

Cortical thickness in perirhinal area BA35 predicts adaptive episodic memory-guided decision making in older adults

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Abstract

Objectives: To make adaptive decisions, it is often necessary to retrieve episodic memories, for example, about whether an item was previously associated with reward. Compared to young adults, older adults are impaired at making adaptive episodic memory-based choices. There are substantial individual differences across older adults, however. In this study, we examined whether hippocampal volume or extrahippocampal cortical thickness in the medial temporal lobe (MTL) is associated with better episodic memory-based decision making in cognitively unimpaired older adults.

Methods: Older adults ($n = 87$; aged 61–88) completed a decision making task and a T1-weighted anatomical MRI scan. In the task, they studied images of houses paired with arbitrary reward values (\$5 or \$0). Later, they made incentivized approach/avoid decisions about these items. Finally, their memory for the items and their values was assessed. MTL structural data were segmented with the ASHS-T1 pipeline to obtain volume measures for anterior and posterior hippocampus, and cortical thickness measures in entorhinal cortex, parahippocampal cortex, and perirhinal cortex Brodmann areas (BAs) 35 and 36.

Results: BA35 cortical thickness was associated with better performance in the decision making task. This effect persisted after adjusting for memory performance, suggesting that BA35 thickness is specifically linked to the retrieval and use of episodic memories at the time of choice.

Discussion: Although this study is cross-sectional, it suggests that atrophy in BA35 may contribute to subtle changes in the ability to use memory to make reward-maximizing choices, even in individuals who do not yet show evident cognitive impairment.

Keywords: Brodmann Area BA35, Structural MRI, Reward, Learning

People often rely on memory for specific episodes to make adaptive approach/avoidance decisions. For example, when deciding what to eat at a restaurant that you have previously visited, whether or not you reorder what you got before depends on what you remember about how rewarding that meal was. Explicit memory for an option and its reward value is necessary to choose high-value options and avoid low-value options that were previously encountered (Murty et al., 2016; Schaper et al., 2019). Older adults' memory-based decisions are less adaptive

than those of young adults (Lempert et al., 2022; van Geen et al., 2025). However, even cognitively unimpaired older adults show substantial individual differences in retrieving memories to support choice. Here, we will test whether these individual differences are associated with volume and/or cortical thickness in subregions of the medial temporal lobe (MTL).

Recent work has examined how episodic memory shapes value-based decisions (Biderman et al., 2020; Sklenar & Leshikar, 2025). In both social and non-social domains, simply

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recognizing that you have seen a stimulus before is insufficient for approaching rewarding stimuli and avoiding low-value stimuli. Instead, recognizing a stimulus *and* correctly remembering its associated value is necessary to maximize reward (FeldmanHall et al., 2021; Kadwe et al., 2022; Lempert et al., 2022; Murty et al., 2016; Schaper et al., 2019; Sklenar et al., 2021, 2022). Consistent with the large literature showing age-related associative memory decline (Old & Naveh-Benjamin, 2008), our prior study showed that older adults had worse memory for item-value associations and therefore made less optimal decisions (Lempert et al., 2022).

Critically, while episodic memory can be leveraged to make adaptive choices, it is not the only information source people use. Older adults use semantic memory to guide choices even when it is irrelevant (Lalla et al., 2022), and in our previous study, older adults made less adaptive decisions in the social domain due not just to poorer associative memory but also to an overreliance on facial trustworthiness cues (Lempert et al., 2022). These findings align with evidence that episodic memory accuracy improves in older adults when semantic knowledge can be used (Castel, 2005; Hargis & Castel, 2018). Mechanisms underlying episodic memory accuracy can therefore be decoupled from those underlying the retrieval and use of episodic memories during choice. Our task assessed memory and decision making separately, allowing us to dissociate neural correlates of each.

