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The effect of visual perspective on episodic memory in aging: A virtual reality study

Silvia Serino [a,c,*], Melanie Bieler-Aeschlimann [b], Andrea Brioschi Guevara [b], Jean-Francois Démonet [b], Andrea Serino [c]

[a] *Department of Psychology, Università degli Studi Milano-Bicocca, Piazza dell'Ateneo Nuovo, 1, 20126 Milano, MI, Italy*
[b] *Leenaards Memory Centre, Department of Clinical Neurosciences, University Hospital of Lausanne (CHUV), Lausanne, Switzerland*
[c] *MySpace Lab, Department of Clinical Neurosciences, University Hospital of Lausanne (CHUV), University of Lausanne, Lausanne, Switzerland*

A R T I C L E I N F O

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A B S T R A C T

The possibility of flexibly retrieving our memories using a first-person or a third-person perspective (1PP or 3PP) has been extensively investigated in episodic memory research. Here, we used a Virtual Reality-based paradigm to manipulate the visual perspective used during the encoding stage to investigate age-related differences in the formation of memories experienced from 1PP vs. 3PP. 32 young adults and 32 seniors participated in the study. Participants navigated through two virtual cities to encode complex real-life virtual events, from either a 1PP (as if from their egocentric viewpoint) or a 3PP, while actively controlling an avatar. While recognition accuracy was higher in young adults after encoding in 1PP compared to 3PP, there was no benefit in memory formation in 1PP for older adults. These findings are discussed in terms of both age-related changes in episodic memory functioning and self-referencing processes.

1. Introduction

Every event we encounter daily is presented from an egocentric, body-centered perspective (first-person perspective, 1PP). However, we can recall events from a field perspective (i.e., 1PP), but also retrieve them from an observer perspective (i.e., in a third-person perspective, 3PP), if we re-experience the original event as external observers and see ourselves in the past retrieved scene (Nigro & Neisser, 1983; Rice & Rubin, 2009; St. Jacques, 2019; Tulving, 1993; Zaman & Russell, 2021). Starting from the seminal work of Nigro and Neisser (Nigro & Neisser, 1983), substantial literature elucidated the circumstances under which either visual perspective is favored depending on the nature of the event recalled. The most consistent finding in visual perspective literature suggests that recent personal memories are typically recalled from the same initially encoded perspective, whereas remote "semanticized" memories are retrieved from an observer perspective (for reviews, see Rice, 2010; Robinson & Swanson, 1993). These findings have been interpreted as evidence for the reconstructive nature of memory: the older the event, the more visual information associated with the original event has been lost, and one relies on general knowledge to reconstruct the mnemonic trace. Although the 1PP is considered the most common visual perspective for recalling memories, people may flexibly construct an observer-like perspective (Nigro & Neisser, 1983; Rice, 2010), and this has an impact on the phenomenological qualities of the memories. For instance, some studies suggest that when memories are spontaneously remembered from a 1PP, shifting to another perspective is associated with decreased

* Corresponding author at: Departement of Psychology, Università degli Studi Milano-Bicocca, Piazza dell'Ateneo Nuovo, 1 20126 MIlan (Italy)
E-mail address: silvia.serino@unimib.it (S. Serino).

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vividness, a lower sense of self associated with the reliving of the original episode, and reduced emotional arousal (Berntsen & Rubin, 2006; Robinson & Swanson, 1993).

While retrieving memories in 1PP or 3PP under normal conditions is possible, it is cognitively impossible to change perspective during the formation of episodic memories, i.e., at the encoding stage. Recently, researchers have been able to manipulate the visual perspective during retrieval and encoding, in experimentally controlled settings, thanks to the implementation of Virtual Reality (VR) paradigms (St. Jacques, 2019). In these paradigms, participants are immersed in highly ecological scenarios reproducing everyday situations (Perez-Marcos, Bieler-Aeschlimann, & Serino, 2018; Repetto, Serino, Macedonia, & Riva, 2016), and they are presented with real-life events in both 1PP and 3PP (Penaud et al., 2022; St. Jacques, 2019). Adopting this set-up, researchers demonstrated that the use of the 1PP, namely the encoding from a body that is felt as one's own, is associated with better subsequent recall than an encoding from a "disembodied" perspective (Bergouignan, Nyberg, & Ehrsson, 2014; Bréchet et al., 2019). More recently, Iriye and St. Jacques (Iriye & Jacques, 2020) found that spatial memory performance improved after a 3PP encoding experience than after a 1PP encoding experience. However, after controlling for the effect of the wider field of view available in 3PP, this effect vanished.

Interestingly, additional differences in terms of memory performance between the two visual perspectives might emerge as people age. As anticipated before, different experimental studies with older populations have already found a greater tendency to recall memories in 3PP (see Piolino et al., 2006; Piolino, Desgranges, & Eustache, 2009). There is not only a general decline in episodic memory abilities with age (e.g., Cansino, 2009; Shing & Lindenberger, 2011; Shing et al., 2010) but, also an increasing tendency to retrieve more general memories, that is, memories that are not associated with a specific event and are not framed by their spatio-temporal context (Levine, Svoboda, Hay, Winocur, & Moscovitch, 2002; Piolino et al., 2010; Piolino, Desgranges, Benali, & Eustache, 2002; St. Jacques & Levine, 2007). Indeed, older participants' episodic recall is characterized by a lack of specificity and details (e.g., Addis, Roberts, & Schacter, 2011; Levine et al., 2002; Schacter, Gaesser, & Addis, 2013).

