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Age-Related Changes in Eye Movements During Pictorial Recall in Older Adults

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Data Availability

The stimuli, data, and code used in this study are available on the Open Science Framework at https://osf.io/tmejy/.

Preregistration

The study was preregistered: https://osf.io/v9gtw.

Competing Interests

The authors declare no competing interests.

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Abstract

During the recall of pictorial information, individuals typically exhibit eye movements directed toward the locations they focused on during perceptual encoding. This behavior is thought to support memory retrieval by linking spatial information to cognitive processes. Given the known memory decline associated with healthy aging, investigating age-related changes in eye movements during recall is crucial. We compared the eye movement patterns of older (N = 38, 65–75 years) and younger adults (N = 37, 20–35 years) during different pictorial recall tasks. Both groups tended to look back at the original stimulus locations; however, this effect was less pronounced in older adults. They displayed less systematic and more dispersed fixations across the screen. Moreover, eye position information generalized to novel objects from previously seen categories in both groups. In terms of performance, older adults performed worse than younger adults on an old/new recognition task but not on a task assessing visual detail recall. Older adults rated their mental images as more vivid than younger adults did, which may reflect differences in the perception or interpretation of vividness, or subjective bias. The observed pattern of eye behavior, together with the relatively preserved recall performance, suggests that older adults rely less on embodied strategies, consistent with prior findings indicating an age-related shift toward gist-based representations. Overall, our results demonstrate that eye movement behavior during pictorial recall changes with age, highlighting the need for further investigation into the underlying mechanisms and possible consequences of this change.

Keywords: Eye Movements; Pictorial Recall; Mental Imagery; Memory; Aging.

Public Significance Statement

This study sheds light on age-related changes in eye movement behavior. Although older adults show less systematic fixation patterns during pictorial recall compared to younger adults, their actual recall remained relatively preserved. These findings suggest that older adults may rely on different memory strategies and point to the importance of further research on the relationship between eye movements, memory, and aging.

Age-Related Changes in Eye Movements During Pictorial Recall in Older Adults

When asked to describe your favorite cup, you are likely to visualize it in your mind. This mental image may include specific details, such as the color of the cup, its shape, and perhaps other familiar kitchen items. As you form this mental image, you might also look toward the spatial location where you last placed your cup. This is an example of the *looking-at-nothing* (LAN) effect, in which our eyes move to locations associated with memories, even when the objects are not physically present. Research suggests that we encode the location of objects spontaneously, even when this information is not required for a specific task (Rosner et al., 2022). Moreover, spatial location is reactivated during recall and guides our eye movements to areas previously visited during encoding (Laeng et al., 2014). The LAN effect has been observed in healthy adults and children across different contexts, such as computer-based tasks and more immersive virtual reality settings, and in both short-term and long-term recall (Altmann, 2004; Brandt et al., 1989; Chiquet et al., 2021, 2022; Hollingworth, 2005; Johansson et al., 2012; Johansson & Johansson, 2014; Laeng & Teodorescu, 2002; Martarelli & Mast, 2011, 2013; Umar et al., 2021). In addition to the recall of visual details, the LAN effect generalizes to new objects within the same category. For example, Martarelli et al. (2017) showed that when pictures of animals were presented in the upper right quadrant of a screen, participants returned their gaze to this quadrant not only when recalling a previously seen animal, but also when visualizing a new animal belonging to the same category. This finding suggests that spatial location is encoded with both visual and semantic information (Ferreira et al., 2008). Furthermore, even though the participants were not instructed to encode the location or informed about the category manipulation, they implicitly organized their mental representation in this way (Martarelli et al., 2017). In light of such findings, the present study aimed to investigate two aspects of the LAN effect in older adults: first, whether the LAN effect itself is present in this population, and second, whether it generalizes to new stimuli within the same categories for older adults. Examining the LAN effect in older adults may help identify age-related changes in memory retrieval strategies, the role of spatial information in pictorial recall, and the extent to which embodied memory processes are preserved with age.

At first glance, the LAN effect may seem paradoxical. Why would individuals look toward areas with no visual information? Why invest cognitive effort in exploring empty spaces? Influenced by early research on visual mental imagery, researchers have continued to propose that these eye movements serve a functional role (Mast & Kosslyn, 2002). Over 50 years ago, Hebb (1968) offered an initial hypothesis suggesting that eye movements aid in the mental reconstruction of visual mental representations. Since then, to examine the role of eye movements during pictorial recall, researchers have assessed the impact of manipulating eye position on memory performance. Indeed, some studies have shown impaired memory performance (e.g., increased errors) when participants were restricted from moving their eyes freely during the visualization of previously seen stimuli (Bochynska & Laeng, 2015; Damiano & Walther, 2019; Johansson et al., 2012; Johansson & Johansson, 2014; Laeng et al., 2014; Laeng & Teodorescu, 2002; Olsen et al., 2014). Another longstanding idea influenced by Hebb (1968) is that there is a relationship between eye movements and the quality of mental imagery. For instance, Martarelli et al. (2022) found that matching the recall location with the original encoding location enhanced access to color details. This suggests that spatial information acts as a scaffolding structure for pictorial recall (Laeng et al., 2014). However, Martarelli et al. (2022) found no effect on the precision of mental images. Overall, these findings contribute to a mixed body of evidence on the functional role of the LAN effect. One way to better understand the role of the LAN effect in pictorial recall is to study how this effect changes with healthy aging. In this vein, Greene and Naveh-Benjamin (2023) have highlighted that the mechanisms underlying older adults' reduced precision in pictorial recall, compared to younger adults, are poorly understood. Notably, memory performance and eye movement behavior in older adults have only been investigated separately until recently. To address this gap, our study has examined whether the LAN effect is present in older adults without manipulating eye positions during recall.

Aging is a complex process characterized by neuroanatomical, biochemical, and functional changes that impact cognitive functioning, particularly episodic memory, which refers to the memory of past events contextualized in time and space (Grady, 2012). Age-related differences in memory performance are well documented, with various reviews and meta-analyses identifying declines across different domains (Fraundorf et al., 2019; Greene & Naveh-Benjamin, 2023; Old & Naveh-Benjamin, 2008; Rhodes et al., 2019; Tromp et al., 2015). The decline in episodic memory with age has been explained in part by difficulties in associative memory, meaning the ability to create and recall associations between items, as opposed to remembering single items alone (Naveh-Benjamin, 2000). Furthermore, studies suggest that older adults experience a decline in representational precision, as they recall information with less accuracy and detail than younger adults (Korkki et al., 2020).

A prominent explanation for such reductions in memory specificity is an age-related shift from verbatim memory (which captures precise, detailed representations) toward gist memory (which encodes general meaning or categorical structure) (e.g., Brainerd & Reyna, 2015). While this shift has often been viewed as a sign of decline, some researchers argue it reflects an adaptive cognitive strategy shaped by accumulated experience, changing goals, or resource limitations (Grilli & Sheldon, 2022). Importantly, this increased reliance is associated with a greater dependence on semantic memory, which involves knowledge and concepts accumulated over a lifetime, compared to episodic memory (Castel, 2005). While semantic representations can support memory retrieval, they may also have detrimental effects, as in cases when, for example, older adults need to discriminate between semantically similar stimuli (Fraundorf et al., 2019). Furthermore, research has shown that older adults report a lower preference for visual and imagery processes compared to younger adults (Ovalle-Fresa & Martarelli, 2024). Aging has also been associated with a decline in the vividness of visual mental imagery, as the ability to generate vivid mental representations of objects or scenes has been shown to diminish with age (Gulyás et al., 2022; Kalkstein et al., 2011). Paradoxically, some studies have found that older adults subjectively report their mental images as equally or even more vivid than those of younger adults, despite showing poorer objective memory performance (e.g., Folville et al., 2020). This suggests a dissociation between subjective vividness and the richness of underlying memory content – possibly reflecting changes in how vividness is monitored or interpreted (Folville et al., 2022).

Recent studies have begun to explore age-related differences in eye movement behavior during perception and pictorial recall processes (Açık et al., 2010; Mazloum-Farzaghi et al., 2023; Ryan et al., 2020; Wynn et al., 2018, 2020, 2021). For example, Mazloum-Farzaghi et al. (2023) investigated fixation distribution in a *face recognition task* and found increased visual exploration during encoding in older adults compared to younger adults, but similar fixation behavior during recognition. The authors suggested that older adults may require more fixations to encode sufficient information that would allow them to achieve performance levels comparable to those of younger adults. In an earlier study, Wynn et al. (2018) used a *change detection task* and compared fixation patterns between older and younger adults during the memory maintenance period (i.e., the interval between encoding and the subsequent change detection task regarding the spatial location of objects). They found similar fixation patterns during both encoding and maintenance in both age groups. However, fixation reinstatement was more pronounced in older adults when their performance matched that of younger adults. In a subsequent study, Wynn et al. (2021) implemented a *pattern completion task*, in which participants viewed partially degraded images (i.e., images with only fragments of the original visible). In this case, older adults showed more pronounced fixation reinstatement when the task exceeded their cognitive resources, thereby suggesting that eye movements during pictorial recall may play a compensatory role. This fixation reinstatement could help counteract age-related memory deficits as task difficulty increases.