Although behavioral research has established the importance of associative memory and its age-related changes in episodic memory-based decisions, less is known about the neural mechanisms of this process. However, the MTL likely plays an important role. In a previous study, the hippocampus was more active when encoding item-value associations for later decision making in young adults compared to older adults, consistent with young adults having better associative memory and making more adaptive memory-based decisions (van Geen et al., 2025). Notably, the hippocampus shows atrophy (reduced volume) even in healthy aging (Driscoll et al., 2003; Wolk et al., 2011). Surrounding cortical regions may likewise matter, since they serve as “way stations,” sending information from the hippocampus to valuation regions in the prefrontal cortex. These extrahippocampal regions, especially Brodmann Area (BA) 35, are early deposition sites for neurofibrillary tangle pathology (Braak & Braak, 1991; Braak & Del Tredici, 2018), even in cognitively unimpaired adults.

In the current study, we used magnetic resonance imaging (MRI) to examine the structural neural correlates of adaptive episodic memory-based decisions in cognitively unimpaired older adults. For each participant, a well-validated automated segmentation pipeline, ASHS-T1 (Xie et al., 2019), was used to segment the MTL in each hemisphere, resulting in the following regions of interest: anterior hippocampus, posterior hippocampus, BA35, BA36, entorhinal cortex, and parahippocampal cortex. We related the volume of the hippocampal regions and the cortical thickness of the extrahippocampal regions to performance on a memory-guided decision making task. Although we anticipated that MTL structural integrity would be associated with the ability to retrieve episodic memories to maximize reward, we had no strong hypothesis about which subregion(s) would show this relationship.

Method

Participants

Ninety-six older adults from the Clinical Core of Penn’s Alzheimer’s Disease Research Center completed an episodic memory-based decision making task and an anatomical MRI scan. We aimed to recruit 100 participants, anticipating a post-exclusion sample of ~82 (80% power to detect $r = 0.3$). Participants are part of a cohort that undergoes neuropsychological assessments and consensus conference evaluation annually. They were all deemed cognitively unimpaired based on the consensus conference. Participants completed the study in the lab ($n = 34$), remotely ($n = 20$), or during functional MRI ($n = 42$). The testing modality had no effect on memory ($F_{(2,49.7)} = 1.69$; $p = .195$) or decision making ($F_{(2,43.6)} = 1.62$; $p = .209$). A subset of these data was reported previously (Lempert et al., 2022; van Geen et al., 2025), so we used the same exclusion criteria (See Supplementary Methods in [Supplementary Material](#)). Our final sample included 87 participants (mean age = 73.2; $SD = 5.49$; range: 61–88; 54 F, 33 M; 64 White non-Hispanic, 20 Black non-Hispanic, 2 White Hispanic, 1 mixed race).

Decision making task

Participants completed a decision making task (Figure 1; Lempert et al., 2022), adapted from Murty et al. (2016). The task consisted of four phases: Reward, Distractor, Decision, and Memory.

In the Reward phase, participants learned associations between stimuli and rewards. Participants viewed 32 house photos sequentially. They were told each house represented a lottery that would pay out either \$5 or \$0. On each trial, participants saw a house with the message, “Lottery is being generated” (1.5 s), followed by the outcome (“You win: \$5” or “You win: \$0”) for 3 s. They then had 4.5 s to rate how they felt about the outcome (1 = Good; 2 = Neutral; 3 = Bad). After a 1 s inter-trial interval (ITI), the next trial began. Sixteen houses paid \$5 (rewarded stimuli), and sixteen paid \$0 (unrewarded stimuli).

Next, during a 5-min distractor phase (included to introduce a delay between encoding and retrieval), participants completed an anagrams task. They were presented with a series of scrambled words and were given 30 s to unscramble each one. A new scrambled word was presented every 30 s.

Then, in the decision phase, participants chose whether to approach or avoid stimuli, some of which had been encountered in the reward phase. On each trial, a line drawing appeared on the left, and a house photo appeared on the right. Again, each house photo represented a lottery, and participants were told that if they selected that option, it would yield the same payout that they received after viewing that house in the reward phase. However, if they did not want to select that option, they could choose the line drawing instead, which represented a lottery chosen at random, and which would result in a 50/50 chance of getting \$5 or \$0. The photo changed from trial to trial; the line drawing did not. The photo was always shown on the right to make it easier for participants to choose quickly. There were 48 trials, each showing a unique house photo. Thirty-two of those photos were previously seen in the Reward phase, while sixteen were new. Participants had 5 s to choose (1 = line drawing;

