Heliyon 9 (2023) e20241

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Aging attenuates the memory advantage for unexpected objects in real-world scenes

Lena Klever [a,b,*], Jasmin Islam [a], Melissa Le-Hoa Võ [c], Jutta Billino [a,b]

[a] *Experimental Psychology, Justus Liebig University Giessen, Germany*
[b] *Center for Mind, Brain, And Behavior (CMBB), University of Marburg and Justus Liebig University Giessen, Germany*
[c] *Department of Psychology, Goethe University Frankfurt, Frankfurt am Main, Germany*

ARTICLE INFO

Keywords:
Aging
Prior knowledge
Schema violations
Object memory
Scene perception

ABSTRACT

Across the adult lifespan memory processes are subject to pronounced changes. Prior knowledge and expectations might critically shape functional differences; however, corresponding findings have remained ambiguous so far. Here, we chose a tailored approach to scrutinize how schema (in-)congruencies affect older and younger adults' memory for objects embedded in real-world scenes, a scenario close to everyday life memory demands. A sample of 23 older (52–81 years) and 23 younger adults (18–38 years) freely viewed 60 photographs of scenes in which target objects were included that were either congruent or incongruent with the given context information. After a delay, recognition performance for those objects was determined. In addition, recognized objects had to be matched to the scene context in which they were previously presented. While we found schema violations beneficial for object recognition across age groups, the advantage was significantly less pronounced in older adults. We moreover observed an age-related congruency bias for matching objects to their original scene context. Our findings support a critical role of predictive processes for age-related memory differences and indicate enhanced weighting of predictions with age. We suggest that recent predictive processing theories provide a particularly useful framework to elaborate on age-related functional vulnerabilities as well as stability.

1. Introduction

We continuously accumulate knowledge about the world. From repeated experiences we learn that our environment follows compositional rules. For instance, objects underlie physical constraints (a toothbrush does not float in space) and are usually found within a certain context (a toothbrush belongs in the bathroom). By abstracting and storing these regularities as schemata, our brains can predict future encounters with similar environments and objects [1]. This prior knowledge of scene structure is particularly useful for object identification, when searching for specific objects or guiding attention towards goal-relevant information [2–4]. Schemata do not only support perception, but are also key for memory processes [5–7]. Given pronounced age-related changes in memory capacities, the functional role of schemata for age effects on object memory might be critical. However, so far studies have rarely addressed how prior knowledge and expectations affect older adults' memory for context-embedded objects.

* Corresponding author.Department of Psychology, Justus-Liebig-Universität, Otto-Behaghel-St 10F, 35394, Giessen, Germany.
E-mail address: Lena.C.Klever@psychol.uni-giessen.de (L. Klever).

https://doi.org/10.1016/j.heliyon.2023.e20241
Received 24 December 2022; Received in revised form 14 September 2023; Accepted 14 September 2023
Available online 16 September 2023

While many cognitive functions, such as processing speed, memory capacities, and inhibitory control are subject to age-related decline, world knowledge remains stable or even improves [8]. An amplified impact of prior knowledge has been suggested to contribute to older adults' decline and stability in memory performance [9]. Increased reliance on predictions could serve as a compensatory mechanism to optimize memory decisions. However, this advantage might fail and even turn to a disadvantage when predictions are violated and an overreliance on them becomes detrimental. Although our environment is generally predictable, deviations from expectations are essential for knowledge updating and adjusting behaviour appropriately [10]. A specific disadvantage for processing unexpected information would critically limit adaptivity to changing environments and affordances.

Several studies have been concerned with the role of schema expectations for object memory in older and younger adults, however, quite heterogenous result patterns have been reported. In order to provide an overview of the pervious findings, it is important to clarify that the generic use of the term *congruency effect* should be avoided since it can refer to contrary effect directions. The term subsumes performance benefits from schema-congruency as well as from schema-incongruency. This ambiguity can be resolved by distinguishing between a congruency advantage, i.e., a memory advantage for objects presented in congruent scene contexts, and an incongruency advantage, i.e., a memory advantage for objects presented in incongruent scene contexts. Whether an object memory advantage arises from schema congruency or schema incongruency, respectively, has been found to substantially depend on instructions during encoding. Notably, studies consistently provided evidence for only minor overall age-related differences in object memory, indicating robust resources in healthy aging [11–17]. However, memory advantages that emerged from object-scene (in) congruencies were subject to specific age effects.