In the present study, we aimed to investigate eye movement behavior during pictorial recall in healthy aging. Older adults were asked to mentally visualize previously encoded stimuli and perform different recall tasks. Specifically, after generating a mental image of a previously seen stimulus, participants were asked to evaluate sentences about its details, rate the vividness of their mental images, and complete an old/new recognition task, all while their eye movements were recorded. These tasks were selected to assess the generalizability of the LAN effect across different types of pictorial recall processes. Image generation, inspection, and vividness rating are commonly used in mental imagery research and reflect distinct aspects of pictorial recall, while the recognition task provided a more traditional measure of memory accuracy. Previous research with young adults has shown that, during pictorial recall, eye movements tend to return to the location at which the stimulus was initially presented (Spivey & Geng, 2001). Our first aim was to test whether this effect was also present in older adults. Based on previous studies suggesting that spatial information is spontaneously encoded and reactivated during pictorial recall, we hypothesized that the LAN effect would also be observed in older adults (Ballard et al., 1997; Richardson & Spivey, 2000). Given that older adults often exhibit reduced representational precision and rely more on semantic memory than episodic detail (Greene & Naveh-Benjamin, 2023; 2024) the presence or absence of the LAN effect in this population may offer insights into the mechanisms by which aging affects pictorial recall.

Previously, Martarelli et al. (2017) demonstrated that the LAN effect is generalized to new stimuli within the same category, thus highlighting that eye movements can be triggered not only by specific visual exemplars, but also by abstract representations of categories. In the present study, we aimed to test whether this generalization of the LAN effect would also occur in older adults. Given that older adults often rely more on semantic memory than episodic memory when performing memory tasks (Dennis et al., 2014; Fraundorf et al., 2019), we expected the LAN effect to generalize to stimuli within the same category as those initially encoded. A generalization of the LAN effect in older adults would also be consistent with an age-related shift toward gist-based recall, suggesting that spatial information continues to scaffold memory retrieval even when specific episodic details are lost. To replicate the findings of Martarelli et al. (2017) using new material, we replaced static images with videos of 3D objects and animals, creating a more ecologically valid perceptual encoding scenario. In parallel with the older group, we tested a group of younger adults using the same video material to replicate both the LAN effect and its generalization. Replicating these results in younger adults provided a baseline for comparison and allowed us to investigate age-related differences.

Method

Method Transparency and Openness

We report how we determined the sample size, all data exclusions, all manipulations, and all measures in the study. All data and research materials are available (https://osf.io/tmejy/). The study was preregistered (https://osf.io/v9gtw).

Participants

This study was approved by the local ethics committee and preregistered on the Open Science Framework (OSF) (https://osf.io/v9gtw). In a previous study, we used a similar design to investigate both the LAN effect and its generalization to other stimuli within the same categories (Martarelli et al., 2017). In that study, we observed a large LAN effect (corresponding vs. non-corresponding area) with a η_p^2 of 0.447. More specific analyses (without pooling non-corresponding areas; see Appendix of Martarelli et al., 2017) showed η_p^2 values of 0.317 for old stimuli (corresponding vs. non-corresponding AOIs) and 0.303 for new stimuli. In general, the LAN effect reported in the literature is large. For instance, Johansson and Johansson (2014) found a substantial LAN effect, with an η^2 of 0.54. Against this background, the primary aim of this study was to examine the LAN effect in older adults, a population in which this effect has not yet been studied. To ensure that we could detect smaller effects if present, we set our target effect size to a medium level (η_p^2 of 0.06). An a priori power analysis using G*Power indicated that a sample size of 35 participants would be sufficient to detect a medium effect (repeated measures ANOVA; parameters: η_p^2 = 0.06, 1-b = 0.95, a = 0.05; Faul et al., 2007).

The older adult group consisted of 38 participants aged 65–75 years (*M* = 69.3, *SD* = 3.2; 24 women). None showed apparent signs of cognitive impairment, as indicated by their scores on the Montreal Cognitive Assessment (MoCA) (Nasreddine et al., 2005). Participants with a MoCA score below 25 were ineligible to participate (see preregistered exclusion criteria on https://osf.io/v9gtw); the present sample had a mean MoCA score of 27.83 (*SD* = 1.38). As we aimed to replicate the results of a previous study (Martarelli et al., 2017) and to examine age group differences, we also tested a group of younger adults. This group included 37 participants (*M* = 26.4, *SD* = 4.6; 25 women). While the preregistered age range for younger adults was 20–30 years, we extended the upper limit to 35 to allow more participants to enroll. In total, 78 participants were recruited. Data from three participants (one younger adult and two older adults) were excluded due to technical issues with the eye tracker.

Recruitment was primarily conducted online via email and social media. Data were collected between February 2022 and December 2022. Since the laboratory was located in a bilingual region, 56% of the participants took part in German, while 44% participated in French. Older adults received CHF 30 for their participation, while younger adults—who did not complete the MoCA—received CHF 25 or an equivalent number of participation credits if they were enrolled as students at UniDistance Suisse.

Stimulus Material

We used 64 stimuli from four different categories: 16 kitchen utensils, 16 office objects, 16 furniture items, and 16 animals. For each category, half of the stimuli were presented both visually and auditorily during encoding (hereafter referred to as “old” stimuli), while the other half were presented only auditorily during pictorial recall (hereafter referred to as “new” stimuli). A four-second video for each of the 32 old stimuli, showing them in a 360-degree rotating view (examples are available on OSF: https://osf.io/tmejy/) was shown during encoding. To enhance the realism, these 32 stimuli were modeled in three dimensions, with their color and texture designed to closely resemble their real-life counterparts. Stimuli from the animal category were taken from a database purchased specifically for this experiment (https://www.basemeshstore.com), while all other stimuli were taken from the public database published by Popic et al. (2020).

The audio recordings included the name of each stimulus and a sentence describing a detail of both the 32 old and 32 new stimuli (see OSF: https://osf.io/tmejy/) for names and sentences in the corresponding languages). The sentences were divided into two groups: half described a specific feature of the stimulus (e.g., “One of the cabinet doors is open”), while the other half described the color of the stimulus (e.g., “The frying pan is blue”). For the sentences describing the 32 old stimuli that were displayed visually, half were correct, and half were incorrect. Instructions for the tasks to be performed were also recorded (i.e., “How vivid is your mental image?” and “Was it an old or a new stimulus?”).

Device

Eye movements were recorded using the EyeLink® 1000 Plus system (SR Research Ltd., Canada). The infrared camera recorded binocular eye movements with a sampling rate of 1000 Hz, a spatial resolution of 0.01°, and a gaze position accuracy of 0.5°. The computer display was a 24-inch screen (1920 × 1080 pixels). Participants were seated at a distance of approximately 70 cm from the screen, with their heads resting on the SR Research Head Support. The experiment was implemented using the Experiment Builder (SR Research Ltd., Canada). Before the encoding and pictorial recall parts of the experiment were conducted, a nine-point grid calibration and a 10-point grid validation procedure were performed to adjust the eye-tracking system. Calibration was successful for all participants (i.e., average horizontal and vertical error $< 0.8°$ angular accuracy).

Procedure

The MoCA (Nasreddine et al., 2005) was administered to older adults before the experiment began. Younger adults proceeded directly to the computer-based experiment, which was divided into two parts: perceptual encoding and pictorial recall.

Perceptual Encoding

Encoding consisted of 32 trials, during which the 32 old stimuli were presented. Each trial began with the presentation of a fixation cross for three seconds, followed by the auditory presentation of the stimulus name via loudspeakers (see Figure 1). A 360-degree rotating video of the stimulus was then shown visually. Participants were instructed to focus on the stimulus and return their gaze to the center of the screen once the video ended. It was not explicitly stated that a pictorial recall test would follow.

The screen was then divided by horizontal and vertical midlines into four equally sized quadrants. The eight stimuli from the same category were always displayed in the same quadrant of the screen. Participants were randomly assigned to one of four encoding blocks, ensuring that each category appeared in every quadrant. The order of the stimulus presentation was randomized across all participants. Once encoding was completed, participants were given the option to take a break before proceeding to the pictorial recall phase.

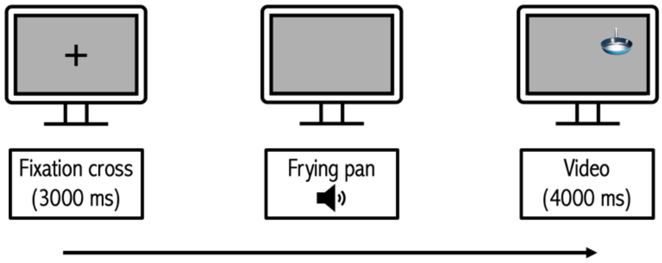

Figure 1. Illustration showing a trial run during encoding

Pictorial Recall

The pictorial recall task included 64 trials, which consisted of the presentation of both the 32 old stimuli and the 32 new stimuli. During this phase, the screen remained gray and empty throughout the trials. Each trial began with a fixation cross for 3000 ms, followed by four tasks (see Figure 2). For the first task (**mental image generation**), participants heard the name of the stimulus and were instructed to generate a mental image of it. They verbally indicated when they had formed the image, at which point the task ended. For the second task (**mental image inspection**), participants were presented with a statement describing the stimulus (e.g., “The frying pan is blue”) and were asked to indicate whether the statement correctly matched their mental image of the stimulus. For the third task (**mental image vividness**), participants rated the vividness of their mental image on a scale from 0 (no image) to 4 (very vivid) after hearing the prompt, “How vivid is your mental image?” Finally, for the fourth task (**old/new recognition task**), participants were asked to determine whether the stimulus they imagined was “old” (i.e., presented during encoding) or “new” (i.e., not shown previously). At the end of each trial, they were instructed to return their gaze to the center of the screen. All responses were given orally to the experimenter, who recorded them by typing them into a document on a computer.