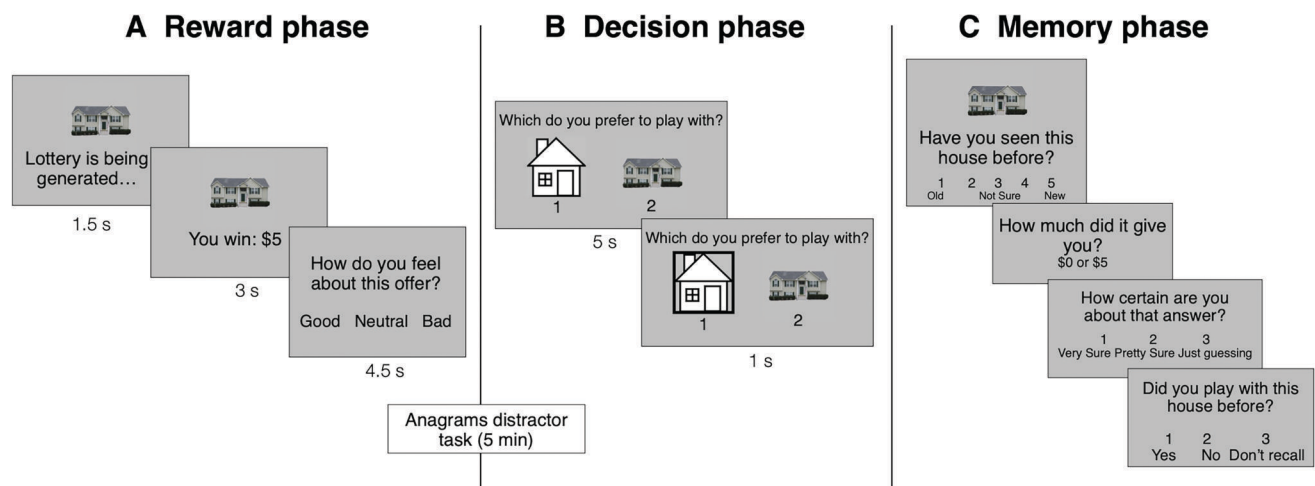


Figure 1 Memory-guided decision making task (non-social condition only). (A) In the Reward phase, participants learned about 32 houses, with half of the houses resulting in \$5 rewards (rewarded stimuli) and half resulting in \$0 (unrewarded stimuli). Then, after a Distractor phase (5-minute anagrams task), participants moved on to the Decision phase (B), in which all stimuli from the Reward phase were shown again, along with 16 novel house stimuli. Participants had 5 s to decide whether to play the lottery associated with the house. Then a bracket appeared for 1 s around the option they chose. After a 1 s ITI, the next trial appeared. Finally, in the self-paced Memory phase (C) with 1 s ITIs, participants judged if they had seen the stimuli before on a scale from definitely old (1) to definitely new (5). If they selected 1, 2, or 3, they then saw three additional questions probing the value of the stimulus (\$0 or \$5), the confidence in that value (1 = very sure; 2 = pretty sure; 3 = just guessing), and whether they remembered playing with that stimulus in the Decision phase (1 = yes; 2 = no; 3 = don't recall). All house stimuli from the Reward phase were shown, along with 16 novel house stimuli.

2 = photo). Then, a bracket appeared around the chosen option for 1 s. The next trial appeared after a 1 s ITI.

Participants were encouraged to use what they remembered from the reward phase to make their choices, since one of their decisions would be selected at random, and they would receive the payout associated with the chosen stimulus as a bonus at the end of the study. Therefore, the best way to maximize monetary gain would be to choose the house photo on trials in which a \$5 house from the Reward phase was presented and to choose the line drawing on trials in which a \$0 house from the Reward phase was presented. Novel house photos were included to index any general bias toward choosing photos. If a participant chose a never-before-seen house photo, they would also have a 50/50 chance of receiving \$5 or \$0. Our measure of adaptive decision making, or decision accuracy, was the proportion of times in which the participant either chose a \$5 house or avoided a \$0 house (by choosing the line drawing), out of all trials in which a house from the reward phase was shown.