Starting from this literature, we investigated potential age-related differences in the formation of memories experienced from 1PP vs. 3PP. To this aim, we developed a novel VR scenario that allowed the exploration of a city including real-life events, in two different conditions of visual perspective: in the 1PP condition, participants could freely move and experience events in VR within an egocentric first-person perspective; in the 3PP condition, participants actively controlled an avatar seen from behind, implying a cognitive projection of their egocentric viewpoint to the position of the avatar (Ganesh, van Schie, de Lange, Thompson, & Wigboldus, 2012). A group of young adults and a group of senior adults were tested. Half of the participants in the 1PP condition and the other half in the 3PP condition visited two different virtual cities. Part After each virtual navigation, participants judged their feelings of presence in the virtual cities recognition test was used to assess memory performance, in which participants were presented with static images of the virtual-life events from the VR scenario. The images included the entire exact scene or objects included in the scene they encoded (i.e., targets), and three types of lures, namely: the same scene but flipped to the other side of the street (i.e., side lures), perceptually similar backgrounds with some details changed concerning the original scene (i.e., perceptual lures) or scene that had never seen before (i.e., novel items). Participants were asked if they had seen that item during the virtual reality experience. They were also asked to rate their confidence in their recognition replies and make a source memory judgment (i.e., in which virtual city they encountered the item).

First, given that 1PP is the natural egocentric perspective for episodic memory encoding (Craik et al., 1999; Ingvar, 1985; Tulving, 1993, 2002), and based on previous literature demonstrating the beneficial effect of adopting a 1PP on subsequent memory performance (Bergouignan et al., 2014; Bréchet et al., 2019; Iriye & Jacques, 2020), we predicted that events encountered trough 1PP would have higher recognition accuracy and source judgments than events experienced from 3PP. However, because some essential features of episodic memory appear to deteriorate with age (Piolino et al., 2006, 2009), older adults may benefit less from 1PP encoding than young adults. Our investigation of memory confidence was exploratory because, to our knowledge, only one study has examined the influence of having a body (as opposed to a "no-body" condition) on confidence levels (Bréchet et al., 2019). Finally, consistent with the reviewed literature and independent of the type of visual perspective used during encoding, we predicted that young participants would perform better in both recognition accuracy and source judgments than older participants.

2. Material and methods

2.1. Participants

Thirty-two young participants [16 females, mean age: 25.1 ± 4.54] and thirty-two older participants [20 females, mean age 60.1 ± 6.24] participated in the study. Nine additional participants initially expressed interest in participating and began the experiment but encountered technical difficulties. Half of the young participants were randomly allocated to the first-person perspective (1PP) encoding condition (mean age 26.5 ± 3.83), and the other half were randomly assigned to the third-person perspective (3PP) encoding condition (mean age 22.9 ± 6.15). Similarly, half of the older participants were randomly allocated to the 1PP encoding condition (mean age: 59.9 ± 5.73), and the other half of them were randomly allocated to the 3PP encoding condition (mean age: 60.2 ± 7.00).

Since data was collected during the COVID-19 outbreak in Switzerland, the experiment has been carried out as a web-based experiment. Young participants were recruited through the participant management software "Sona-Systems, whereas older adults were recruited through the local CHUV ecosystem and 3rd age local associations, and 3rd universities. The following criteria were included as inclusion criteria for participation: 1) being at least 18 years old (young cohort) or 55 years old (older cohort); 2) having normal or corrected-to-normal vision, and 3) having access to a computer with Internet access. Exclusion criteria (self-reported) included the presence of a psychiatric or neurological disorder diagnosis. An online survey (including all the experimental tasks) was developed using the Qualtrics Survey software (Qualtrics, Provo, UT, USA) to allow participants to complete the experiment from their homes. Participants were directly contacted by one of the researchers through email with instructions and a personalized link to the survey. After a short screening questionnaire to check their eligibility criteria, participants who met the above-mentioned eligibility criteria were provided with information about the study design and asked to sign the informed consent. The experiment was conducted by the principles of the 1964 Declaration of Helsinki and approved by the ethical committee "Commission cantonale d'éthique de la recherche sur l'être humain" in Vaud, Switzerland (Project-ID 2017-01588). All participants were financially reimbursed for their time (20 Swiss Francs) and gave informed consent before participating.

2.2. Task and procedure

2.2.1. Virtual reality episodic memory task

The Virtual Reality (VR)-based episodic memory task consisted of two encoding trials in which the participants navigated in two virtual cities (namely, Virtual City 1 and Virtual City 2, counterbalanced order) to encode a total of 8 complex real-life virtual events (i.e., market stands). Virtual cities were constructed with a single main street (620 virtual meters in length) surrounded by buildings and other common city elements (e.g., trees, plants, pedestrian crossing). Each city has a unique landmark (skyscraper or city hall) that marks the end of navigation for each virtual city, unique real-life events, namely meeting a virtual character at a market stand (see below), were placed along the sidewalk so that each participant was exposed to the same number of events on each side of the path (i.e., two complex virtual real-life events on the left side and two complex virtual real-life events on the right side).). Both virtual environments were ad-hoc developed using Unity software (vers. 10; Smith Micro Software, Aliso Viejo, California, USA). Human models were developed using Mixamo software (https://www.mixamo.com/#/?page=1&type=Character). Unity software features a compiler to WebGL that we used to make the VR-based platform playable from a web browser. The generated HTML page is uploaded to a web server. We used Infomaniak to host the server (https://www.infomaniak.com/en). The experiment ran only on laptops and personal computers.