When explicit instructions drawing attention to possible object-scene (in)congruencies were provided, observers consistently, i.e., older and younger adults, showed a memory advantage for objects that are congruent with schema-based expectations about a given scene [11–13]. Importantly, this congruency advantage was found to be more pronounced in older adults. The age-related benefit was observed in absolute object recognition performance as well as in memory for object details. These findings suggest an enhanced schema bias in older adults. While boosting recognition performance, though, the overreliance on prior knowledge could induce increased false alarm rates, qualifying a putative age-specific advantage.

In contrast to evidence for congruency advantages, memory studies that refrained from giving explicit instructions about object-scene (in-)congruencies yielded a reversed result pattern. Here, memory advantages were observed for objects that are incongruent with schema-based expectations about a given scene, i.e., incongruency advantages [14–17]. Performance benefits were robustly present across age groups, however, age effects on the magnitude of these incongruency advantages have remained ambiguous. In a paradigm using schematic line drawings of scenes, older adults showed more pronounced advantages than younger adults [16]. In contrast, studies focusing on objects embedded in real-world scenes yielded similar benefits across age groups [18] or even an opposite trend, i.e., less pronounced incongruency advantages in older than in younger adults [14,15,17]. In summary, the latter studies provided evidence that object memory can reliably benefit from object-scene incongruencies across the adult lifespan, but the advantage seems limited in older adults, indicating that prioritized processing of incongruent objects might be weakened.

We here aimed to specifically focus on naturalistic scenarios in which memory for objects might be required in everyday life. We particularly considered three criteria for the memory task to be close to real-world affordances that have not been combined in the previous studies described above. First, we presented objects naturally embedded in real-world scenes in contrast to a detached presentation [11–13,16]. In addition, photographs were supposed to ensure a standardized and controlled presentation of scenes, refraining from real-world settings [14,15,18]. Second, we presented the scenes in a free-viewing paradigm without additional task, e.g., a search task or an explicit object memory task [13,16,17]. Tasks per se affect how context information in scenes is processed [3,19] and might confound age effects [20,21]. Finally, we did not provide explicit instructions on possible object-scene inconsistencies [11–13], avoiding strategic processes that are especially vulnerable during ageing [22]. This tailored approach allows us to scrutinize how prior knowledge and expectations shape age effects on object memory in real-world scenes under free-viewing conditions.

2. Methods

2.1. Participants

A total of 23 older (11 males, age [years]: $M = 69.3$, $SD = 8.0$) and 23 younger adults (11 males, age [years]: $M = 26.8$, $SD = 6.1$) participated in this study. Older adults were part of our local database and screened for cognitive impairment using the MoCA [23]. Younger adults were recruited by calls for participation and matched in terms of educational background and reported gender. Older adults reported slightly fewer years of school education than younger adults, 11.7 years ($SD = 1.7$) and 12.7 years ($SD = 0.9$), respectively. Overall our sample is characterized by a bias towards higher educational levels with 52.2% of our participants having completed a higher academic degree. Neurologic or psychiatric disorders were screened out by self-report. Procedures and methods conformed to the Declaration of Helsinki [24] and were approved by the local ethics committee at Justus Liebig University Giessen (LEK 2017–0025). All participants provided informed written consent prior to the experiment.

2.2. Setup

Data was collected via an online platform (https://www.testable.org/). Participants carried out the experiment using their own stationary computers. Given the online setting of our study, we had to tolerate variance in the actual setups our participants used. However, basic technical parameters were logged and we were able to confirm that there were no systematic setup differences between our both age groups. With regard to operating systems, equivalent proportions of older and younger adults run macOS (13.0% vs.

26.1%) or Windows (87.0% vs. 73.9%), indicating similar distributions, $\chi^2(1, N = 46) = 1.24$, $p = .265$. Screen resolution varied in width between 810 px and 2560 px, in height between 614 px and 1440 px, and in the diagonal between 1249 px and 1809 px. Most importantly, we observed for neither parameter significant differences between both age groups (all two-sample *t*-tests yielded $ps > .08$).

Stimulus size was standardized by a calibration procedure so that stimuli scaled with the screen resolution of the participants' screens. At the start of the experiment, participants were asked to match the length of a line shown on their screens to the length of a bank card. General instructions ensured undisturbed, quite conditions and a fixed viewing distance from the screen, i.e., a distance approximately equal to the length of an arm (~60 cm).