Finally, in the Memory phase, participants indicated their memory for items and their associated outcomes from the Reward phase. Participants judged whether each of 48 photos (32 from the reward phase; 16 new) had been shown before, on a 1–5 scale. If they selected 1, 2, or 3, they were then asked for the value of the stimulus from the reward phase (\$0 or \$5), to rate their confidence in that answer, and to indicate whether they chose that stimulus in the decision phase. If they selected 4 or 5 for the item memory question, the follow-up questions were omitted. For correctly recognized items, associative memory was quantified using d' , treating \$5 houses correctly labeled as being worth \$5 as hits, \$5 stimuli labeled as \$0 as misses, \$0 stimuli labeled as \$5 as false alarms, and \$0 stimuli labeled as \$0 as correct rejections.

The task also included a social condition (See Supplementary Methods in [Supplementary Material](#)). Here, we focus on the non-social condition only, given prior evidence that older adults generally did not rely on episodic memory for social decisions ([Lempert et al., 2022](#)).

MRI data acquisition and segmentation

T1-weighted high-resolution magnetization-prepared rapid-acquisition gradient echo ($0.8 \times 0.8 \times 0.8 \text{ mm}^3$ voxels; TR/TE/TI = 1600/3.87/950 ms; flip angle = 15°) anatomical scans were collected on a Siemens Prisma 3T MRI with a 64-channel head coil. For participants who completed more than one scan, we used the scan that was closest in time to task completion. For those who completed the task while undergoing fMRI, the anatomical scan was on the same day.

MTL subregions were segmented using an automatic pipeline, ASHS-T1 ([Xie et al., 2019](#)). This technique uses a multi-atlas label fusion approach ([Wang et al., 2013](#)) together with a tailored segmentation protocol to take into account anatomical variability in the MTL cortex. For the anterior and posterior hippocampus, we used volume measures averaged across hemispheres. For the entorhinal cortex, BA35, BA36, and the parahippocampal cortex, we used median cortical thickness measures averaged across the hemispheres. Cortical thickness measures were estimated using a graph-based multi-template thickness pipeline taking the ASHS-T1 automatic segmentation as input ([Xie et al., 2017](#)). The cortical thickness pipeline failed to produce high-quality thickness measurements for some scans; in these cases ($n = 38$), we used the most proximal MRI scan with a successful segmentation ($n = 1$ was excluded from thickness analyses for failed segmentation). For the volume measures, the average

time between the MRI scan and the task was 177 days ($SD = 472$; range: -876 to $1,889$ days). For cortical thickness, it was 345 days ($SD = 507$; range: -876 to $1,910$ days). The number of days after the scan that the task was performed was used as a covariate in all analyses. For any significant associations, we planned to conduct sensitivity analyses to ensure that results were similar when excluding participants whose scans took place >2 years before or after the task.

Analyses

In each linear regression, age, sex, years of education, and the time between the task and the scan were entered as covariates, with the neural measure as the independent variable, and decision making accuracy (i.e., proportion of times that participants approached rewarded stimuli and avoided unrewarded stimuli) as the dependent variable. For the hippocampal volume analyses, we included the square root of intracranial volume as an additional covariate. Intracranial volume was not included as an additional covariate for thickness analyses because cortical thickness measures are less biased by intracranial volume compared to volume measures (Barnes et al., 2010). Standardized regression coefficients and 95% confidence intervals are reported. We corrected for multiple comparisons across these six regressions using the Benjamini-Hochberg false discovery rate procedure (Benjamini & Hochberg, 1995). Because these were our primary, confirmatory analyses, only this set of statistical tests was corrected for multiple comparisons.

For any regression models that reached significance, we planned to run post-hoc exploratory analyses, the results of which we treated as significant if $p < .05$ (uncorrected). These included: (1) re-running the regression after excluding participants ($n = 12$) whose scans occurred >2 years before or after the task, (2) re-running the regression with associative memory d' as the dependent variable instead, (3) including associative memory d' as an additional covariate in the model, (4) including intracranial volume as an additional covariate in the model (if applicable—this is already included in the volume analyses), and (5) conducting the regression separately for the left and right hemispheres.