Participants were instructed that the experiment would simulate a tour of a city on the day of a street market. They were informed that they would be visiting various market stands and were specifically instructed to pay attention to and memorize the details of those market stands (i.e., the character near the market stand, the type of product, the shop sign, and the side of the street where the market stand was located). They were explicitly instructed to pay attention only to stands with human characters; two additional events for each city served as distractions, and they stood without a human character. The events designed in the two cities were semantically related (i.e., similar stands of a street market) and had similar perceptual features in terms of design characteristics. To control their navigation in virtual environments (speed of navigation: 15 m/s), participants were invited to press a button on the keyboard (i.e., the arrow). When they got close to the market stand, they were automatically redirected in front of the target item a (for a total of 5 s to ensure that all participants were exposed to the target event with the same viewpoint and duration) and the virtual characters

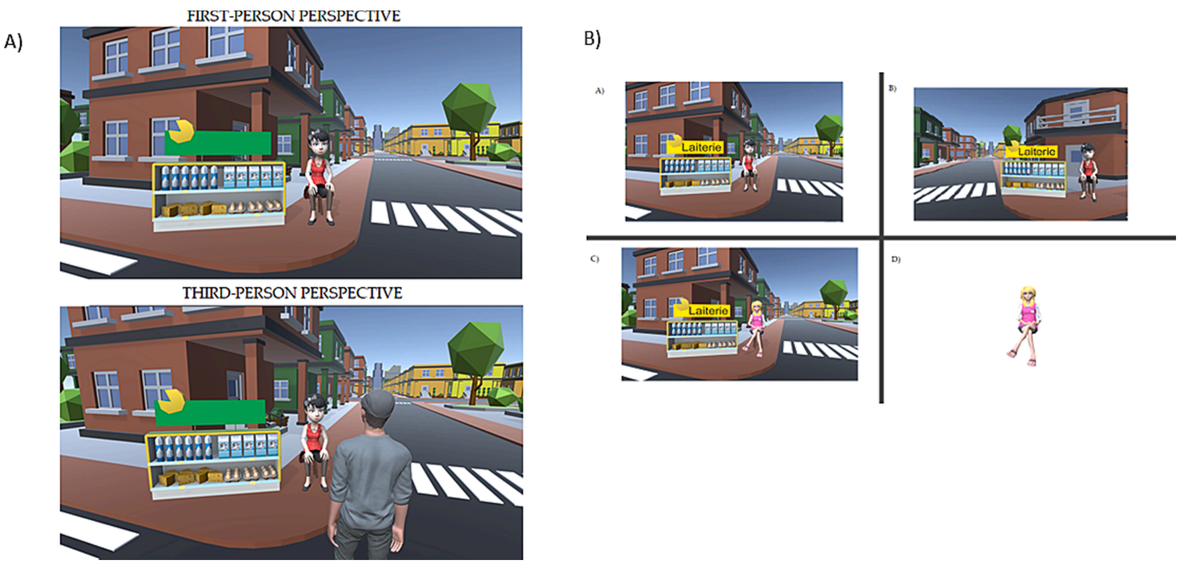

Fig. 1. A) The Virtual Reality (VR)-based episodic memory task consisted of two encoding conditions in which the participants navigated through two virtual cities to encode a total of complex real-life virtual events (i.e., market stands) from either 1) a first-person perspective (Group 1- 1PP), as if from their egocentric viewpoint, or 2) a third-person perspective (Group 2- 3PP), while actively controlling an avatar B) The recognition task consists of 88 trials presenting photographic images of the virtual real-life scenes seen during the navigation (old, N = 32) or unstudied elements (new, N = 56). The old images (A) included the exact scene or objects (*target items*) seen during the virtual navigation. The new, unstudied photographic images included: *side lures* (B), namely target items encoded during the virtual navigation, but from the flipped side of the street where the market stand was located during the navigation (side lures, N = 8); the *perceptual lures* (C), namely old items in which some perceptual details such as the character near the market stand or the type of product had changed (perceptual lures, N = 24); or completely novel, unstudied objects (*novel items*, N = 24).

produced a greeting animation (1.5 s); we did not introduce a time limit on memorizing all the details of the stands. When they felt they had correctly remembered the details of the frames could press the space button to continue the task. In a pilot laboratory testing of the set-up (N = 32, young adults, mean age: 23.6, SD = 2.26), we found that each city was explored for approximately three minutes (average encoding time for Virtual City 1 = 160.7 ± 86.01 s; average encoding time for Virtual City 2 = 158.48 ± 112. 60).

As it is possible to see in Fig. 1, participants encoded the items as from 1) a 1PP (Group 1- 1PP), as if from their egocentric viewpoint (without an avatar), or 2) a 3PP (Group 2- 3PP), while they actively controlled an avatar (Fig. 1A). In 1PP, they were told to navigate in a virtual city to memorize details from market stands. In 3PP, they were told that a virtual character would navigate a virtual city to memorize details from market stands. The camera field of view did not change between these two visual perspectives.

At the end of each virtual navigation, participants were presented with three items from the IPG group Presence Questionnaire (IPQ, https://www.igroup.org/ (Schubert, 2003), which allows for evaluating the spatial presence, involvement, and realism for experienced environments, and were asked to indicate their agreement on a 7-point Likert scale ranging from "complete disagreement" (−3) to "complete agreement" (+3). The average of the presence ratings after the two encoding trials was computed.