The experiment lasted approximately 45 minutes in total. An additional questionnaire, the Object-Spatial Imagery Questionnaire (OSIQ, Blajenkova et al., 2006), was included for explorative purposes but is not further considered in this article.

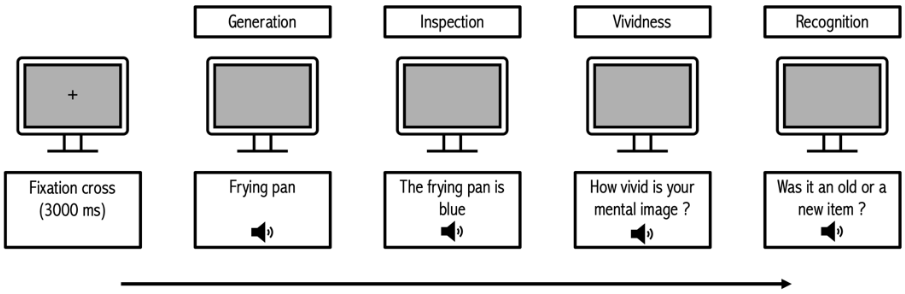

Figure 2. Illustration showing a trial run of the pictorial recall phase. The four tasks were performed in succession, each beginning with an auditory cue (i.e., the name of the stimulus or sentence) and ending with the participant's response.

Analyses

We analyzed participants' eye movements during both pictorial recall and perceptual encoding. Eye movement metrics included dwell-time (ms), dwell-time percentages, and fixation count. A fixation was defined by the visual gaze at the same location on the screen for at least 100 ms. Dwell-time referred to the total time participants spent looking at an area of interest (AOI), while dwell-time percentages were calculated by dividing the time participants spent looking at an AOI by the total time per trial and multiplying by 100. AOIs were classified as either corresponding vs. non-corresponding. The corresponding AOI referred to the quadrant of the screen where the videos of all stimuli in one category were presented. The other quadrants were defined as non-corresponding AOIs. We calculated the mean dwell-time of all non-corresponding AOIs to account for the weighted time of looking at one of the three non-corresponding quadrants. We report additional analyses based on dwell-time percentages in the supplementary material on OSF (https://osf.io/tmejy/). Regarding our main hypotheses (the LAN effect and the generalization effect), the choice of dwell-time metric (raw milliseconds vs. percentage) did not affect the pattern of results, nor did it alter whether the null hypothesis was accepted or rejected. We chose to report dwell-time in milliseconds in the main text, as this metric is more straightforward when interpreting main effects of task or comparing across groups (older vs. younger adults).

We used repeated-measures analyses of variance (ANOVAs) to check for differences in dwell-time between AOIs (corresponding vs. non-corresponding), tasks (mental image generation, mental image inspection, mental image vividness, and old/new recognition tasks), and stimulus types (old vs. new stimuli). We further used a mixed-model ANOVA to check for differences between age groups (older vs. younger adults). The analysis of dwell-time during pictorial recall included trials with correct responses for old items in both the mental image inspection and the old/new recognition tasks. For new items, we included all trials in the mental image inspection task (as no correct response was defined by design), but only correct rejections in the recognition task.

We were also interested in whether pictorial recall performance and vividness ratings differed between older and younger adults. Pictorial recall performance was defined as the percentage of correct answers during the mental image inspection and old/new recognition tasks. For the mental image inspection, the percentage indicated the rate at which the participants correctly evaluated the statements describing the 32 old stimuli. For the stimulus recognition, the percentage indicated the rate at which the participants correctly discriminated between old and new stimuli (i.e., percentage of hits and correct rejections). We performed independent sample *t*-tests to compare pictorial recall performance during mental image inspection and during old/new recognition tasks between older and younger adults. Vividness was descriptively analyzed using frequencies, modes, and medians, and an independent sample *t*-test was conducted to assess group differences. To explore associations between the LAN effect and recall performance, we conducted exploratory correlation analyses and mixed-effects modeling. As measures of effect size, we reported partial eta squared (η^2_p) for the ANOVAs and Cohen's *d* for the *t*-tests. The Greenhouse–Geisser correction was applied when sphericity was violated. All tests were two-tailed, and the alpha level was set to 0.05. All statistical analyses were performed in Rstudio (Rstudio Team, 2020). All codes and scripts are available on OSF (https://osf.io/tmejy/).

Results

Dwell Time during Pictorial Recall

Older adults

To assess whether the LAN effect and the generalization to other stimuli within the same categories were present in *older adults*, we conducted a three-way repeated-measures ANOVA to investigate the effect of the AOI (corresponding vs. non-corresponding), task (mental image generation, mental image inspection, mental image vividness, and old/new recognition task), and stimulus type (old vs. new stimuli) on dwell-time. The results are visualized in Figures 3. The full ANOVA table with the results is reported in Appendix A. The analysis revealed no significant three-way interaction between AOI, task and stimulus type *(p* = .852) and no significant two-way interactions between AOI and task (*p* = .174) or between AOI and stimulus type (*p* = .316). However, we found a significant two-way interaction between task and stimulus type (F[2.46, 88.58] = 4.19, p = .012, η^2_p = .104). To unpack this interaction, we conducted post hoc pairwise comparisons, correcting for multiple testing using the Bonferroni correction. For old stimuli, dwell-time was significantly higher during mental image inspection compared to mental image generation (t(36) = 6.43, p < .001, d = 1.06) and mental image vividness (t(36) = 5.12, p < .001, d = 0.84) and significantly lower during mental image generation compared to old/new recognition (t(36) = 4.36, p < .001, d = 0.72) and compared to mental image vividness (t(36) = 3.04, p = .026, d = 0.50). For new stimuli, dwell-time was significantly higher during mental image inspection compared to image generation (t(36) = 4.11, p = .001, d = 0.68) and mental image vividness (t(36) = 3.60, p = .006, d = 0.59).The analysis further revealed a significant main effect of AOI (F[1, 36] = 6.06, p = .019, η^2_p = 0.14), suggesting that older adults spent more time on the areas associated with the location of the encoded stimuli (M = 851.92 ms, SD = 395.29) compared to non-corresponding areas (M = 704.37 ms, SD = 228.29) when recalling both old and new stimuli during all tasks. We also found a main effect of task (F[2.08, 74.86] = 14.68, p < 0.001, η^2_p = .29), with highest values observed during mental image inspection (M = 886.89, SD = 348.77) and lowest during mental image generation (M = 664.32, SD = 283.83), reflecting task-specific differences in dwell-time.