2.3. Stimuli

We used indoor scenes photographs taken from the SCEGRAM database [25]. Based on the consistency ratings for every object-scene condition that are provided with the database, we derived two groups of object-scene combinations with which we maximized the difference between scenes with regard to supposed violated expectations. Given the above described calibration procedure, scenes were displayed at an approximate size of 18.9° × 14.3°. The scenes gave context information by six different room types (e.g., kitchen, bathroom). Target objects were naturally embedded in these scenes and were either congruent or incongruent with the given context (see Fig. 1A for examples). Target objects without scene context and distractor objects, taken from another database [26], were used for recognition. For recognition individual objects were displayed at an approximate size of 12.0° × 7.4°. Distractor objects were carefully chosen to match the target objects with regard to actual size, color, and semantical congruency with the given six room types. In addition, scenes without target objects were presented for matching recognized objects to their remembered context. A choice of three different scenes next to each other was presented, each with an approximate size of 8.6° × 6.5°.

2.4. Procedure

Participants first freely viewed 60 scenes, of which half contained target objects congruent or incongruent with the context, respectively. Participants saw each object and each scene, respectively, only once. There were no repetitions. Instructions called for memorizing the scenes in general and did not point to objects. The scenes were presented in randomized order, 3000 ms each with an ISI of 800 ms. Subsequently, participants filled out some unrelated questionnaires, introducing a delay of $M = 14 \pm 1$ min. Finally, participants were presented with the 60 target and 60 distractor objects after one another in randomized order. They had to label each object as *old* or *new*, i.e. whether they have seen it in the scenes or not. If labelled as *old*, objects had to be matched to the scene presented in previously. Three alternative scenes were offered, one scene giving a congruent, two scenes giving an incongruent context (see Fig. 1B). This configuration was chosen according to similar procedures in previous work [11], focusing in particular on congruency biases in scene associations for objects encoded in an incongruent context. When the valid incongruent scene context is erroneously not selected, participants either opt for the second incongruent scene or the congruent scene. Given these two options the

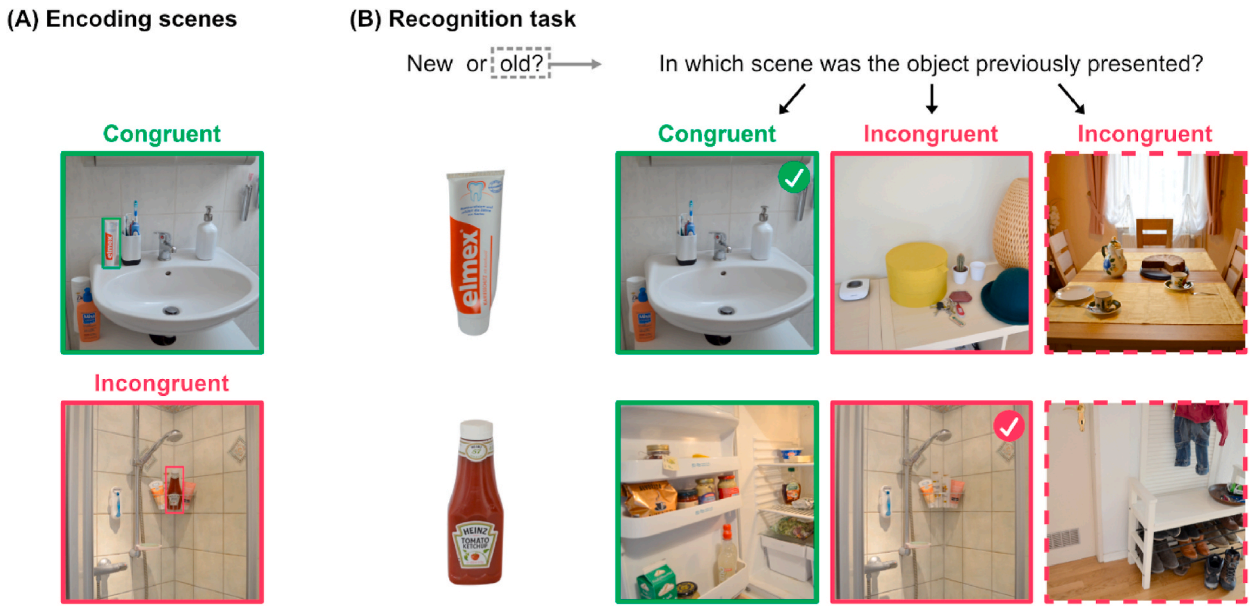

Fig. 1. Illustration of encoding and recognition procedures. (A) Scenes for encoding contained naturally embedded objects that were either congruent or incongruent with the given context. (B) Recognition procedure for a congruent target (upper row) and an incongruent target object (lower row). *Note*: Colored frames and labels are here used for illustration and were not used in the actual procedures.

congruency bias in associative scene memory can be evaluated. Responses were entered via the keyboard. All participants were familiarized with the procedure by two preceding demonstration trials based on additional scenes and objects, not included in the main experiment.