2.2.2. Recognition task

The recognition task was implemented in PsychoPy 3 (Peirce, 2007), https://www.psychopy.org/) and made available for remote testing via the ability to generate an HTML page containing the task and its javascript code. As for the VR-based episodic memory task, we used Infomaniak to host the server (https://www.infomaniak.com/en). As explained later in the Experimental Procedure section, participants completed in a counterbalanced order two encoding trials (namely, Virtual City 1 and Virtual City 2). After each encoding stage, they were asked to rate their sense of presence on three items from IPQ (Schubert, 2003). After that, they were asked to complete the recognition task. The recognition task consists of 88 trials presenting photographic images of the virtual real-life scenes seen during the navigation (old items, N = 32) or unstudied elements (new items, N = 56) (Fig. 1B). The old images included the exact scene or objects (i.e., the character near the market stand, the type of product, and the stop sign). These were considered target items. The new, unstudied elements contained three different types of items: 1) side lures, which are old items (encoded during the virtual navigation) taken from the flipped perspective (side lures, N = 8); 2) the perceptual lures, which are old items where some perceptual details such as the character near the market stand or the type of product had changed (perceptual lures, N = 24); 3) completely novel, unstudied objects (novel items, N = 24). Each image was preceded with a blank screen sign presented for 500 ms and lasted on the screen for 5 s. Participants decided whether an idea had been presented in one of the virtual cities during the encoding stage ("yes," by pressing the button "1″ on the keyboard) or not ('no,' by pressing the button "2″ on the keyboard). If participants answered yes, they also made a source-based judgment (i.e., which city they encountered the item in). Finally, for the "yes response," participants were asked to make a confidence memory judgment on a 5-point Likert scale, from "1", *not at all*, to "5", "*very sure*."

2.2.3. Experimental Procedure

Participants completed the task using their computer's web browser and the Qualtrics Survey emailed to them. The experiment consisted of two encoding trials (namely, Virtual City 1 and Virtual City 2, in a counterbalanced order) where all participants navigated in two virtual cities to encode a total of 8 virtual life events, followed by a recognition task. The key element of the study was the manipulation of the visual perspective by changing the camera location in the virtual environment, as Iriye and St. Jacques did (2021). More precisely, at the beginning of the experiment, all participants in both age groups were randomly assigned to one of two conditions: 1) a 1PP (Group 1- 1PP), namely participants encoded the items as if from their egocentric viewpoint (without an avatar), or 2) a 3PP (Group 2- 3PP), namely participants encoded the items while they actively controlled an avatar seen from the behind. The recognition task was identical for all participants in both age groups and encoding conditions.

2.2.4. Data analysis

We carried out several ANOVAs to investigate the effects of age and experimental manipulation on the different outcome measures. First, to explore age-related differences in the formation of memories experienced in 1PP vs. 3PP on presence ratings, we carried out an ANOVA with Visual Perspective (Group 1-1PP vs. Group 2-3PP) and Age (Younger Adults vs. Older Adults) as between-subject factors on presence scores.

To assess memory performance, the following accuracy measures from the recognition task were analyzed: proportion of hits ("yes" responses to target items, hit rate, expressed in percentage) and proportion of false alarms ("yes" responses to lures and novel items, false alarm rate, expressed in percentage); we also computed a global index of corrected recognition, by subtracting false alarm rates to new items from hit rates to target items (Snodgrass & Corwin, 1988). To assess source accuracy, we analyzed source hits, which were defined as the proportion of "yes" responses to target items where the correct virtual city was also identified, namely correct source judgments for target items correctly identified as old. We carried out a series of ANOVA with Visual Perspective (Group 1-1PP vs. Group 2-3PP) and Age (Younger Adults vs. Older Adults) as between-subject factors on hit rate, false alarm rate, corrected recognition, and source-memory rate. Additionally, we also evaluated participants' lure discrimination performance. False alarms responses were further analyzed based on participants' responses to the three potential sources of false alarms "side lure false alarms" ("yes" responses to side lures), "perceptual lure false alarms" ("yes" responses to perceptual lures), and "novel item false alarms" ("yes" responses to unstudied, novel items). All these false alarm rates were not normally distributed, consequently, we explored potential differences in the proportion of false alarms for the different categories of lures between the two age groups and between the visual perspective adopted during the encoding with a series of non-parametric Mann-Whitney tests. To explore differences between the two age groups concerning the visual perspective adopted during the encoding of memory confidence, we performed an ANOVA with Visual Perspective (Group 1-1PP vs. Group 2-3PP) and Age (Younger Adults vs. Older Adults) as between-subject factors on memory confidence judgments.

Before analysis, outlier responses were removed using the interquartile range method on each outcome distribution, and assumptions for ANOVA were checked. For all the analyses carried out, significant ANOVA effects were explored by post-hoc tests using Tukey correction. The significance level was set to alpha 0.05. All statistical analyses have been carried out with the statistical software JAMOVI.

3. Results

3.1. Sense of presence

Results revealed a significant interaction between the visual perspective adopted during the encoding of virtual life events and age [Visual Perspective × Age: $F (1,60) = 4.70$, $P = 0.034$, $\eta p2 = 0.073$]. Tukey-corrected post-hoc tests (see Fig. 2) indicated that younger participants experienced a higher sense of presence after the encoding in 1PP condition [$t(60) = 2.861$; $P = 0.029$; ($M_{young\ adults1PP} = 0.896$, $SEM = 0.296$) concerning older ones ($M_{older\ adults1PP} = -0.708$, $SEM = 0.467$). No significant differences emerged between the two age groups concerning the level of presence experienced in the 3PP condition [($M_{young\ adults3PP} = -2.167$; $SEM = 0.421$; $M_{older\ adults3PP} = 0.115$; $SEM = 0.374$), $P > 0.05$]. There were main effects of Visual Perspective or Age were not significant.

3.2. Episodic memory performance

Means and SEM of episodic memory performance measures divided as a function of age and type of perspective adopted during the encoding stage are presented in Table 1.