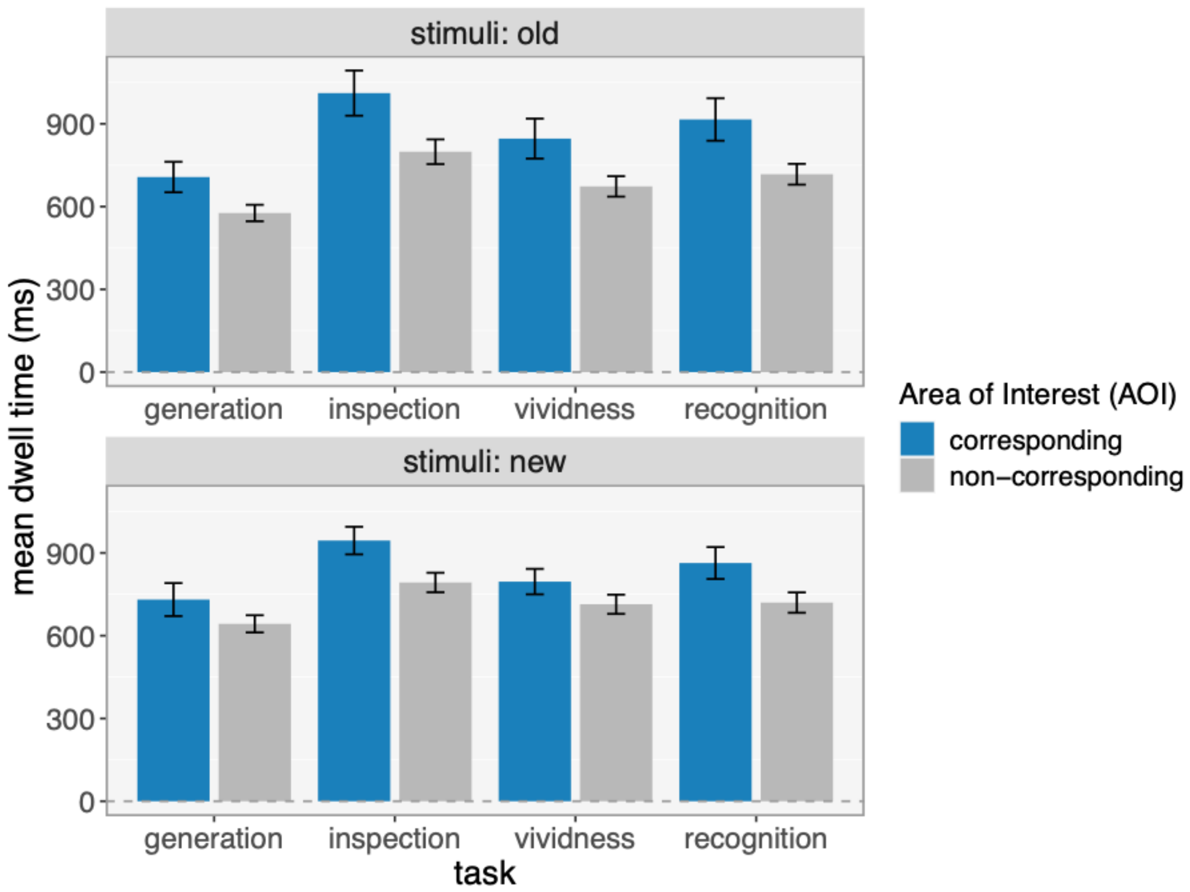

Figure 3. Mean dwell-time as a function of AOI, task, and stimulus type in older adults.

Younger adults

To replicate the LAN and generalization effects in *younger adults*, we conducted a second three-way repeated-measures ANOVA to examine the effect of AOI (corresponding vs. non-corresponding), task (mental image generation, mental image inspection, mental image vividness, and old/new recognition task), and stimulus type (old vs. new) on dwell-time. The results are visualized in Figures 4. The full ANOVA table with the results is reported in Appendix B. The analysis revealed a significant three-way interaction between AOI, task, and stimulus type (F[2.15, 79.48] = 3.29, p = .039, η^2_p = .08). Pairwise comparisons revealed significantly higher dwell-time for corresponding compared to non-corresponding AOIs across all four tasks and for both old and new stimuli: during mental image generation for old (t[37] = 2.80, p = .008, d = 0.45) and new stimuli (t[37] = 2.15, p = .038, d = 0.35); mental image inspection for old (t[37] = 3.76, p < .001, d = 0.61) and new stimuli (t[37] = 2.85, p = .007, d = 0.46); mental image vividness for old (t[37] = 3.24, p = .003, d = 0.53) and new stimuli (t[37] = = 3.06, p = .004, d = 0.50); and old/new recognition for old (t[37] = = 3.33, p = .002, d = 0.54) and new stimuli (*t*[37] = 2.77, p = .009, d = 0.45). These findings indicate a robust LAN effect across all tasks and both stimulus types (see Figure 4). The analysis revealed no significant interaction between AOI and stimulus type (*F*[1, 37] = 3.87, p = .057, η^2_p = .10). However, we found significant two-way interactions between AOI and task (*F*[1.88, 69.49] = 3.23, p = .048, η^2_p = .08) and between task and stimulus type (*F*[2.21, 81.68] = 10.07, p < .001, η^2_p = .21). Regarding the AOI × task interaction, pairwise comparisons again revealed significant differences in dwell-time between corresponding and non-corresponding AOIs across all tasks during mental image generation (*t*[37] = 2.56, p = .015, d = 0.42), mental image inspection (*t*[37] = 3.629, p < .001, d = 0.59), mental image vividness (*t*[37] = 3.43, p = .002, d = 0.56) and during old/new recognition (*t*[37] = 3.40, p = .002, d = 0.55). Regarding the task × stimulus type interaction, pairwise comparisons showed significantly lower dwell-time for old stimuli during mental image generation compared to mental image inspection (*t*[37] = 4.66, p < .001, d = 0.76) and old/new recognition (*t*[37] = = 2.98, p = .028, d = 0.48). Dwell-time was also significantly lower during mental image vividness compared to mental image inspection (*t*[37] = 3.46, p = .008, d = 0.56) and old/new recognition (*t*[37] = = 3.40, p = .010, d = 0.55.

The analysis further revealed significant main effects of AOI (*F*[1, 37] = 11.77, p = .001, η^2_p = .24), task (*F*[1.69, 62.42] = 3.91, p = .032, η^2_p = .10), and stimulus type (*F*[1, 37] = 4.28, p = .046, η^2_p = .10). On average, dwell-time was greater for corresponding AOIs (*M* = 1220.28 ms, *SD* = 858.41) than for non-corresponding AOIs (*M* = 708.83 ms, *SD* = 296.16), with the highest values observed during mental image inspection (*M* = 1030.06 ms, *SD* = 782.83) and the lowest during mental image generation (*M* = 890.98 ms, *SD* = 708.36). Furthermore, participants looked longer at old stimuli (*M* = 993.81 ms, *SD* = 765.29) than at new stimuli (*M* = 935.30 ms, *SD* = 606.97), indicating greater engagement with previously encoded items.

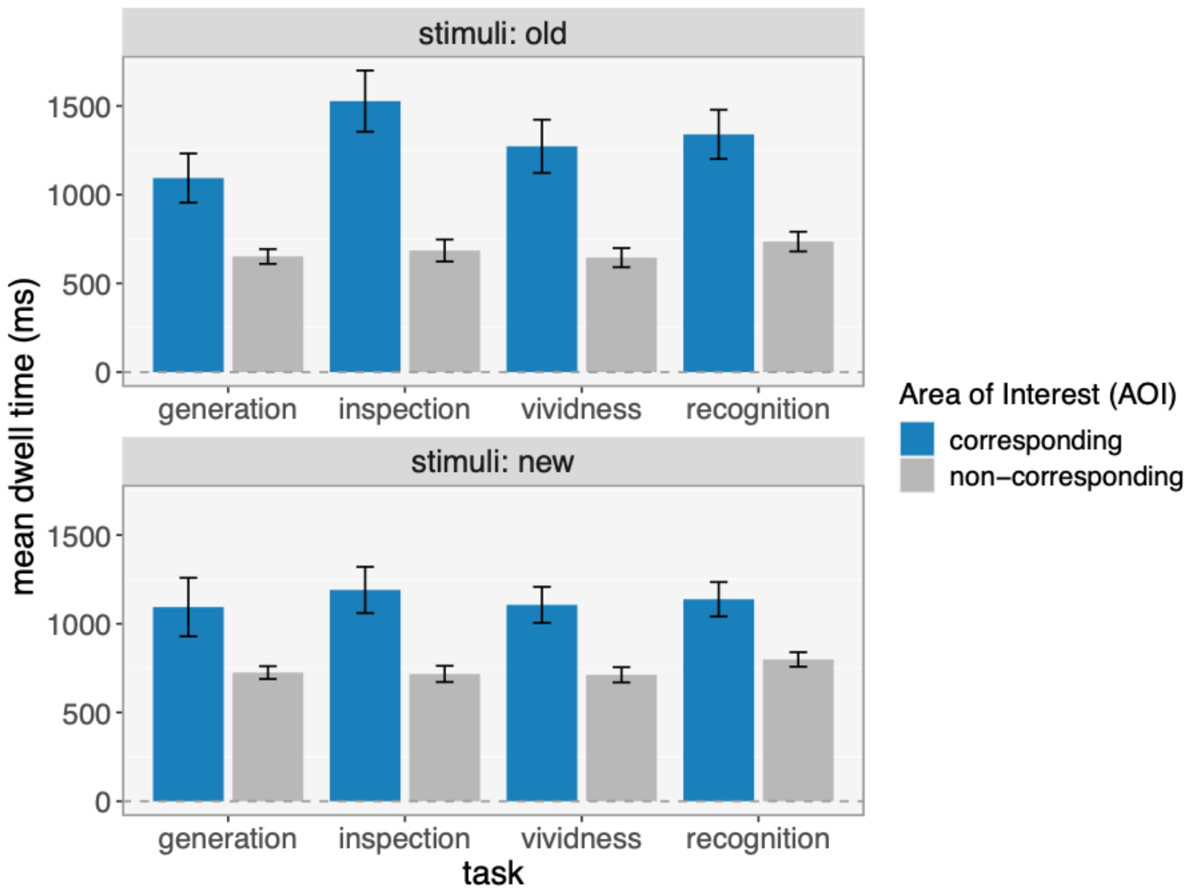

Figure 4. Mean dwell-time as a function of AOI, task, and stimulus type in younger adults.

