Autobiographical memory specificity and mnemonic discrimination

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Abstract

Autobiographical memory specificity (AMS) refers to the tendency to recall events that occurred at a particular time and place. We examined the hypothesis that AMS is associated with pattern separation, which is an essential component of episodic memory that may allow us to encode and retain the unique aspects of events. In Study 1 (N = 94) and Study 2 (preregistered; N = 99), participants completed the Autobiographical Memory Test, which measures AMS, and the Mnemonic Similarity Task measuring pattern separation. We coded Autobiographical Memory Test responses conventionally and then further classified the categoric memory responses (i) that contained words indicating repetitions or regularity (e.g., always, often) and (ii) did not contain these words. The pattern separation ability correlated positively with specific memories and correlated negatively with categoric memories lacking those words. We propose to distinguish these two types of categoric memory and discuss the integrative model of autobiographical memory structure.

Keywords: mnemonic similarity task; autobiographical memory specificity; overgeneral memory; hippocampus; pattern separation

Introduction

Remembering a past event with its temporal and spatial details is a basic psychological function. Autobiographical memory specificity (AMS), typically defined as an ability to retrieve an episodic memory of an event that occurred at a particular time and place, lasting no more than a day (Williams et al., 2007), has been shown to be associated with well-being and everyday functioning, such as social problem solving and future thinking (Jing, Madore, & Schacter, 2016; Sumner, 2012; Williams et al., 2007). For example, remembering the details of a past quarrel with friends can help prevent similar problems in the future. On the other hand, reduced AMS covers retrieval of episodic memories with less specific spatiotemporal information as well as semantic memories and self-knowledge. This inability to retrieve a specific memory is known as a cognitive marker of psychopathology including depression (Barry, Hallford, & Takano, 2021; van Vreeswijk & de Wilde, 2004; King et al., 2010; Liu et al., 2013; Williams et al., 2007) and posttraumatic stress disorder (PTSD; Barry et al., 2018; Moore & Zoellner, 2007; Ono, Devilly, & Shum, 2016). Although non-specific autobiographical memory has several variants and different forms, researchers in clinical psychological science have mainly focused on an overgeneral, categoric memory referring to repeated events or a summary of similar events that one experienced in the past (e.g., *I have always failed exams; I played in a park when I was little*). Experimental evidence has suggested that reduced AMS is related to poor executive control (e.g., Dalgleish et al., 2007), avoidance of remembering past events (e.g., Raes et al., 2003), and abstract processing in a form of self-reference and rumination (e.g., Watkins, Teasdale, & Williams, 2000), which are all known as cognitive phenotypes of depression and other psychological disorders (for reviews, Sumner, 2012; Williams et al., 2007).

Theories of autobiographical memory have proposed that human memory has a multi-level hierarchical structure with the top level (i.e., experience-far level) representing semantic/general knowledge about self and with bottom level (i.e., experience-near level)

storing sensory and perceptual details of a particular event and experience (Conway, Justice, & D'Argembeau, 2019; Renoult et al., 2012; Williams et al., 2007). The researchers placed categoric memory in the middle level that codes generic aspects or a summary of individual events. Researchers have assumed that categoric memory (and memory with reduced specificity in general) is retrieved when people searched down through the memory hierarchy from the top to the bottom level but the search is truncated at the top or middle level (Eade et al., 2006; Haque et al., 2014). For example, the cue word “happy” evokes a semantic associate information “my son”; then, a categoric memory “my son is always smiling and playing” is retrieved from the semantic information, followed by retrieval of a specific memory “last Saturday, my son was smiling and playing at Disneyland”. However, in some cases, the retrieval stops at categoric memory.

How does the truncation of memory search (and thus, reduced AMS) take place? As a putative mechanism, the present study shed new light on pattern separation, which is an ability to discriminate between similar but different stimuli (e.g., Stark, Kirwan, & Stark, 2019). Pattern separation is known as an essential component of episodic memory and hippocampal function (Yassa & Stark, 2011; Zotow, Bisby, & Burgess, 2020) that forms distinctive memory representations for perceptually different stimuli with overlapping features (Moscovitch, Cabeza, Winocur, & Nadel, 2016). We hypothesized that pattern separation would help go beyond a general event representation and to reach contextual (or spatiotemporal) details of individual events that are the key to forming a specific autobiographical memory (Tulving, 1972; Rubin & Umanath, 2015). More specifically, pattern separation may be required to encode and retain episodic memories (Bonnici, Chadwick, Maguire, 2013; Stark et al., 2019), which would facilitate successful retrieval of event-specific information without (con)fusion with generic aspects of similar events. It is known that episodic memory details require the formation of item-context associations (i.e., source and associative memories) and the discrimination of similar events (Stevenson et al.,

2020), and the findings would be applied to autobiographical memory. While one previous study has shown the association between source memory performance and AMS (Raes et al., 2006), the link between pattern separation and AMS has not been explored.