Results revealed a significant Visual Perspective × Age interaction on hit rate [$F(1,57) = 9.907$, $P = 0.003$, $\eta p2 = 0.148$]. Post-hoc comparisons (see Fig. 3) indicated that 1PP experiences were associated with better hits recognition for the younger participants ($M_{young\ adults1PP} = 88.0$, $SEM = 1.32$), but not for older ones ($M_{older\ adults1PP} = 65.6$, $SEM = 4.42$), [$t(57) = 3.803$, $P = 0.002$)]. Moreover, a significant difference between the two types of encoding emerged in the group of young adults: adopting a 1PP at the encoding resulted in a better ability to identify target items in comparison to a 3PP [$M_{young\ adults1PP} = 88.0$, $SEM = 1.32$), $M_{young\ adults3PP} = 71.3$, $SEM = 4.73$, $t(57) = 2.840$, $P = 0.031$). Finally, as expected, there was a main effect of Age [$F(1,57) = 5.643$, $P = 0.021$, $\eta p2 = 0.090$], indicating that younger participants globally were able to successfully identify more target items in comparison to older adults ($M_{young\ adults} = 0.778$, $SEM = 0.03$; $M_{older\ adults} = 0.700$; $SEM = 0.03$).

Coherently, results from the correct recognition index revealed a significant interaction between Age and Visual Perspective [$F (1,54) = 6.69$, $P = 0.012$, $\eta p2 = 0.110$]. Post-hoc comparisons (see Fig. 4) revealed that younger participants ($M_{young\ adults1PP} = 76.9$, $SEM = 2.80$) performed significantly better than older ones ($M_{older\ adults1PP} = 51.0$; $SEM = 4.77$) after encoding virtual life-events in 1PP [$t(54) = 4.117$; $P < 0.001$)]. No difference emerged between the two age groups after encoding in 3PP [$t(54) = 0.470$; $P = 0.965$)]. The comparison between the encoding of events in 1PP vs. 3PP for younger participants ($M_{young\ adults1PP} = 76.9$, $SEM = 2.80$, $M_{young\ adults3PP} = 59.3$, $SEM = 4.37$) revealed a significantly better performance for 1PP encoding [$t(54) = 2.748$; $P = 0.039$)].

Moreover, the main effect of Age was also significant [$F(1,54) = 10.56$, $P = 0.002$, $\eta p2 = 0.164$], revealing that younger participants were more globally able to successfully identify target items than older adults [$M_{young\ adults} = 67.5$, $SEM = 3.12$; $M_{older\ adults} = 53.5$; $SEM = 3.43$).

For the false alarm rate, the interaction between Visual Perspective and Age was not significant, nor was the main effect of visual perspective. Results only indicated that older adults had a higher tendency to falsely recognize unstudied items than younger ones

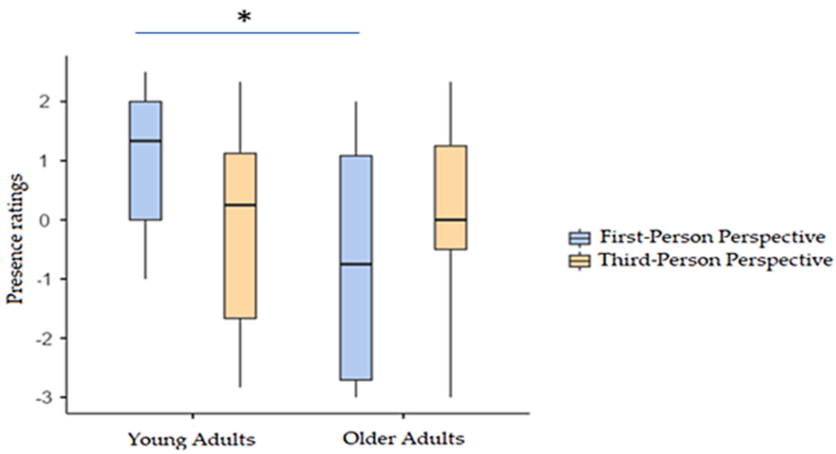

Fig. 2. Box plots of average presence ratings for younger and older adults as a function of the visual perspective adopted during the encoding. The middle line indicates the median, the box represents the 2nd and 3rd quartile value ranges, and the vertical lines represent the minimum and maximum values for each condition and group. (*) $P < 0.05$.

Table 1
Episodic memory performance (hit rate, false alarm rate, corrected recognition, source discrimination accuracy, false alarm rate for perspective lures, perspective lures, and novel items) is indicated in percentage + SEM and as a function of age and type of perspective adopted during the encoding (Young Adults vs. Older Adults, First-person perspective vs. Third-person perspective).

		Hit rate	False alarm rate	Corrected recognition	Source discrimination accuracy	False alarm rate - perspective lures	False alarm rate -perceptual lures	False alarm rate - novel items
Young adults	First-Person Perspective	88.0 (1.32)	11.5 (2.05)	76.9 (2.80)	70.5 (3.68)	19.5 (5.70)	10.8 (2.49)	10.3 (2.06)
	Third-Person Perspective	71.3 (4.73)	11.1 (2.37)	59.3 (4.37)	57.5 (4.70)	17.2 (5.34)	13.5 (3.24)	13.3 (3.06)
Older adults	First-Person Perspective	65.6 (4.42)	14.6 (2.36)	51.0 (4.77)	50.2 (5.20)	24.2 (6.89)	15.6 (2.86)	13.4(2.08)
	Third-Person Perspective	74.4 (3.98)	19.3 (3.08)	56.4 (5.01)	51.3 (3.87)	32 (8.15)	24.5 (4.22)	20.4 (3.05)