Comparison of older vs. younger adults

To explore whether the LAN and generalization effects differed between older and younger adults, we conducted an additional mixed ANOVA to investigate the effect of age group (older vs. younger adults), AOI (corresponding vs. non-corresponding), task (mental image generation, mental image inspection, mental image vividness, and old/new recognition task), and stimulus type (old vs. new stimuli) on dwell-time. Based on the results presented above, we decided to compute this analysis, even though it was not pre-registered. The full ANOVA table with the results is reported in Appendix C. The analysis revealed no significant four and three-way interactions ($p > .102$). We did, however, find a two-way interaction between age group and AOI ($F[1, 73] = 5.0$, $p = .028$, $\eta^2_p = .06$), suggesting different patterns of the LAN effect between older vs. younger adults. This interaction reflects an ordinal pattern: both age groups showed significant differences in dwell-time between corresponding and non-corresponding AOIs across tasks, but the effects were substantially more pronounced in younger adults. Specifically, post hoc comparisons indicated that the AOI difference was significant in both older adults (t[36] = 2.46, p = .019, d = 0.40) and younger adults (t[36] = 3.43, p = .001, d = 0.56), with the latter showing a larger effect size. This suggests that while both groups engage in analogous eye movement behaviors reflecting LAN effects, the magnitude of these effects is consistently reduced in older adults. This group difference is illustrated in Figure 5.

We also found significant interactions between stimulus type and task (F[2.32, 162.17] = 13.77, p < .001, η^2_p = .16), between AOI and task (F[2.01, 146.39] = 4.19, p = .017, η^2_p = .05), and between AOI and stimulus type (F[1, 73] = 4.83, p = .031 η^2_p = .06), as well as significant main effects of age group (F[1, 73] = 11.01, p = .001, η^2_p = .13), AOI (F[1, 73] = 16.50, p < .001, η^2_p = .18), and task (F[1.84, 134.57] = 14.74, p <.001, η^2_p = .17). Means and standard deviations of dwell-time by task, age group, stimulus type, and AOI are reported in Appendix D.

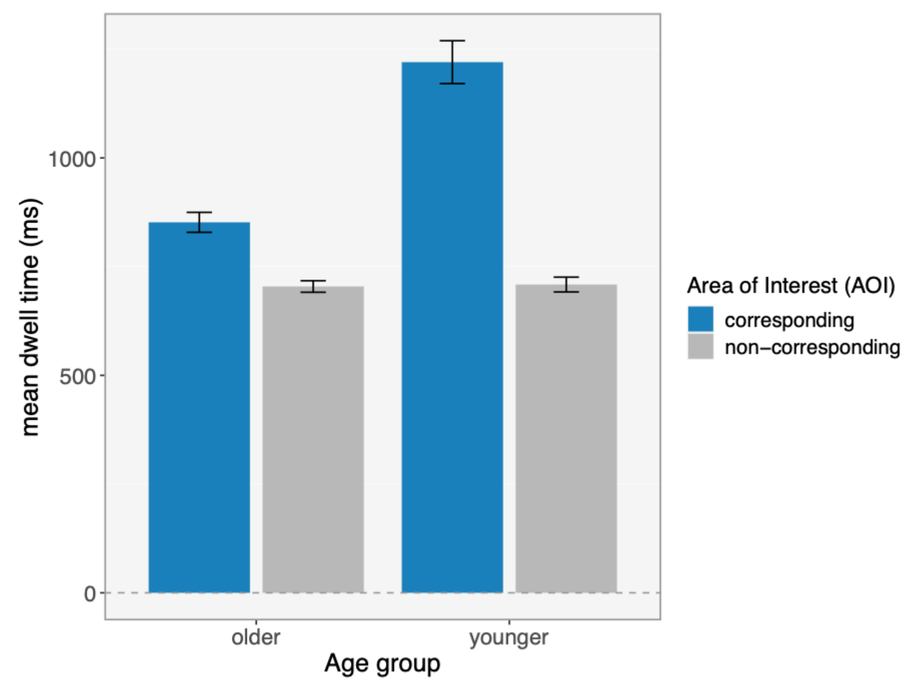

Figure 5 Mean dwell-time as a function of AOI and age group.

Dwell Time during Perceptual Encoding

To assess the differences between age groups during encoding, we conducted a mixed-model ANOVA to investigate the effect of AOI (corresponding vs. non-corresponding) and age group (older vs. younger adults) on dwell-time. We found no significant two-way interaction between AOI and age-group (F[1, 73] = 3.01, p = .087, η^2_p = .06). The main effect of AOI (F[1, 73] = 2004.19, p < .001, η^2_p =

.97) indicated a higher dwell-time in the area in which the videos were presented (corresponding AOI) for both younger (*M* = 4240.34. ms, *SD* = 483.87) and older adults (*M* = 3983.36 ms, *SD* = 641.32) than in the non-corresponding areas (*M* = 585.91 ms, *SD* = 63.49 for younger adults; *M* = 601.60 ms, *SD* = 224.03 for older adults). This result confirms the proper encoding of the stimuli. We also found a significant main effect of age group ($F[1, 73] = 4.67$, $p = .034$, $\eta^2_p = .06$). On average, younger adults showed longer dwell-times (*M* = 2413.12 ms, *SD* = 1871.03) compared to older adults (*M* = 2292.48 ms, *SD* = 1768.00).

Error Trials

To explore whether the LAN effect is specific to correctly remembered items, we conducted an additional mixed ANOVA on error trials, with AOI (corresponding vs. non-corresponding) and task (mental image generation, mental image inspection, mental image vividness, and old/new recognition task) as within-subject factors and age-group as between-subject factor. Note that this analysis was not preregistered and is therefore considered exploratory. Moreover, it is based on a relatively small number of error trials. The full ANOVA table with the results is reported in Appendix E. The analysis revealed no significant three- or two-way interactions ($p > .194$). We also found no significant main effects for AOI ($F[1, 62] = .2.69$, $p = .106$, $\eta^2_p = .04$) or age group ($F[1, 62] = 2.580$, $p = .099$, $\eta^2_p = .04$). However, we found a main effect of task ($F[2.33, 144.63] = 5.46$, $p = .004$, $\eta^2_p = .08$) with highest values during mental image inspection (*M* = 899.25 ms, *SD* = 827.38) and lowest during mental image generation (*M* = 722.92 ms, *SD* = 675.09). Means and standard deviations of dwell-time by task, age-group, and AOI are reported in Appendix F.

Fixations

The results of the analyses reported above revealed that the LAN effect was less pronounced in older adults than in younger adults. To further investigate this difference, we plotted fixations during encoding and recall, which were merged for all stimuli and divided by age group, task, and location of the corresponding AOI (i.e., the quadrant of the screen in which the stimuli were presented during encoding; see Figure 6's upper plot for older adults and the bottom plot for younger adults).

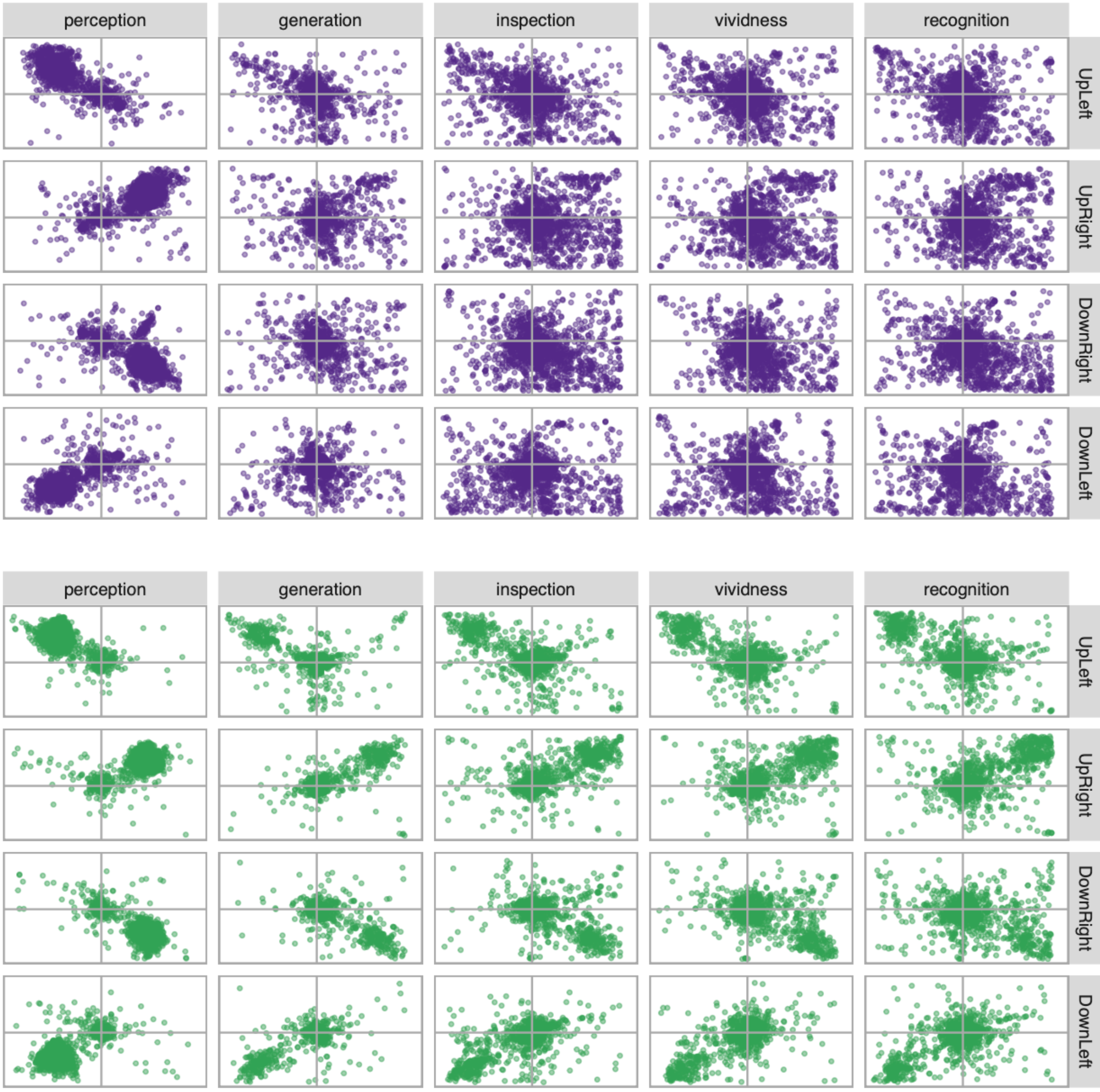

Figure 6. Plots illustrating fixations of older adults (upper plot) and younger adults (bottom plot) during encoding and pictorial recall for old stimuli. Each column corresponds to one task (i.e., mental image generation, mental image inspection, mental image vividness, and old/new recognition tasks). Each line corresponds to the location of the corresponding AOI (i.e., the quadrant of the screen in which the stimuli were presented during encoding).