2.5. Data analyses

All measures we used for evaluation of memory performance were calculated for each individual participant and were than submitted to statistical analyses. Recognition performance was assessed in terms of the well-established d prime index (d') [27]. D′ is a measure of discriminability based on signal detection theory that is unaffected by response biases. It is given by the difference between the z-transformed standardized proportions of correct detections and false alarms, characterizing the ability to discriminate targets from distractors. In our memory task, higher d' values indicate better recognition performance. To evaluate how well participants remembered the scene context of objects, we calculated the proportion of scene selection errors relative to the overall number of correctly recognized objects. Data were analyzed using mixed ANOVAs with the between-subject factor *age group* (older vs. younger) and the within-subject factor *context* (congruent vs. incongruent). In order to explore whether scene selection errors for incongruent objects were driven by a congruency bias, i.e., a bias to associate those objects erroneously with congruent scene contexts, we additionally calculated which proportion of these errors were made in favor of the congruent scene. Response times for *old* and *new* decisions were explored using median values. Since response times tend to be skewed and are prone to outlier data, median values provide a more robust measure than mean values. Data were submitted to a two-factorial ANOVA with the between-subject factor *age group* (older vs. younger) and the within-subject factor *object type* (distractor, congruent, incongruent). If appropriate, main analyses were followed by post hoc paired comparisons with Bonferroni-Holm correction. Significance level was set to $\alpha = .05$ in all statistical analyses. If not stated otherwise, descriptive values are given as means ± SEMs.

3. Results

3.1. Object memory

We first determined whether object memory systematically varies between the two context conditions and two age groups (Fig. 2). We submitted d' values to a two-factorial ANOVA with *age group* as between-subjects factor and repeated measures on the factor *context*. The analysis yielded significant main effects of *age group*, $F(1, 44) = 11.47$, $p = .001$, $\eta_p^2 = 0.21$, and *context*, $F(1, 44) = 134.11$, $p < .001$, $\eta_p^2 = 0.75$. However, these main effects were qualified by a significant interaction effect, $F(1, 44) = 13.43$, $p < .001$, $\eta_p^2 = 0.23$. Follow-up *t*-tests showed that memory for objects encoded in an incongruent context was better than those encoded in a congruent context both in older and younger adults ($t(22) = 7.57$, $p < .01$, $d = 1.58$, and $t(22) = 8.94$, $p < .01$, $d = 1.87$, respectively). Notably, this memory advantage was less pronounced in older adults: While object memory was comparable between both age groups in the congruent context condition, $t(44) = 0.87$, $p = .388$, $d = 0.25$, older adults' memory performance was lower in the incongruent context condition, $t(44) = 4.32$, $p < .01$, $d = 1.28$.

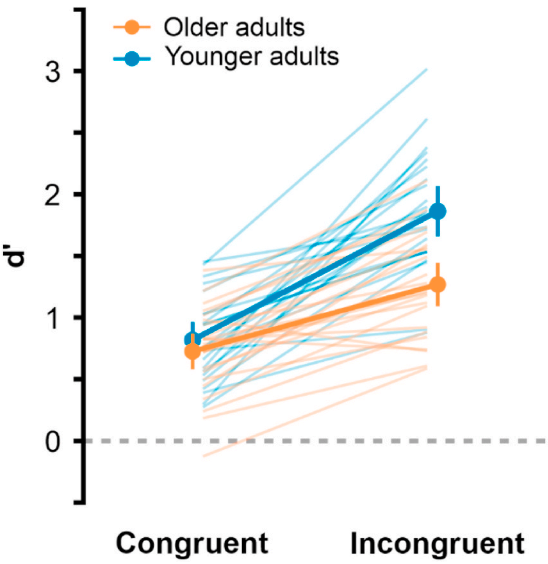

Fig. 2. Effects of age group and encoding context, i.e., congruent and incongruent, on object memory. Filled dots show the mean across observers and semi-transparent lines provide individual data. Older adults are plotted in orange, younger adults in blue. Error bars give 95% confidence intervals.