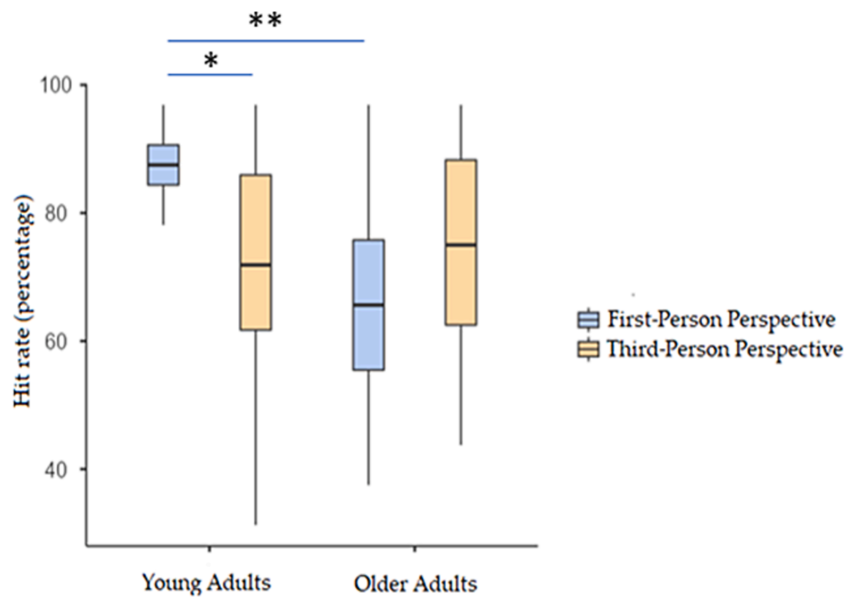

Fig. 3. Box plots of hit rate (proportion of hit expressed as a percentage) for younger and older adults as a function of the visual perspective adopted during the encoding. The middle line indicates the median, the box represents the 2nd and 3rd quartile value ranges, and the vertical lines represent the minimum and maximum values for each condition and group. (*) $P < 0.05$. (**) $P < 0.01$.

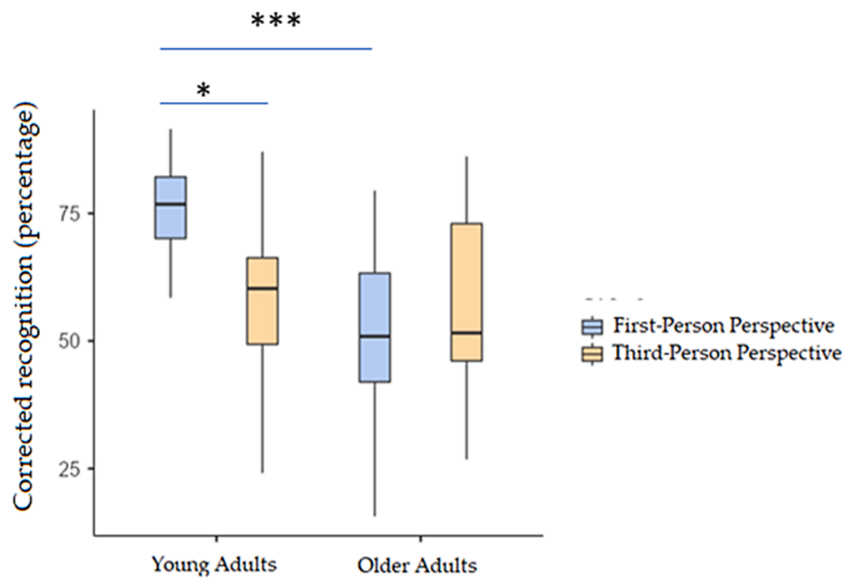

Fig. 4. Box plots of corrected recognition index (calculated by subtracting false alarm rates to new items from hit rates to target items and expressed in percentage) for younger and older adults as a function of the visual perspective adopted during the encoding. The middle line indicates the median, the box represents the 2nd and 3rd quartile value ranges, and the vertical lines represent the minimum and maximum values for each condition and group. (*) $P < 0.05$. (**) $P < 0.01$ (***) $P < 0.001$.

[Main effect of Age: $F(1,57) = 5.280$, $P = 0.025$, $\eta p2 = 0.085$, $M_{young\ adults} = 11.3$, $SEM = 1.53$; $M_{older\ adults} = 16.8$; $SEM = 1.93$)]. We further explored potential age-related differences by separately analyzing false alarm responses for the different categories of lures (i.e., side lures, perceptual lures, and novel items). Results indicated that older participants falsely recognized the perceptual lures [($M_{young\ adults} = 12.1$, $SEM = 2.03$; $M_{older\ adults} = 20.1$; $SEM = 2.63$, Mann-Whitney = 337.000; $df = 62$; $P = 0.018$)] and novel items [($M_{young\ adults} = 11.8$, $SEM = 1.83$; $M_{older\ adults} = 16.9$; $SEM = 1.92$, Mann-Whitney = 358.000; $df = 62$; $P = 0.038$)] as targets more often than younger ones. No other age-related differences emerged for the other categories (all $Ps > 0.05$). No significant differences emerged in the proportion of false alarms for the different categories of lures between the two visual perspectives (all $Ps > 0.05$).

Finally, regarding source accuracy, the interaction between Visual Perspective and Age was insignificant, and neither was the main effect of visual perspective. Results indicated that younger adults were more able to correctly identify the correct virtual city in comparison to older ones [Main effect of Age: $F(1,57) = 8.87$, $P = 0.004$, $\eta p2 = 0.135$, $M_{young\ adults} = 64.2$, $SEM = 3.14$; $M_{older\ adults} = 50.7$; $SEM = 3.26$)].