Consistent with the statistical analyses reported above, the plots showed more dispersed fixations across the screen in older adults compared to younger adults during pictorial recall. This suggests fewer systematic fixation patterns in older compared to younger adults. These differences in fixation patterns between older and younger adults were also apparent for new stimuli. Plots showing the fixations for new stimuli are provided in Appendix G.

Pictorial Recall Performance

To compare pictorial recall performance between older and younger adults, we conducted independent sample *t*-tests. We found no difference in memory performance in the mental image inspection task between age groups (older adults: 68.24%, *SD* = 8.45 correct; younger adults: 70.15%, *SD* = 8.92 correct; *t*[73] = 0.95, *p* = 0.346, *d* = 0.219). However, older adults were less accurate on the old/new recognition task (older adults: 87.25%, *SD* = 6.03 correct; younger adults: 90.20%, *SD* = 6.74 correct; *t*[73] = 2.00, *p* = 0.049, *d* = 0.461).

Vividness Rating

The frequencies, modes, and medians of the vividness ratings for both age groups are reported in Table 1. Descriptive statistics revealed that older adults rated their mental images as very vivid (mode = 4, median = 4) more frequently (60%) than younger adults (mode = 3, median = 3), who rated their images as very vivid 34% of the time. This pattern was confirmed by a significant *t*-test, which showed that older adults (*M* = 3.36, *SD* = 0.95) rated their mental images as significantly more vivid than younger adults (*M* = 2.94, *SD* = 1.01, *t*[73] = 2.87, *p* = 0.005, *d* = 0.658).

Table 1. Descriptive analysis of the vividness rating (frequencies in %, mode, and median)

Age group	*0 (%)*	*1(%)*	*2(%)*	*3(%)*	*4 (%)*	*mode*	*median*
Older adults	2.47	2.26	11.84	23.42	60.01	4	4
Younger adults	2.12	6.68	7.00	21.20	35.77	3	3

***Note*.** The vividness rating is measured on a 0 to 4 Likert scale, where 0 = no image, and 4 = very vivid.

LAN Effect and Pictorial Recall Performance

To explore whether the LAN effect predicted pictorial recall performance, we conducted additional models on trial level. The analyses were based on old stimuli only, because pictorial recall performance was defined as the correct evaluation of each sentence during the mental image inspection task (Model 1) and as the correct recognition of each stimulus as „old“ during the old/new recognition task (Model 2). The LAN effect was defined as dwell-time percentage in the corresponding AOI across all tasks for each trial. Due to the dichotomy of the outcome variables (correct vs. incorrect), we used generalized linear mixed-effects models with a binomial link function to estimate the probability of a correct response. Both models included LAN (grand mean centered), age group (older adults vs. younger adults) and their interaction as fixed effects. Furthermore, we included random intercepts for participants to account for repeated measurements.

For the mental image inspection task (Model 1), none of the fixed effects were statistically significant (LAN, b = –0.03, SE = 0.07, z = –0.37, p = .712; age group, b = 0.08, SE = 0.09, z = 0.87, p = .384; LAN × age group, b = 0.11, SE = 0.09, z = 1.16, p = .247). Model comparison indicated that the full model did not significantly improve model fit over the intercept-only model, $\chi^2(3)$ = 2.73, p = .436. These results suggest that the LAN effect did not significantly predict performance in the mental image inspection task for both older and younger adults.

For the old/new recognition task (Model 2), again no significant effects of LAN, age group or interaction were observed (LAN, b = 0.15, SE = 0.09, z = 1.66, p = .097; age group, b = 0.20, SE = 0.18, z = 1.08, p = .281; LAN × age group, b = 0.03, SE = 0.13, z = 0.21, p = .830). However, the full model explained significantly more variance than the intercept-only model, $\chi^2(3)$ = 8.27, p = .041, suggesting that, while individual predictors were not statistically significant, the combined effects modestly improved model fit. Model-predicted probabilities of correct recognition by age group are illustrated in Figure 7.

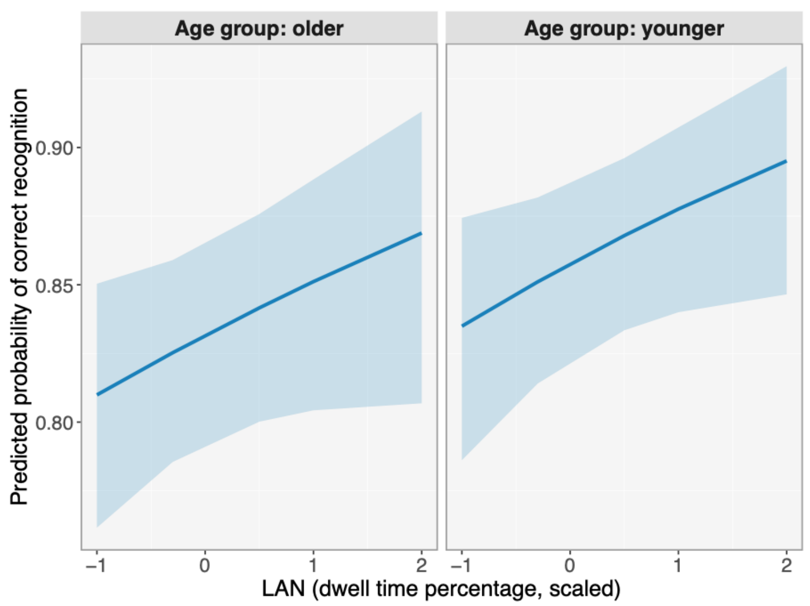

Figure 7. Predicted probabilities of correct recognition by LAN effect (dwell-time percentage in the corresponding area of interest) and age group.

LAN Effect and Vividness

To explore whether the LAN effect predicted vividness, we conducted an additional trial-level analysis including all stimuli. We used a linear mixed-effects model, with LAN (grand mean-centered), age group (older adults vs. younger adults), and their interaction as fixed effects. Random intercepts for participants were included to account for repeated measurements. The effect of age group was significant (age group, $b = -0.40$, $SE = 0.14$, $t = -3.249$, $p = .002$), consistent with our earlier analysis (see Vividness Rating). The effects of LAN and the LAN × age group interaction were not significant (LAN, $b < 0.001$, $SE = 0.001$, $t = 0.457$, $p = .647$; LAN × age group, $b < 0.001$, $SE < 0.001$, $t = 0.789$, $p = .430$). A model comparison indicated that the full model significantly improved model fit over the intercept-only model, $\chi^2(3) = 12.389$, $p = .006$.

Discussion

The primary aim of this study was to investigate the presence of the LAN effect in older adults, as memory often declines with healthy aging. Revisiting previous locations has been proposed as a scaffold for generating and inspecting visual mental images (e.g., Martarelli et al., 2022). Thus, we sought to determine whether older adults also engage in LAN behavior during pictorial recall. By examining age-related changes in eye movement behavior, we aimed to gain insights into the mechanisms underlying memory decline in aging populations. Our results demonstrate that the LAN effect is present in older adults, although in a weaker form compared to younger adults. Older adults exhibited fewer systematic fixations, with their gazes more dispersed across the screen during pictorial recall. Additionally, unlike younger adults, older adults showed no differences in the LAN effect across tasks or between old and new stimuli. Despite these age-related differences in eye movement patterns, there were no significant differences in performance on the mental image inspection task between older and younger adults. For the old/new recognition task, a marginally significant difference was found, with younger adults slightly outperforming older adults. Interestingly, older adults rated their mental images as more vivid than those of younger adults, which raises questions about how mental image vividness is perceived or reported across age groups.

In line with earlier studies, we found that participants tended to look back at locations visited during encoding when visualizing previously seen stimuli, even when the screen was blank (e.g., Martarelli et al., 2017). This behavior supports the notion of integrated mental representations linking spatial cues with cognitive processes. Previous studies suggest that such revisits to prior locations may strengthen pictorial recall by activating memory traces that link spatial and visual information (e.g., Ferreira et al., 2008; see also Richardson et al., 2009). Although our study was not designed to directly test the functional role of eye movements, we found that eye movements to corresponding locations occurred predominantly on correctly solved trials (e.g., Martarelli & Mast, 2011; but see Chiquet et al., 2022, for differing findings), suggesting that such behavior may support retrieval.

