditions across all measures, including emotion (SAM), cognitive performance (PASAT), and psychological well-being (Revised PGC Morale Scale). Consequently, hypotheses H2-2a, H2-2b, H2-3a, H2-3b, and H2-4 were not supported. This lack of condition-specific effects contrasts with the findings regarding the specificity of retrieved events, which demonstrated a significant advantage for the Child Avatar condition. This discrepancy raises important questions about the relationship between detailed reminiscence and the broader therapeutic outcomes of RT.

One possible explanation for the lack of significant differences is the robust main effect of Timing observed across several measures. Valence scores on the SAM ($p < .001$), cognitive performance on the 2-second interval PASAT ($p < .001$), and psychological well-being measured by the Revised PGC Morale Scale ($p = .074$, marginal significance)

all demonstrated overall improvement from pre- to post-experiment assessments, regardless of the avatar condition. These results suggest that VR-RT with self-avatars itself was highly effective in promoting emotional, cognitive, and psychological benefits. This strong general effect, which was not observed in Experiment 1, may have reduced the opportunity to detect additional condition-specific differences, as both conditions benefitted substantially from the inherently evocative nature of reminiscence about past experiences.

The hypothesized effects may also require a longer intervention period to manifest. The single-session design of this study may not have provided sufficient time for the emotional, cognitive, and psychological benefits of detailed reminiscence to translate into measurable therapeutic outcomes. A long-term design with repeated VR-RT sessions, similar to previous studies validated over weeks or months [48, 55, 100], may reveal more pronounced condition-specific differences.

Another possible explanation lies in participants' limited awareness of their self-avatars during the tasks. In Experiment 1, several participants reported not paying much attention to the avatars, which prompted modifications in Experiment 2, such as displaying a virtual mirror during the reminiscence tasks to ensure that the avatars remained visible throughout. However, even with this adjustment, post-experiment feedback suggested that participants' attention to their self-avatars was still relatively low; only seven out of 24 participants reported being aware of their avatars during the reminiscence tasks. This diminished engagement with the avatars could have restricted their potential effects, limiting the condition-specific impacts. These findings suggest that enhancing participants' engagement with and awareness of their self-avatars, through interactive designs or tasks that explicitly integrate their self-avatars into the reminiscenceprocess, may be necessary to amplify their therapeutic impact.

4.5.3 VR Experience. IPQ Presence scores and VEQ subscale scores revealed no significant differences between the two conditions (failing to support H2-5, H2-6a, H2-6b, and H2-6c), suggesting that the age of the self-avatars did not significantly influence the participants' sense of presence or embodiment. This result suggests that the virtual mirror, while intended to enhance avatar awareness, did not sufficiently engage participants with their avatars to influence their overall VR experience.

4.5.4 Subjective Age Perception. The results for subjective age perception revealed no significant differences between the Child and Old Avatar conditions, failing to support H2-7a and H2-7b. This outcome contrasts with previous research suggesting that embodying a child avatar induces a sense of rejuvenation [91]. A possible explanation for this is the nature of the reminiscence tasks. Specifically, reminiscing about one's past naturally evokes feelings of nostalgia and reconnection with one's younger self [1, 68]. This inherent characteristic of the task likely strengthened feelings of being younger while attenuating feelings of being older across both conditions, thereby reducing the potential to detect statistical differences between the conditions.

5 Limitations and Future Work

This study provides valuable insights into the role of self-avatars in enhancing the effectiveness of VR-RT; however, several limitations suggest areas for future research and development. First, although this study focused specifically on the age-related characteristics of self-avatars, it did not consider other potentially influential attributes. Prior research on the Proteus effect suggests that features of self-avatars such as sex [84], posture [19], and body shape [57] can significantly alter user experiences in VR. Furthermore, avatars of other users within VR have also been reported to influence users' cognition and perception [54, 92]. Future studies should systematically investigate these characteristics,

including attributes beyond age in self-avatars and the features of others' avatars, to better understand how these factors optimize VR-RT outcomes.

Next, the VEs used in this study were based on 360-degree images with limited interactive elements. More interactive environments may have provided a stronger sense of immersion and embodiment, thereby potentially amplifying the effects of the self-avatars in VR-RT [6, 34]. For instance, if participants could touch and move objects within VR, they could have deepened their connection to the surrounding environments and strengthened their sense of presence. Future studies should explore the role of richer interactivity within VR to further amplify the therapeutic benefits of VR-RT.

Another limitation of this study is its focus on healthy older adults, which may limit the generalizability of the findings to more diverse populations. Specifically, individuals with more severe cognitive impairments, such as advanced dementia or those experiencing significant social isolation, may respond differently to VR-RT interventions. These populations often face unique psychological and emotional challenges [5], and their engagement with self-avatars may yield distinct outcomes. Future research should expand to include these groups and explore how VR-RT can be adapted to address their specific needs, potentially enhancing their cognitive, emotional, and social well-being.

Finally, this study employed generic avatars and standardized VEs for all participants. However, creating personalized VR experiences could significantly enhance immersion and engagement [49, 61]. By integrating artificial intelligence technologies to generate personalized avatars resembling participants' current or past appearances and VEs tailored to their unique life histories, future research could unlock new dimensions of VR-RT, enhancing its effectiveness and fostering deeper emotional resonance for each participant.

6 Conclusion

This study investigated the effects of self-avatars on VR-RT through two experiments involving older adults. Participants engaged in reminiscence tasks while immersed in VEs depicting mid-20th-century Japanese landscapes, a period corresponding to their childhood.

Experiment 1 investigated the effects of the presence of self-avatars on VR-RT by comparing conditions with or without self-avatars. The results revealed that participants with self-avatars exhibited a marginally significant improvement in the specificity of their reminiscence and a significantly greater enhancement in cognitive functions. These findings suggest that self-avatars can serve as effective contextual anchors, promoting more detailed memory retrieval while supporting cognitive engagement.

Subsequently, Experiment 2 explored the role of self-avatar design, focusing on the effect of avatar age by comparing child avatars with older adult avatars. Participants embodying child avatars retrieved events with significantly greater specificity than those embodying the older adult avatars, underscoring the influence of self-avatar age design on the reminiscence. Additionally, significant improvements in cognitive function and emotion were observed across both conditions, highlighting the overall benefits of the VR-RT intervention using self-avatars.

These insights emphasize the importance of utilizing and designing avatars, and contribute to the growing body of research on VR-RT. By refining VR-RT methodologies, we can unlock their full potential to enhance the therapeutic effects for older adults, offering powerful tools to address the challenges of an aging society.

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