Pattern separation has been measured by the mnemonic similarity task (MST; Kirwan & Stark, 2007; for a review, Stark et al., 2019). In this task, participants are first given incidental encoding of pictorial stimuli (i.e., encoding phase); second, in the test phase, they perform a recognition test, determining whether each presented stimulus is old, new, or similar but not identical to the encoded stimuli. Based on these participants' responses, two indices are defined: the *lure discrimination index*, indicating the performance of pattern separation between similar and old stimuli, and the *corrected recognition score*, which is a traditional index of episodic memory performance reflecting the ability to differentiate old and new stimuli that is calculated by subtracting the False Alarm (judged new as old) from the Hit (judged old as old correctly). Importantly, the findings from the MST suggest that the ability to distinguish similar items, rather than corrected recognition, is critical for episodic memory details (Stark et al., 2019), because discrimination of similar items reduces the interference of overlapping memories and allows us to construct the contextual details of memories (Zotow et al., 2021). Furthermore, correct recognition decisions can be made on the basis of familiarity without the recollection of memory details (Yonelinas, Aly, Wang, & Koen, 2010). Previous studies have shown a decrease in the lure discrimination index but not in corrected recognition among older people (Toner, Pirogovsky, Kirwan, & Gilbert, 2009; Yassa et al., 2011) and patients with schizophrenia (Das et al., 2014; Kraguljac et al., 2018) and depression (Déry et al., 2013; Shelton & Kirwan, 2013). These populations also exhibit reduced AMS or increased categoric memories (Kwok et al., 2021; Ros et al., 2018; Williams et al., 2007).

While investigating the association between pattern separation and AMS, we delved in different forms or subtypes of categoric memory. Categoric memory is characterized by a lack

of temporal specificity (i.e., information about a particular time or moment events occurred) that is necessary for specific memory (Rubin, 2019). Specifically, our focus was on the presence vs. absence of the words that tap into the repetitions, regularity, and frequency of an event(s) in each categoric memory reported instead of specific memories. These words, such as *always* and *often*, may indicate that accessing an individual specific event was not successful – that is, when retrieving specific memories from abstract cues, it is necessary to come down through an autobiographical memory hierarchy from the top to the bottom, but the memory search sometimes stopped at the general categoric level of this hierarchy and this was trapped by a semantic representation. For instance, the attention of depressed patients is often captured by the activated negative and abstract self-representations during memory search (Williams et al., 2007). Linguistic analyses on autobiographical memory revealed that these words are often used in non-specific memory (Takano et al., 2017) and that the word-use pattern shapes a gradient across similar and different categories of autobiographical memory (Takano et al., 2018). That is, memory responses (specific and categoric memory) tend to contain a larger number of words and a richer vocabulary as compared to non-memory responses (semantic associates), whereas categoric memory and semantic associates share some features like ambiguous (or lack of) temporal expressions. In the AMT, we can easily find a categoric memory *with* the words of repetitions and regularity (say RP words) – this type of categoric memory can be interpreted as an immature event (or episodic) memory, which involves much semantic representation and points to a high degree of abstraction (often difficult to distinguish from semantic associates; e.g., *I often go for a walk in the park*; Table 1). On the other hand, a categoric memory *without* the words of repetitions and regularity describes an event(s), which is typically inadequate to be an independent specific memory because of a lack of temporal specificity but provides a less clear indication of semantic knowledge (e.g., *When I'm on vacation, I visit parks for a workout*; Table 1).

We implemented these distinctions in a somewhat exploratory manner as it is difficult

(if not impossible) to identify an objective criterion to define the extent to which semantic representation is involved in a categoric memory¹. However, the key idea is that the narrative of categoric memory shows variability in the amount of non-episodic, semantic information and this variability may inform the relevance of pattern separation in retrieving autobiographical memory. Renoult et al. (2012) introduced a typology of personal semantics (i.e., generalized knowledge of events from one's personal past) and contrasted autobiographical facts and self-knowledge (cf. semantic associates, Williams et al., 2007) vs. repeated events that are closer to episodic memory (cf. categoric memory). One of the important findings in the literature is that repeated events differ from the other types of personal semantics in that they are associated (as are memories of specific, unique events) with hippocampal and medial temporal lobe activity (Addis, McIntosh et al., 2004; Renoult et al., 2012). This neuropsychological evidence may suggest that regardless of the limited sensory and perceptual details in the narrative, repeated events (and categoric memory) entail recollection of past events but also reflect semantic knowledge. Although the model of Renoult et al. (2012) is not always consistent with the classification of autobiographical memory proposed by Williams et al. (2007), we were particularly interested in the border of semantic and episodic memory in the continuum. We expected that pattern separation would be a good marker to study the involvement of hippocampal functions in retrieving categoric but still episodic memory.