However, the results of our exploratory trial-level analyses yielded mixed results. The LAN effect did not significantly predict performance on the mental image inspection task. In the recognition task, the full model explained more variance than the intercept-only model, but individual predictors were not significant. While this may point to a modest role for the LAN effect, these findings remain correlational and should be interpreted with caution (cf. Kumcu & Thompson, 2020).

Our findings indicate that the LAN effect diminishes with age, which likely reflects age-related changes in memory processing. The reduced specificity of eye movement patterns in older adults may reflect a form of behavioral dedifferentiation, consistent with neural-level findings (Koen et al., 2020). That is, just as neural representations become less distinct with age, so too might the spatial reinstatement via eye movements become less precise, even when performance remains relatively intact. However, our results contrast with those reported in previous research (e.g., Wynn et al., 2018, 2021), likely due to methodological differences. For example, Wynn et al. (2018) examined fixation reinstatement during the maintenance phase, whereas we measured the LAN effect during long-term recall. The delay between encoding and pictorial recall was much longer in our study, which may have made the participants less accurate in reinstating spatial information, thereby limiting their ability to use spatial location as a compensatory strategy for memory decline. Another difference lies in the abstraction level of the stimuli. Specifically, Wynn et al. (2018) used abstract objects, whereas our stimuli were concrete and familiar. Although our aim was to study episodic memory, it is conceivable that semantic memory played a role in our task, particularly for older adults. This aligns with previous research suggesting that older adults tend to rely more on semantic information than episodic information in memory tasks (Dennis et al., 2014; Naspi et al. 2022). Relatedly, Conti et al. (2024) examined how scene construction is supported by eye movements using a blank-screen paradigm, and how this process varies with age and task complexity. They found that older adults made more fixations and saccades during simpler trials, but showed a reduction in eye movements after the second element was introduced – possibly indicating a compensatory shift of cognitive resources from external scanning to internal visualization. Younger adults maintained a stable level of eye movements across complexity levels. This shift in older adults may help explain the reduced LAN effect in our data, suggesting a strategy that favors internal over external cues, under higher cognitive load.

A further explanation for the LAN effect involves the fixed pairing of stimulus categories with screen quadrants during encoding. Because each semantic category was consistently associated with a specific screen location, it is possible that participants – especially older adults – learned these category-location associations and relied on them during recall. This may account for the reduced differentiation in gaze behavior between old and new items among older adults. Rather than reflecting precise item-location memory, the observed gaze behavior may have been guided by generalized category expectations. While this interpretation remains speculative, it aligns with evidence of age-related declines in hippocampal pattern separation processes, which support the discrimination of similar memories (Yassa and Stark, 2011). Supporting this, Salvato et al. (2016) found that only younger adults showed a correlation between orienting behavior and explicit memory, suggesting a decoupling between gaze and memory in aging. Taken together, these results indicate that older adults may rely on qualitatively different retrieval strategies that place less emphasis on spatially grounded mechanisms.

Despite differences in eye behavior, we found no significant difference in the mental image inspection task between older and younger adults, contrary to our expectations. This task required participants to evaluate sentences about specific object details by integrating features like color into a unique mental representation. Given that older adults tend to show reduced memory precision (Korkki et al., 2020), we anticipated greater difficulty in recalling object details among older participants. However, our results did not support this prediction. Different explanations are possible for these findings. First, during encoding, the participants viewed a four-second video presentation accompanied by the stimulus name, and this combination of verbal and visual modalities may have enhanced the encoding depth. Furthermore, previous studies have suggested that multisensory encoding can serve as a compensatory strategy for older adults (Laurienti et al., 2006). Additionally, the total number of stimuli (32) may have been within the limits of the available cognitive resources for encoding. Importantly, this dissociation between eye movements and mental image inspection performance deserves careful consideration. It is possible that eye-tracking measures reflect differences in retrieval strategy rather than recall accuracy per se. This may point to an age-related shift toward gist-based processing, which, although less detailed, can be adaptive in supporting memory-guided behavior in older adults (Grilli & Sheldon, 2022). However, we cannot rule out that some of the observed age effects originate during encoding. Although there was no interaction between age group and AOI, older adults showed reduced dwell-time during encoding overall. This may suggest that older adults engaged less with the visual stimuli or used different encoding strategies from the outset. The possibility remains that age-related differences in initial processing contributed to later variability in recall performance and eye movement patterns.

For the recognition task, statistical analysis revealed a marginally significant difference in performance between older and younger adults ($p = 0.049$), with younger adults slightly outperforming older ones. This finding aligns with previous research demonstrating an age-related decline in recognition memory (Old & Naveh-Benjamin, 2008; Rhodes et al., 2019). Evidence suggests that older adults tend to be less effective at recognition tasks, particularly when the stimuli to be discriminated against belong to the same semantic category, as in our experiment (Fraundorf et al., 2019). Since the new stimuli in our study shared the same semantic category as the old stimuli, older adults likely faced greater difficulty distinguishing between old and new stimuli compared to younger adults. Older adults rated their mental images as more vivid than younger adults. This finding could suggest that older adults either perceive or interpret vividness differently, or it might reflect a subjective bias in which older adults may feel more confident about their perceptions of vividness (Folville et al., 2022; see e.g., also Conti et al., 2024).

Our study has several limitations. First, our power analysis was designed to detect a LAN effect within the older adult population (within subjects), rather than testing for differences between younger and older adults. This limits the generalizability of our findings to direct comparisons between age groups. Future research should aim to replicate the findings with a larger sample size, especially the differences between younger and older adults. Second, despite using video stimuli to enhance ecological validity, the experimental setup remained highly controlled. Using more naturalistic tasks in future research would improve the ecological validity of the paradigm and its relevance to everyday memory (Martarelli et al., 2023). Third, recognition performance was near ceiling, which may have masked age differences. Future research should adopt more challenging recognition tasks. Fourth, our older adult sample had a narrow age range (65–75) and all scored above 26 on the MoCA, indicating intact cognition. Prior studies often included older participants over 80, which may explain stronger age effects in those samples. Including a broader and more heterogeneous older adult population may help clarify whether observed differences reflect normal age-related changes or early, subtle cognitive declines not captured by standard screening tools.

Overall, our findings align with growing evidence that eye movements play an active role in cognitive processes such as pictorial recall and mental simulation (e.g., Wynn et al., 2022). The results suggest that eye movement behavior during pictorial recall changes with age, which potentially reflects subtle shifts in memory processing. Accordingly, the results point to semantic memory as a possible compensatory mechanism in older adults, which may help mitigate the decline in episodic memory by providing more generalized retrieval cues. This interpretation is consistent with the notion that older adults increasingly rely on gist-based representations, which capture the general meaning or category of stimuli rather than specific visual details. Such a shift may help explain both the less systematic eye movement patterns and the relatively preserved performance on the pictorial recall tasks. Future research is needed to further clarify the role of eye movements in memory decline during healthy aging. For example, manipulating eye position during recall or encoding with older adults, as has been done with younger participants, could provide valuable insights into the functional role of eye movements in pictorial recall. Additionally, using more complex tasks or real-world scenarios may help to determine how these findings translate into everyday memory challenges.

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Appendix A

ANOVA table showing the effect of stimuli, task, and AOI on dwell-time in older adults.

Predictor	*Num DF*	*Den DF*	*F-value*	*p-value*	η^2_p
Pictorial recall					
Stimuli	1.00	36.00	0.06	.803	.00
Task	**2.08**	**74.86**	**14.68**	**< .001**	**.29**
AOI	**1.00**	**36.00**	**6.06**	**.019**	**.14**
Stimuli:Task	**2.46**	**88.58**	**4.19**	**.012**	**.10**
Stimuli:AOI	1.00	36.00	1.04	.316	.03
Task:AOI	3.00	108.00	1.69	.074	.05
Stimuli:Task:AOI	2.46	88.62	0.21	.852	.01

Note. AOI = area of interest

Appendix B

ANOVA table showing the effect of stimuli, task, and AOI on dwell-time in younger adults.

Predictor	*Num DF*	*Den DF*	*F-value*	*p-value*	η^2_p
Pictorial recall					
Stimuli	**1.00**	**37.00**	**4.28**	**.046**	**.10**
Task	**1.69**	**62.42**	**3.91**	**.032**	**.10**
AOI	**1.00**	**37.00**	**11.77**	**.001**	**.24**
Stimuli:Task	**2.21**	**81.68**	**10.07**	**< .001**	**.21**
Stimuli:AOI	1.00	37.00	3.87	.057	.10
Task:AOI	**1.88**	**69.49**	**3.23**	**.048**	**.10**
Stimuli:Task:AOI	**2.15**	**79.48**	**3.29**	**.039**	**.08**

Note. AOI = area of interest

Appendix C

ANOVA table showing the effect of age-group, stimuli, task, and AOI on dwell-time.