3.2. Scene memory

Participants' ability to remember the correct scene context of target objects was evaluated by the error rates in matching correctly recognized objects to corresponding scenes (Fig. 3). We ran a two-factorial ANOVA with *age group* as between-subject factor and repeated measures on the factor *context*. The main effects for *age group*, $F(1, 44) = 10.48$, $p = .002$, $\eta_p^2 = 0.19$, and *context*, $F(1, 44) = 69.24$, $p < .001$, $\eta_p^2 = 0.61$, reached significance, but were qualified by a significant interaction effect, $F(1, 44) = 9.12$, $p = .004$, $\eta_p^2 = 0.17$. Follow-up *t*-tests indicated that older and younger adults made considerably more errors assigning incongruent than congruent objects to the correct scenes ($t(22) = 6.95$, $p < .01$, $d = 1.45$, and $t(22) = 4.59$, $p < .01$, $d = 0.96$, respectively). However, the increase in error rates was more pronounced in older adults. Whereas error rates of both age groups did not differ for congruent target objects, $t(44) = 0.25$, $p = .804$, $d = 0.07$, older adults were especially prone to errors when assigning incongruent objects to their corresponding scenes, $t(44) = 3.99$, $p < .01$, $d = 1.18$.

3.3. Response times

We analyzed how response times in the object recognition task varied across age groups and object types, i.e., distractor, congruent, and incongruent objects. Median response times were submitted to a mixed ANOVA with the between-subject factor *age group* and the within-subject factor *object type* (Fig. 4). We determined a significant main effect for *age group*, indicating age-related slowing, $F(1, 44) = 25.99$, $p < .001$, $\eta_p^2 = 0.37$. The main effect for *object type* was also significant, $F(2, 88) = 10.45$, $p < .001$, $\eta_p^2 = 0.19$. There was no interaction between both main effects, $F(2, 88) = 0.50$, $p = .607$, $\eta_p^2 = 0.01$, suggesting that response times were similarly affected across age groups. The main effect of *object type* was followed up by paired comparisons. Responses were faster for distractors than for congruent objects, $t(45) = 4.54$, $p < .01$, $d = 0.67$, and incongruent objects, $t(45) = 3.50$, $p < .01$, $d = 0.52$), target objects. Response times for congruent and incongruent target objects did not differ, $t(45) = 0.67$, $p = .502$, $d = 0.10$.

4. Discussion

Prior knowledge has been suggested to be a key factor in understanding older adults' memory performance [9]. However, it is not well understood how violations of expectations affect memory for context-embedded objects – especially under naturalistic viewing conditions. Object-scene inconsistencies challenge prior knowledge and provide substantial informational gain which could aid memory [28]. This benefit might be attenuated in older adults. Using well-controlled photographs of real-world indoor scenes containing object-scene (in)consistencies, we addressed the question whether violations of scene context expectations affect memory for embedded objects differentially in older and younger adults.

We found that schema violations are overall beneficial for object memory in older and younger adults. As target objects were embedded in a rich, natural environment, we suggest that object-scene relationships were automatically processed, requiring minimal processing resources [29,30]. This might have facilitated to observe robust memory benefits in older adults although they face reduced

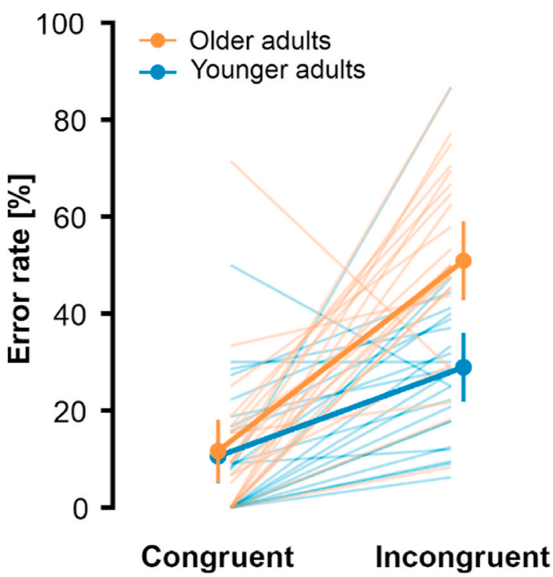

Fig. 3. Effects of age group and encoding context, i.e., congruent and incongruent, on error rates during scene selection. Filled dots show the mean across observers and semi-transparent lines provide individual data. Older adults are plotted in orange, younger adults in blue. Error bars give 95% confidence intervals. Exploration of scene selections for incongruent objects showed that older adults erroneously favored the congruent scene in 72% of the time, whereas younger adults showed a rate of 37%. These rates support a more pronounced congruency bias in older adults.