Results

Episodic memory-based decision making performance ($M = 0.51$; $SD = 0.08$) was associated with cortical thickness in BA35 ($b = 0.32$; 95% CI $[0.10, 0.54]$; $p_{\text{uncorrected}} = 0.004$; $p_{\text{corrected}} = 0.024$; Figure 2), but not with the structural features of other MTL subregions (Table 1; Supplementary Figure 1). Participants with greater BA35 cortical thickness made more adaptive choices. This association remained significant after excluding participants ($n = 12$) whose scans occurred >2 years before or after the task ($b = 0.23$; 95% CI $[0.0002, 0.469]$; $p = .050$) and when including intracranial volume as an additional covariate ($b = 0.31$; 95% CI $[0.09, 0.54]$; $p = .006$).

To test if this effect was explained by an association between BA35 thickness and episodic memory, we performed the same regression with associative d' ($M = 0.13$; $SD = 0.58$) as the dependent variable but found no significant relationship ($b = 0.14$; 95%

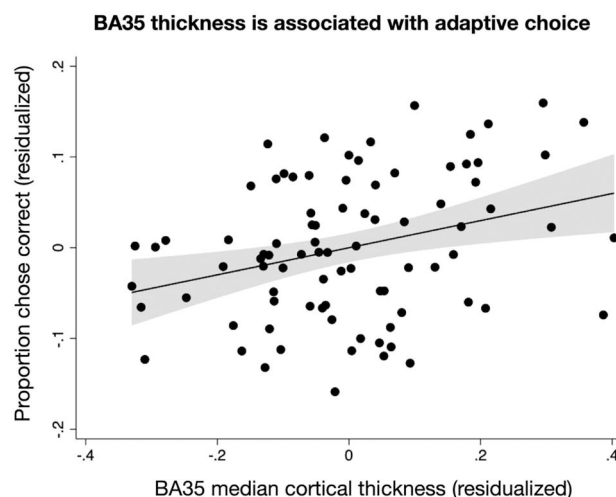


Figure 2 Association between median cortical thickness in BA35 and decision accuracy. Median cortical thickness in BA35 (averaged across hemispheres) was associated with an increased propensity toward choosing rewarded stimuli and avoiding unrewarded stimuli in the Decision phase ($b = 0.32$; 95% CI $[0.10, 0.54]$, $p = .004$). The residual plot after regressing out the influence of age, sex, years of education, and the time between the task and the MRI scan is shown. The line is the best-fit line, and the shaded region represents the 95% confidence interval.

CI $[-0.09, 0.36]$; $p = .233$). Moreover, when entering associative d' as an additional covariate in the regression predicting decision accuracy, BA35 thickness still predicted decision accuracy ($b = 0.31$; 95% CI $[0.09, 0.53]$; $p = .006$). Thus, BA35 appears to be specifically associated with the ability to use episodic memories adaptively during decision making, rather than the ability to retrieve episodic memories generally.

Finally, median cortical thickness in both the left ($b = 0.25$; 95% CI $[0.03, 0.47]$; $p = .025$) and right BA35 ($b = 0.29$; 95% CI $[0.08, 0.51]$; $p = .009$) was associated with decision accuracy.

Discussion

We found that, in cognitively unimpaired older adults, cortical thickness in the perirhinal cortex region BA35 was associated with more adaptive decision making based on memory for single previous experiences. We found no associations with the other MTL subregions tested, including hippocampus, BA36, entorhinal cortex, and parahippocampal cortex. Furthermore, BA35 cortical thickness was not associated with performance on the explicit memory task, showing that this region may be specifically associated with the ability to use episodic memory appropriately during value-based choice.

Previous studies have shown that having explicit memory for the association between an item and its value is critical for making adaptive approach/avoid decisions about previously encountered items (Murty et al., 2016; Sklenar & Leshikar, 2025). Older adults are less likely than young adults to remember item-value associations and to leverage them at the time of choice (Lempert et al., 2022). In our study, we build on these results, finding a selective association between cortical thickness in

Table 1 Regression results with MTL subregions predicting decision accuracy.