3.3. Confidence judgments

Results from the ANOVA with Visual Perspective (Group 1-1PP vs. Group 2-3PP) and Age (Younger Adults vs. Older Adults) as between-subject factors on confidence responses revealed no main effect of visual perspective nor an interaction effect. On the other side, a significant difference between younger and older participants in confidence responses emerged, namely older adults were less confident in their memory judgments [Main effect of Age: $F(1,60) = 11.9230$, $P = 0.001$, $\eta p2 = 0.166$, $M_{young\ adults} = 4.22$, $SEM = 0.08$; $M_{older\ adults} = 3.72$, $SEM = 0.114$). In addition, a linear multiple regression was carried out with confidence responses as the dependent variable and hit rate, Visual Perspective, and Age Group as predictor variables. We additionally computed a product term of Visual Perspective and Age Group as a representation of the interaction of these variables. We then performed a stepwise multiple linear regression analysis to elucidate whether the proportion of hits, Visual Perspective, and Age Group, or an interaction of these variables are predictors of confidence judgments. Results revealed that these variables significantly predicted confidence, $F(3, 60) = 5.334P = 0.003$, $R2 = 0.21$). Only the age group added statistically significantly to the prediction ($P = 0.001$), showing again that older adults were less confident in their memory processes. The change in R2 by the addition of the interaction term Visual Perspective × Age Group was 0.003, which was not statistically significant.

4. Discussion

The possibility of flexibly retrieving our memories using a first-person or a third-person perspective (1PP or 3PP) has been extensively investigated in episodic memory research (Eich, Nelson, Leghari, & Handy, 2009; Freton et al., 2014; Zaman & Russell, 2021). With the introduction of Virtual Reality (VR), researchers have the opportunity to investigate whether different perspectives at the encoding stage influence recognition at the retrieval stage (for a recent review, see St. Jacques, 2019). Here, we used a VR-based paradigm to manipulate the visual perspective used during the encoding stage to specifically investigate age-related differences in the formation of memories experienced from 1PP vs. 3PP. A recognition task using targets and lure images from events encountered while navigating virtual cities was used to assess episodic memory. We hypothesized that encoding virtual-life events in 1PP would lead to an improvement in episodic memory performance when compared to encoding virtual-life events in 3PP. However, because the features of episodic memory change with age (e.g., Addis, Roberts, & Schacter, 2011; Levine et al., 2002; Schacter, Gaesser, & Addis, 2013), we hypothesized that this advantage for 1PP would emerge differently in young versus older adults.

Results confirmed this hypothesis. While in young adults, recognition accuracy was higher after encoding in 1PP as compared to 3PP, there was no beneficial effect on the formation of memories in 1PP for the older adults. The observed improvement in recognition performance after encoding in 1PP is consistent with recent experimental findings in young adults (Bergouignan et al., 2014; Bréchet et al., 2019; Iriye & Jacques, 2020; Penaud et al., 2022), as 1PP is the default mode of processing information, and of episodic memory, in particular, implying a specific reference to the self (Craik et al., 1999; Tulving, 2002). Furthermore, this beneficial effect of 1PP is consistent with studies demonstrating that encoding self-related information usually improves subsequent performance. (i.e., self-reference effect (Klein, 2012; Penaud et al., 2022; Symons & Johnson, 1997). In a typical self-reference memory task, participants are typically presented with a list of items to be remembered in two encoding conditions: in one condition, participants are asked to process these items with self-relevant cues, while in the second condition, participants are asked to process these items with other-referent cues. Encoding events in an egocentric, body-centered 1PP might imply a stronger self-reference than encoding them in 3PP (see also Penaud et al., 2022), thus resulting in better memory. As a result, our findings are consistent with evidence demonstrating that processing and storing self-related information is faster and more accurate (Frings & Wentura, 2014; Klein, 2012; Mattan, Quinn, Apperly, Sui, & Rotshtein, 2015). However, in our study, there was no explicit instruction to perform encoding in a self-referential manner, and we did not ask participants to mentally adopt the avatar's perspective rather than their own in 3PP (as in Piolino et al., 2002). Future studies should investigate age-related differences in memory performance by comparing a self-referential 1PP encoding as opposed to an other-referential 3PP one.

The current findings are novel in that this beneficial effect of 1PP on encoding was not observed in older adults. The first possible explanation of this finding is related to well-known age-related changes in episodic memory functioning. Some essential features of episodic memory, such as the sense of re-experiencing the event and the use of the original field perspective, deteriorate with age (Piolino et al., 2006, 2009). In particular, a recent study (Kapsetaki et al., 2021) found a specific deficit in the use of egocentric representations (i.e., representations coding self-to-object relationships) used to sustain effective episodic recall in aging. The authors developed a novel paradigm in which participants experienced 3D scenes from various viewing angles to determine whether the ability to recall one's visual perspective could be related to the richness of autobiographical recall and how this relationship would be affected by age. Their findings showed that older adults were particularly impaired in distinguishing items that had shifted from their encoded egocentric perspective from those shown in the same perspective as the initial one. More importantly, they found that older adults had a poorer autobiographical recall and that autobiographical task scores did not correlate with the ability to recall one's visual perspective, whereas this correlation existed in young adults. According to the authors, older adults had difficulty reconstructing an egocentric image from their perspective that they must identify as "their" scene in the subsequent recall.

Interestingly, differences in the effect of using a 1PP vs. a 3PP on memory performance between young and old adults were also associated with differences in their perspective-dependent sense of presence in 1PP vs. 3PP. While younger participants reported a stronger sense of presence in virtual environments when using a 1PP versus a 3PP, no differences were found in older adults. One possibility is that the reduced sense of presence experienced by older adults during virtual navigation, also in 1PP, is associated with a decreased attentional engagement towards the item to be encoded, which is consistent with the reduction in attentional resources seen in aging (Castel & Craik, 2003; Craik, Govoni, Naveh-Benjamin, & Anderson, 1996). Makowski and colleagues (Makowski, Sperduti, Nicolas, & Piolino, 2017) investigated the relationship between presence and memory performance and found that participants who reported a greater sense of presence during the encoding also had better memory accuracy, as a result of a higher level of selective attention towards the material to be remembered. However, some authors proposed a broader definition of presence, defining it as the sensation of being "there" in the experienced world (Sanchez-Vives & Slater, 2005), which also implies a subjective self-experience (Riva & Mantovani, 2012). According to this viewpoint, lower feelings of presence may indicate that older adults were unable to perceive themselves as protagonists of their experiences, making memory encoding less self-referenced.