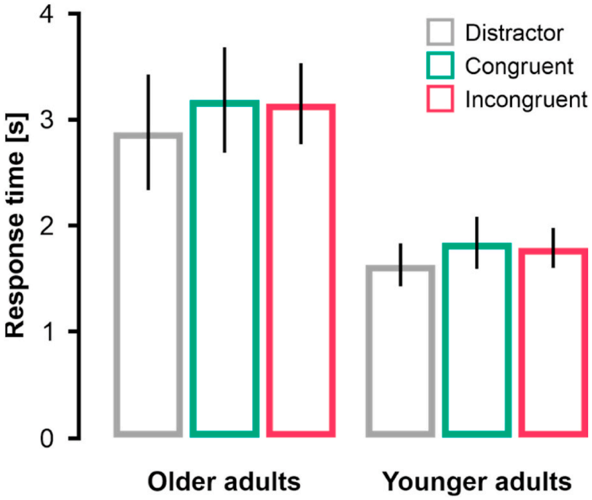

Fig. 4. Mean response times as a function of age group and object type, i.e., distractor, congruent, incongruent. Error bars correspond to 95% confidence intervals.

processing capacities and processing speed [31,32]. In addition, associative demands, being especially challenging in old age [33], were minimized. However, we determined an age-related reduction of the incongruency advantage. This finding corroborates previous results showing less pronounced incongruency advantages in older than in younger adults [14,15,17]. In addition, older adults' memory representations of scene context were biased towards congruent information. This was reflected in a greater number of schema-congruent errors when participants were asked to match correctly recognized objects encoded in an incongruent context [see also [11,12]]. Older adults tended to erroneously associate a congruent scene context. Such a congruency bias has been observed for memory of object locations in scenes [17], but here we showed that it is of even broader relevance, affecting memory for the whole scene context. Analysis of response times overall corroborated age-related slowing. Retrieval processes, though, were similarly shaped in both age groups – with faster responses for distractors and no difference for objects encoded in a congruent or incongruent context.

Our findings are consistent with recent models on how prior knowledge shapes perception [10]. Information processing is supposed to be first biased towards prior knowledge. But when an event is greatly unexpected, it elicits surprise, which, in turn, could signal the necessity to update existing knowledge, leading to enhanced processing. Although rooted in perception, this model may be applied to memory and is in principle compatible with previous accounts [5,28]. Our data indicate that older and younger adults weigh unexpected information differently, but we can only speculate at which memory stages, i.e., encoding or retrieval, age-related differences emerge. In addition, it remains to be explored whether predictive processing might be specifically hampered by age-related general slowing of information processing [32].

Given the crucial role of active vision for memory [34], age-related differences in encoding could explain why the memory advantage for incongruent objects is attenuated in older adults. It is well documented that younger adults fixate incongruent objects earlier, longer, and more frequently [e.g., 35, 36], while processing of congruent objects is reduced [37]. We suppose that this fixation pattern also holds for older adults, leading to an overall augmented encoding of incongruent information. However, it might be less pronounced due to greater viewing of congruent regions [17] and possibly a reduced motivation for exploring novel information [38]. Alternatively, retrieval processes might be biased toward congruent information due to age-related vulnerabilities in critical functional neural networks, involving in particular the ventromedial prefrontal cortex and the medial temporal lobes [5,7].

Our findings provide novel insights into the role of expectations for object memory in naturalistic scenarios and age-related vulnerabilities. We have shown that incongruent context efficiently boosts object memory across the adult lifespan and that the principle mechanisms are quite similar in older and younger adults. Schema violations can be beneficial for stabilizing memory performance in older age. However, the advantage is significantly attenuated and qualified by an overall congruency bias in older adults. We suggest that our memory data reflects critical age-related changes that can be related to recent predictive processing theories [compare [10, 37]]. These have put forward that functional efficiency of predictions crucially depends on the precision of the information input. While high precision is supposed to go along with a particularly high sensitivity to unexpected information, low precision is supposed to bias processing towards predictions. Given reduced sensory precision with increasing age, it appears consistent that, although violations of expectations remain a powerful way to enhance information processing, this mechanism is weakened. At the same time, an increased bias towards predictions, e.g., a more pronounced congruency bias, can be expected. To conclude, predictive processing theories seem well suited to contribute to our understanding of age-related functional changes and allow to consider vulnerabilities as well as stability within a coherent framework.

Author contribution statement

Lena Klever; Jutta Billino: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper. Jasmin Islam: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data. Melissa Le-Hoa Võ: Conceived and designed the experiments; Contributed reagents, materials, analysis tools or data.

Data availability statement

Data are publicly available at the https://doi.org/10.5281/zenodo.8339094.

Commercial relationships

None.

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.