Region	<i>M</i>	<i>SD</i>	<i>b</i>	95% CI	<i>p</i> -value (uncorr)	<i>p</i> -value (FDR-corr)
Anterior hippocampus volume ^a	1700 mm ³	261 mm ³	0.02	[−0.23, 0.27]	.852	.906
Posterior hippocampus volume ^a	1638 mm ³	187 mm ³	0.05	[−0.21, 0.31]	.687	.906
ERC median cortical thickness ^b	2.07 mm	0.15 mm	−0.14	[−0.36, 0.09]	.239	.478
BA35 median cortical thickness ^b	2.26 mm	0.18 mm	0.32	[0.10, 0.54]	.004	.024
BA36 median cortical thickness ^b	2.35 mm	0.18 mm	−0.01	[−0.23, 0.21]	.906	.906
PHC median cortical thickness ^b	2.10 mm	0.14 mm	0.17	[−0.05, 0.39]	.125	.375

Note. BA = Brodmann's area; ERC = entorhinal cortex; PHC = parahippocampal cortex. Summary statistics for thickness and volume measures, as well as standardized regression coefficients (*b*), confidence intervals (CIs), and uncorrected *p*-values for the predictors of interest from each of the six regressions predicting decision accuracy.

^aRegression controlled for age, sex, years of education, square root of intracranial volume, and the number of days between the task and the scan.

^bRegression controlled for age, sex, years of education, and the number of days between the task and the scan.

BA35 and episodic memory-based decision making in older adults. Given that BA35 is the earliest deposition site for AD neurofibrillary tangle pathology (Braak & Braak, 1991), it is possible that AD pathology is contributing to less adaptive decision making even in cognitively unimpaired individuals. This is consistent with research showing that difficulty with financial decisions can signal neurodegeneration (Barnes et al., 2014; Nicholas et al., 2021). This explanation is speculative, however, and should be examined in future studies that directly measure AD pathology.

More research is needed to determine the precise function of BA35 in decision making. The perirhinal cortex is critical for processing knowledge about objects (Kealy & Commins, 2011; Klooster et al., 2021; Murray & Bussey, 1999), and for integrating features of an object together to support item recognition (Bonnen et al., 2025; Clarke & Tyler, 2014; Taylor et al., 2006). In our task, BA35 may be facilitating the recognition of house images integrated with their values. Although BA35 thickness was not associated with *explicit* memory for images and their values in the memory test, our memory measure might have been too noisy to detect an association (e.g., it did not differentiate between guesses and high-confidence responses). Indeed, none of the MTL regions we tested were associated with explicit memory (Supplementary Table 1).

This research is limited in that it is cross-sectional, so we cannot conclude that atrophy in BA35 causes deficits in decision making. Moreover, while most participants' scans were within a year of doing the task, others' scans were a few years before or after behavioral data collection. Cognitively unimpaired participants tend to show relatively stable structural features over these time intervals, but the rate of neural change can differ between individuals, and some can undergo more rapid decline (Raz & Rodrigue, 2006). This possibility complicates the relationship between brain structure and cognition when measures are collected across different time intervals for different individuals. To address this limitation, we controlled for time-since-scan in our models and performed a sensitivity analysis to ensure that results remained similar when excluding participants whose scans were >2 years from the task. Nevertheless, longitudinal work is needed to better understand the precise relationship between neural decline and cognitive impairment.

In sum, reduced cortical thickness in the perirhinal area BA35 was associated with less adaptive memory-based decision

making in older adults. Even in the absence of detectable memory impairments, it is possible that atrophy in this region reduces the tendency to leverage episodic memory to optimize choices.

Supplementary material

Supplementary material is available at *The Journals of Gerontology, Series B: Psychological Sciences and Social Sciences* online.

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Conflicts of interest

L.X. received personal consulting fees from Galileo CDS, Inc. L.X. has been an employee of Siemens Healthineers since May 2022, but the current study was related to his work at the University of Pennsylvania. All other authors declare no conflicts of interest.

Data availability

The data reported in this study are available and can be accessed at <https://osf.io/cuf2h/files/osfstorage>. The analysis code is also available at that link. Materials (e.g., task code) will be made available upon request. This study was not preregistered.

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