Given that pattern separation is known as one of the hippocampal functions that distinguishes between perceptually similar stimuli and events (Stark et al., 2019), we

¹ The presence of RP words may not be a necessary-sufficient condition for a categoric AND highly semantic memory; for example, "I brought my brother to school *everyday*" can be interpreted as events but not as a semantic fact. Yet, we followed the operationalization of Renoult et al. (2016), who used general time cues (e.g., Everyday, Often) for autobiographical facts.

hypothesized that reduced AMS would be, overall, associated with poor pattern separation; however, this association would be unique to categoric memory that has less semantic representation (or more episodic subtype, as indicated by the absence of RP words; see also Table 1). On the other hand, categoric memory with more semantic representation (or the subtype close to semantic associates, as indicated by the presence of RP words; see also Table 1) would involve little or no recollection of past events, and thus, would be independent of hippocampal functions – therefore, a null association with pattern separation was expected.

The current study consisted of two experiments. Study 1 targeted a general population, and participants (crowd workers) completed the Autobiographical Memory Test (Debeer, Hermans, & Raes, 2009; Williams & Broadbent, 1986) and MST (for AMS and pattern separation, respectively) online. Study 2 was a pre-registered study to replicate the findings of Study 1. We recruited undergraduate students, and the data collection was conducted in-person and individually. These changes in the study protocol were implemented because we wanted to reduce the potential for noise in the online assessments (e.g., variability in participants' effort and understanding of the task instructions). Furthermore, we measured general intelligence as a control to show the unique associations between AMS and pattern separation.

Data Availability

All data are available from OSF (<https://osf.io/t3jr6/>).

Study 1

Participants

The experiment was advertised on Yahoo! Crowdsourcing (<https://crowdsourcing.yahoo.co.jp/>) as a study of autobiographical memory. The inclusion criteria for participation were Japanese participants aged between 20 and 35 years to control

for language differences and the effect of aging. One hundred and twenty-five Japanese individuals participated in the online experiment (58 men and 67 women; mean age = 30.62, SD = 4.40 years). All experiments were conducted in Japanese. We excluded the following participants from statistical analyses: two individuals reported technical issues in the implementation of the online experiment, three wished to be excluded from the analysis, one was older than 36 years of age, 10 skipped or responded inappropriately to more than half of the trials in the Autobiographical Memory Test, and one did not respond to more than 20 trials in the MST encoding phase. Among the remaining participants, we calculated the correct response rate in the MST test phase and excluded the participants with less than 45% correct responses ($n = 7$) according to the criterion used in previous studies (e.g., Shelton & Kirwan, 2013). To exclude the participants with biased response categories in the MST test phase, which could also be considered a type of effort minimization, we calculated the number of responses for each category (i.e., “old”, “similar”, and “new” responses) and excluded the participants who had a proportion of responses that was at least ± 2.5 SD from the mean (Van Selst & Jolicoeur, 1994) for each response ($n = 7$). Ultimately, 94 participants (41 males and 53 females; mean age = 29.99, SD = 4.18 years) were included in our analysis.

Autobiographical Memory Test: Written Version with Minimal Instructions

The Autobiographical Memory Test (Williams & Broadbent, 1986) with minimal instruction (Debeer et al., 2009) was used to assess AMS. A written version with no time limit, as in some previous studies (e.g., Wessel et al., 2001), was used in this study for online administration. According to the minimal instructions (Debeer et al., 2009), the participants were asked to describe a past event. The participants were also instructed to describe the event with a minimum of 10 Japanese characters to prevent minimization of effort (i.e., satisficing) in their responses. Ten neutral cue words (park, explanation, something to do, advice, traveling, leisure, conversation, attitude, effort, and carry; in Japanese: 公園, 説明, 用事,