Acknowledgements

This work was funded by the German Research Foundation (Deutsche Forschungsgemeinschaft, DFG), Collaborative Research Centre SFB/TRR 135: Cardinal Mechanisms of Perception, project number 222641018. We thank Sabine Margolf for assistance with the data collection.

References

[1] M.L.-H. Võ, The meaning and structure of scenes, Vis. Res. 181 (2021) 10–20, https://doi.org/10.1016/j.visres.2020.11.003.
[2] M. Bar, Visual objects in context, Nat. Rev. Neurosci. 5 (2004) 617–629, https://doi.org/10.1038/nrn1476.
[3] M.B. Neider, G.J. Zelinsky, Scene context guides eye movements during visual search, Vis. Res. 46 (2006) 614–621, https://doi.org/10.1016/j.visres.2005.08.025.
[4] J.M. Henderson, Gaze control as prediction, Trends Cognit. Sci. 21 (2017) 15–23, https://doi.org/10.1016/j.tics.2016.11.003.
[5] M.T. van Kesteren, D.J. Ruiter, G. Fernández, R.N. Henson, How schema and novelty augment memory formation, Trends Neurosci. 35 (2012) 211–219, https://doi.org/10.1016/j.tins.2012.02.001.
[6] D. Tse, R.F. Langston, M. Kakeyama, I. Bethus, P.A. Spooner, E.R. Wood, et al., Schemas and memory consolidation, Science 316 (2007) 76–82, https://doi.org/10.1126/science.1135935.
[7] A. Gilboa, H. Marlatte, Neurobiology of schemas and schema-mediated memory, Trends Cognit. Sci. 21 (2017) 618–631, https://doi.org/10.1016/j.tics.2017.04.013.
[8] D.C. Park, P. Reuter-Lorenz, The adaptive brain: aging and neurocognitive scaffolding, Annu. Rev. Psychol. 60 (2009) 173–196, https://doi.org/10.1146/annurev.psych.59.103006.093656.
[9] M. Umanath, E.J. Marsh, Understanding how prior knowledge influences memory in older adults, Perspect. Psychol. Sci. (2014) 408–426, https://doi.org/10.1177/1745691614535933.
[10] C. Press, P. Kok, D. Yon, The perceptual prediction paradox, Trends Cognit. Sci. 24 (2020) 13–24, https://doi.org/10.1016/j.tics.2019.11.003.
[11] G. Brod, Y.L. Shing, A boon and a bane: comparing the effects of prior knowledge on memory across the lifespan, Dev. Psychol. (2019) 1326–1337, https://doi.org/10.1037/dev0000712.
[12] X. Chen, L. Varghese, W.J. Jagust, A double-edged sword: the role of prior knowledge in memory aging, Front. Aging Neurosci. 14 (2022) 1–13, https://doi.org/10.3389/fnagi.2022.874767.
[13] C.E. Webb, N.A. Dennis, Memory for the usual: the influence of schemas on memory for non-schematic information in younger and older adults, Cogn. Neuropsychol. 37 (2020) 58–74, https://doi.org/10.1080/02643294.2019.1674798.
[14] M.W. Prull, Adult age differences in memory for schema-consistent and schema-inconsistent objects in a real-world setting, Aging Neuropsychol. Cognit. 22 (2015) 731–754, https://doi.org/10.1080/13825585.2015.1037821.
[15] T. Mäntylä, L. Bäckman, Aging and memory for expected and unexpected objects in real-world settings, JEP (J. Environ. Psychol.): Learning, Memory, and Cognition 18 (1992) 1298–1309, https://doi.org/10.1037//0278-7393.18.6.1298.
[16] T.M. Hess, S.J. Slaughter, Schematic knowledge influences on memory for scene information in young and older adults, Dev. Psychol. 26 (1990) 855–865, https://doi.org/10.1037/0012-1649.26.5.855.
[17] J.S. Wynn, J.D. Ryan, M. Moscovitch, Effects of prior knowledge on active vision and memory in younger and older adults, J. Exp. Psychol. Gen. 149 (2020) 518–529, https://doi.org/10.1037/xge0000657.
[18] X. Qin, T.M. Bochsler, A. Aizpurua, A.M.Y. Cheong, W. Koutstaal, G.E. Legge, Incidental memory of younger and older adults for objects encountered in a real world context, PLoS One 9 (2014), e99051, https://doi.org/10.1371/journal.pone.0099051.
[19] D. Draschkow, J.M. Wolfe, M.L.-H. Võ, Seek and you shall remember: scene semantics interact with visual search to build better memories, J. Vis. 14 (2014) 1–18, https://doi.org/10.1167/14.8.10.
[20] M.B. Neider, A.F. Kramer, Older adults capitalize on contextual information to guide search, Exp. Aging Res. (2011) 539–571, https://doi.org/10.1080/0361073X.2011.619864.
[21] M.E. Smith, L.C. Loschky, H.R. Bailey, Knowledge guides attention to goal-relevant information in older adults, Cogn Res Princ Implic 6 (2021) 56, https://doi.org/10.1186/s41235-021-00321-1.
[22] R.L. West, An application of prefrontal cortex function theory to cognitive aging, Psychol. Bull. 120 (1996) 272–292, https://doi.org/10.1037//0033-2909.120.2.272.
[23] Z. Nasreddine, N.A. Phillips, V. Bédirian, S. Charbonneau, V. Whitehead, I. Collin, et al., The Montreal Cognitive assessment, MoCA: a brief screening tool for mild cognitive impairment, J. Am. Geriatr. Soc. 53 (2005) 695–699, https://doi.org/10.1111/j.1532-5415.2005.53221.x.