Predictor	*Num DF*	*Den DF*	*F-value*	*p-value*	η^2_p
Pictorial recall					
Age-group	**1.00**	**73.00**	**11.01**	**.001**	**.13**
Stimuli	1.00	73.00	3.29	.074	.04
Task	**1.84**	**134.57**	**14.74**	**< .001**	**.17**
AOI	**1.00**	**73.00**	**16.50**	**< .001**	**.19**
Age-group:Stimuli	1.00	73.00	2.31	.133	.03
Age-group:Task	1.84	134.57	0.76	.459	.01
Age-group:AOI	**1.00**	**73.00**	**5.03**	**.028**	**.06**
Stimuli:Task	**2.32**	**169.17**	**13.77**	**< .001**	**.16**
Stimuli:AOI	**1.00**	**73.00**	**4.83**	**.031**	**.06**
Task:AOI	**2.01**	**146.39**	**4.19**	**.017**	**.05**
Age-group:Stimuli:Task	2.32	169.17	2.23	.102	.03
Age-group:Stimuli:AOI	1.00	73.00	1.63	.206	.02
Age-group:Task:AOI	2.01	146.39	1.65	.196	.02
Stimuli:Task:AOI	2.31	168.32	2.59	.07	.03
Age-group:Stimuli:Task:AOI	2.31	168.32	2.05	.125	.03

Note. AOI = area of interest

Appendix D

Means and standard deviations of dwell-time by task, age group, stimuli, and AOI.

Task	*Age Group*	*Stimulus Type*	*AOI*	*M*	*SD*
Generation	Older	Old	C	706.98	335.93
			Non-C	576.57	181.39
		New	C	730.82	363.95
			Non-C	642.89	189.6
	Younger	Old	C	1093.61	852.69
			Non-C	651.63	256.06
		New	C	1093.83	1017.05
			Non-C	724.83	221.68
Inspection	Older	Old	C	1011.29	497.67
			Non-C	798.75	272.57
		New	C	944.84	303.51
			Non-C	792.7	214.81
	Younger	Old	C	1527.16	1062.91
			Non-C	685.32	381.91
		New	C	1190.61	802.12
			Non-C	717.14	281.19
Recognition	Older	Old	C	915.67	468.94
			Non-C	717.12	229.3
		New	C	863.43	351.36
			Non-C	720.0	224.17
	Younger	Old	C	1339.7	853.64
			Non-C	735.52	342.46
		New	C	1138.09	598.05
			Non-C	798.98	251.85
Vividness	Older	Old	C	846.3	440.67
			Non-C	673.01	225.42
		New	C	795.98	280.26
			Non-C	713.89	211.58
	Younger	Old	C	1272.61	924.42
			Non-C	644.93	332.88
		New	C	1106.61	624.99
			Non-C	712.28	263.76

Note. AOI = area of interest, C = corresponding area of interest, Non-C = non-corresponding area of interest

Appendix E

ANOVA table showing the effects of age-group, task and AOI on dwell-time in error trials.

Predictor	*Num DF*	*Den DF*	*F-value*	*p-value*	η^2_p
Pictorial recall					
Age-group	1.00	62.00	2.80	.099	0.04
Task	**2.33**	**144.63**	**5.46**	**.003**	**0.08**
AOI	1.00	62.00	2.69	.106	0.04
Age-group:Task	2.33	144.63	0.28	.788	<.01
Age-group:AOI	1.00	62.00	1.71	.195	0.03
Task:AOI	2.35	145.82	0.04	.974	<.01
Age-group:Task:AOI	2.35	145.82	0.47	.659	<.01

***Note*.** AOI = area of interest

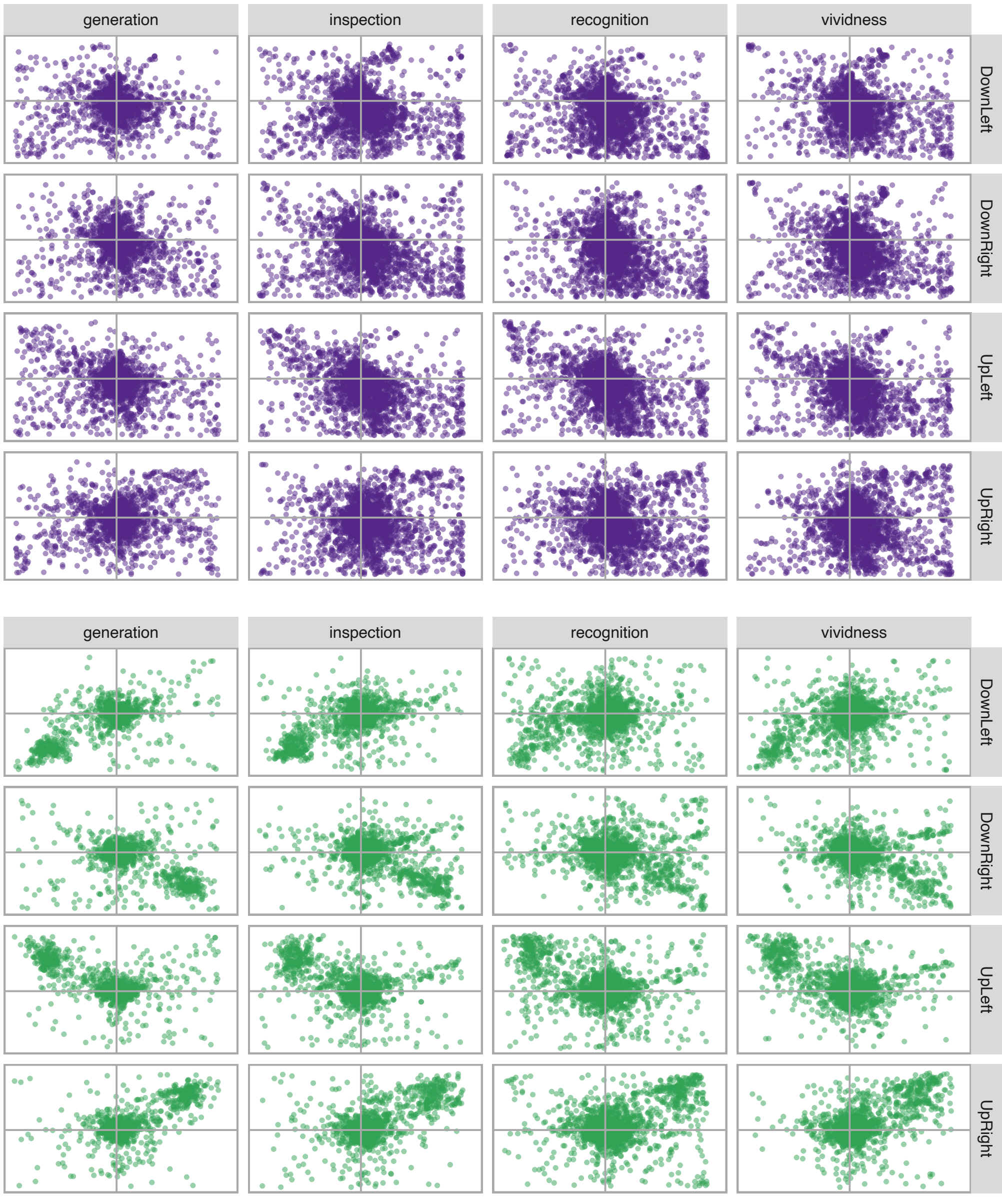
Appendix F

Means and standard deviations of dwell-time by task, age group, stimuli, and AOI.

Task	*Age Group*	*Stimulus Type*	*AOI*	*M*	*SD*
Generation	Older	Old	C	731.40	607.76
			Non-C	621.07	319.31
		New	C	887.25	1106.56
			Non-C	654.90	376.46
	Younger	Old	C	815.77	731.53
			Non-C	837.61	382.54
		New	C	1213.20	1336.13
			Non-C	734.96	467.86
Inspection	Older	Old	C	819.86	755.40
			Non-C	795.26	407.49
		New	C	1156.55	1376.97
			Non-C	794.62	462.05
	Younger	Old	C	750.38	791.98
			Non-C	687.68	362.44
		New	C	1066.45	1216.47
			Non-C	664.70	438.22
Recognition	Older	Old	C	731.40	607.76
			Non-C	621.07	319.31
		New	C	887.25	1106.56
			Non-C	654.90	376.46
	Younger	Old	C	815.77	731.53
			Non-C	837.61	382.54
		New	C	1213.20	1336.13
			Non-C	734.96	467.86
Vividness	Older	Old	C	819.86	755.40
			Non-C	795.26	407.49
		New	C	1156.55	1376.97
			Non-C	794.62	462.05
	Younger	Old	C	750.38	791.98
			Non-C	687.68	362.44
		New	C	1066.45	1216.47
			Non-C	664.70	438.22

Note. AOI = area of interest, C = corresponding area of interest, Non-C = non-corresponding area of interest

Appendix G



Plots illustrating the fixations for older adults (upper plot) and younger adults (bottom plot) during the different tasks of the visual memory experiment for the new stimuli. Each column corresponds to one task (i.e., *perceptual encoding*, generation, inspection, vividness, and recognition during *pictorial recall)*. Each line corresponds to the location of the corresponding area of interest (i.e., the quadrant of the screen in which the stimuli were presented during *perceptual encoding)*.