These results also suggest the importance of considering potential age-related differences in the perception of the identity of the actor. In the current study, we manipulated the visual perspective by changing the camera location in the virtual environment, as Iriye and St. Jacques did (2021). As a result, participants navigated the virtual cities either from their egocentric viewpoint (without an avatar) or while actively controlling an avatar seen from behind. Because the avatar is another person, but it is visible only in 3PP, our 1PP vs 3PP manipulation implies also a "self–other manipulation". Accordingly, these results might indicate that the "self–other manipulation" was not effective for older participants. In support of this hypothesis, it is critical to remember there was no difference between the two age groups after the 3PP encoding, but only after the 1PP condition.

Finally, it is also worth noting that age-related differences in 1PP in feelings of presence may be related to the fact that younger adults are more used to virtual experiences than older adults.

Finally, in line with literature about age-related differences in episodic memory (De Brigard, Langella, Stanley, Castel, & Giovanello, 2020; Rhodes, Greene, & Naveh-Benjamin, 2019), in terms of recognition and source memory, our findings showed that older adults performed worse than young adults. Older participants, in particular, reported not only lower hit rates but also a higher percentage of false alarms when compared to younger participants, confirming that memory issues in seniors were characterized by difficulty discriminating unstudied items from targets, which is consistent with other studies (Devitt & Schacter, 2016; Gallo, Bell, Beier, & Schacter, 2006; Koutstaal, 2003; Trelle, Henson, Green, & Simons, 2017). These difficulties were further confirmed when we analyzed the features of unstudied items determining the older participants' proneness to false alarms. When considering the different types of lures presented in the recognition task (i.e., side lures, perceptually similar scenes, and novel unstudied items), we found more frequent false recognition in older adults for perceptually similar images, in line with recent studies pointing out the role of perceptual similarity in contributing to false recognitions in older people (Abichou et al., 2021; Burnside, Hope, Gill, & Morcom, 2017; Dennis & Turney, 2018). On the other hand, no difference between the two encoding conditions was found in confidence judgments. These results align with Brechet et al. (2019), who demonstrated an increase in memory performance, but not in confidence, for the embodied memory task in virtual reality compared to the body-absent condition. Finally, considering that this experiment was conducted as an online study, it is important to mention that the differences in memory performance between younger and older participants can also partially depend on the greater familiarity that young people have with VR and with technology in general.

Some limitations of this study must be acknowledged. First, due to the restrictive measures in place due to the COVID-19 pandemic at the time of testing, we had to conduct the study online. Even though a growing number of studies have demonstrated the feasibility of conducting remote-based experiments for a variety of cognitive processes with little effect on data quality (see for example (Huber & Gajos, 2020), because it is an unsupervised setting, some factors could not be completely controlled, and thus some issues must be addressed in future studies on this topic. First, while "immersion" (i.e., the objective capability of the technology to deliver sensorial stimulations like manifestations in the physical world) and presence are distinct concepts, there is evidence that users can experience greater feelings of presence in more immersive VR setups. As a result, future research should investigate potential age-related differences in memory encoding from two different perspectives using immersive VR technology (as in Galvan Debarba et al., 2017)). Second, because the experiment was entirely unsupervised, and because we needed to keep the experiment as short as possible, we decided not to include standardized cognitive testing to screen older participants for the presence of subtle cognitive impairments. Furthermore, to increase the likelihood that our older participants had sufficient technological proficiency and were able to participate in the online study, we decided to include participants starting at the age of 55, rather than 65. Although large cross-sectional studies have shown that age-related memory decline in healthy aging begins around the age of 60 (Rönnlund, Nyberg, Bäckman, & Nilsson, 2005), future studies should consider the opportunity to include different age groups to further evaluate potential age differences in the formation of memories experienced from different visual perspectives. Third, we should note that we administer the recognition task immediately following the two encoding trials in the two virtual cities. Future research should investigate whether age-related differences in the formation of 1PP vs. 3PP memories are qualitatively different when tested with a delayed memory test.

Concerning future clinical applications, future research could investigate the feasibility of using our task as a simple, easy-to-administer, and ecological instrument to assess subtle memory deficits in older adults and individuals with memory disorders. Our task appears indeed able to fully capture all the multifaceted aspects of episodic memory (factual, spatial, temporal, and binding, see La Corte, Sperduti, Abichou, & Piolino, 2019) simultaneously and ecologically.

5. Conclusion

By investigating age-related differences in the formation of memories encoded in 1PP or 3PP, the current study adds to the growing body of evidence demonstrating the benefits of using a 1PP for young adults. We present important new findings by demonstrating that 1PP did not benefit older adults during memory formation, which is relevant to our understanding of age-related changes in memory processes. Our virtual reality scenarios and tasks can also be used to investigate memory performance and experience in clinical populations with memory disorders.

CRediT authorship contribution statement

Silvia Serino: Conceptualization, Funding acquisition, Formal analysis, Methodology, Writing – original draft, Writing – review & editing. **Melanie Bieler-Aeschlimann:** Methodology, Writing – review & editing. **Andrea Brioschi Guevara:** Methodology, Writing – review & editing. **Jean-Francois Démonet:** Methodology, Conceptualization, Supervision, Writing – review & editing. **Andrea Serino:** Conceptualization, Supervision, Funding acquisition, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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