[24] World Medical Association, World medical association declaration of Helsinki: ethical principles for medical research involving human subjects, JAMA 310 (2013) 2191–2194, https://doi.org/10.1001/jama.2013.281053.
[25] S. Öhlschläger, M.L.-H. Võ, SCEGRAM: an image database for semantic and syntactic inconsistencies in scenes, Behav. Res. Methods 49 (2017) 1780–1791, https://doi.org/10.3758/s13428-016-0820-3.
[26] J. Blechert, A. Meule, N.A. Busch, K. Ohla, Food-pics: an image database for experimental research on eating and appetite, Front. Psychol. (2014) 1–10, https://doi.org/10.3389/fpsyg.2014.00617.
[27] D.M. Green, J.A. Swets, Signal Detection Theory and Psychophysics, Wiley, New York, 1974.
[28] A. Greve, E. Cooper, R. Tibon, R.N. Henson, Knowledge is power: prior knowledge aids memory for both congruent and incongruent events, but in different ways, J. Exp. Psychol. Gen. 148 (2019) 325–341, https://doi.org/10.1037/xge0000498.
[29] T.H.W. Cornelissen, M.L.-H. Võ, Stuck on semantics: processing of irrelevant object-scene inconsistencies modulates ongoing gaze behavior, Atten. Percept. Psychophys. 79 (2017) 154–168, https://doi.org/10.3758/s13414-016-1203-7.
[30] K.K. Evans, J.M. Wolfe, Sometimes it helps to be taken out of context: memory for objects in scenes, Vis. Cognit. (2022) 229–244, https://doi.org/10.1080/13506285.2021.2023245.
[31] F.I.M. Craik, S. Trehub (Eds.), Aging and Cognitive Processes, Springer US, Boston, MA, 1982.
[32] T.A. Salthouse, The processing-speed theory of adult age differences in cognition, Psychol. Rev. 103 (1996) 403–428, https://doi.org/10.1037/0033-295x.103.3.403.
[33] M. Naveh-Benjamin, Adult age differences in memory performance: tests of an associative deficit hypothesis, JEP (J. Environ. Psychol.): Learning, Memory, and Cognition 26 (2000) 1170–1187, https://doi.org/10.1037/0278-7393.26.5.1170.
[34] J.D. Ryan, K. Shen, The eyes are a window into memory, Current Opinion in Behavioral Sciences 32 (2020) 1–6, https://doi.org/10.1016/j.cobeha.2019.12.014.
[35] V.S. Bonitz, R.D. Gordon, Attention to smoking-related and incongruous objects during scene viewing, Acta Psychol. 129 (2008) 255–263, https://doi.org/10.1016/j.actpsy.2008.08.006.
[36] G.R. Loftus, N.H. Mackworth, Cognitive determinants of fixation location during picture viewing, JEP (J. Environ. Psychol.): Human Perception and Performance 4 (1978) 565–572, https://doi.org/10.1037/0096-1523.4.4.565.
[37] E. Spaak, M.V. Peelen, FP de Lange, Scene context impairs perception of semantically congruent objects, Psychol. Sci. 33 (2022) 299–313, https://doi.org/10.1177/09567976211032676.
[38] E. Düzel, N. Bunzeck, M. Guitart-Masip, S. Düzel, NOvelty-related motivation of anticipation and exploration by dopamine (NOMAD): implications for healthy aging, Neurosci. Biobehav. Rev. 34 (2010) 660–669, https://doi.org/10.1016/j.neubiorev.2009.08.006.