アドバイス, 旅行, 暇, 会話, 態度, 努力, 運搬), mostly adapted from previous studies (Brittlebank, Scott, Williams, & Ferrier, 1993; Williams et al., 1996), were presented in a random order. After data collection, following a standard scoring method (e.g., Griffith et al., 2012), two independent raters who were blinded to the study hypotheses and other variables classified all memories into the following five categories: (a) specific memory, which reflects an event occurring at a particular time and place and lasting less than a day (e.g., My brother came to visit me at home yesterday); (b) categoric memory, a memory summarizing similar and/or repeated events (e.g., I always have fun when playing with my friends); (c) extended memory, which reflects an event lasting more than a day (e.g., I went to Australia this year); (d) semantic association, which does not reflect an event but instead consists of semantic memories associated with the cue (e.g., I'm happy); and (e) omission or inappropriate response. The two independent raters had a good level of agreement ($k = .77$), and if their classifications were different, they discussed the item until they agreed on a final classification. After implementing this standard scoring procedure, the independent raters further classified categoric memories into two types depending on the presence and absence of RP words, representing repetitions, regularity and frequency of events². Interrater agreement in this procedure was excellent ($k = .86$). This operationalization follows Renoult et al.'s (2016) experimental manipulations. The researchers presented participants with questions containing RP words (e.g., Usually I wear white socks?) and participants had to respond to these questions with yes (applicable to me) or no. This manipulation was meant to

² The Japanese RP words that appeared in categoric memories to describe the frequency of the event are as follows: a lot (多い), always (いつも), often (よく), sometimes (たまに), every day (毎日), every morning (毎朝), every day (日々), many times (何度も), daily (日常), often (度々), these days (最近), routine (日課), always (常に), usually (たいてい), a lot (たくさん), often (頻繁に), always (必ず), and every time (毎回). Note that some of the words are rendered identically in English due to translation limitations.

evoke an autobiographical fact, which was contrasted with another manipulation, i.e., presenting questions without RP words (e.g., When shopping I have worn white socks?), to cue repeated events. Note that the terminology may appear somewhat tricky – the presence of RP words corresponds to an autobiographical fact whereas the absence of RP words corresponds to repeated events (however, see also Renoult et al., 2012).

The proportion of specific memories among responses, excluding omitted or inappropriate responses, was calculated and considered a measure of AMS. The proportions of categoric memory with RP words and without RP words were also calculated using the same procedure. Note that the exclusion of omissions from the denominator can affect the AMS (Griffith et al., 2012) but not if the number of omissions is small, as in this study. As a precaution, we report the number of each response as well as the proportions calculated by excluding omissions from the denominator.

MST

The MST is a computerized task used to measure mnemonic discrimination. The original task was built in PsychoPy, but we imported the program to jsPsych 6.1.0 (de Leeuw, 2015) for online implementation. This task consisted of an encoding phase and a test phase. Participants were initially instructed to determine whether the objects presented on the computer screen were for indoor or outdoor use, with a total of 128 everyday objects displayed in sequence for 3 seconds each. For the objects, we used the images from Set C validated by Dr Craig Stark (<https://github.com/celstark/MST>). In the test phase administered as a surprise immediately after the encoding phase, the participants were asked to determine whether the objects presented next were the same as objects presented in the encoding phase (“target”), similar to those presented in the encoding phase (“lure”), or new objects that were not presented in the encoding phase (“foil”). Here, 64 target items, 64 similar items, and 64 foil items were randomly presented, and participants responded in a self-paced manner.

According to previous studies (for a review, Stark et al., 2019), the lure discrimination index was calculated by subtracting the proportion of “similar” responses to foil items from the proportion of “similar” responses to lure items, and the corrected recognition score was calculated by subtracting the proportion of “old” responses to foil items from the proportion of “old” responses to target items.

Procedure

Following the instructions on the site, participants were informed of the ethical considerations and agreed to participate in this experiment. They then connected to our online experiment website and completed the experiment. They performed the Autobiographical Memory Test first, followed by the MST. Finally, they were asked questions for the validation of the experiment. After the completion of the experiment, participants were paid shopping voucher worth 300 JPY (approximately 3 USD) via the online survey system in exchange for their participation. This study was approved by the ethics committee of [blind for review].

Statistical Analysis

All analyses were conducted using the JASP (JASP Team, 2022) or R statistics. We directly tested our hypothesis by first calculating the correlation between the lure discrimination index and the proportion of specific memories. We then examined the second hypothesis regarding categoric memories with RP words. In addition to the frequentist framework, the Bayes factor was used to test significant and null correlations for each hypothesis. The criteria presented by Wetzels & Wagenmakers (2012) (and see Jeffreys, 1961) were used to interpret the Bayes factors. According to the criteria, $BF_{10} > 3$ favors an alternative hypothesis with a significant correlation, while $BF_{10} < 1/3$ favors a null hypothesis with no correlation, and in BF_{01} these interpretations are reversed. We further conducted analysis using an R package, *BFpack*, which calculates the Bayes factors for testing the

equality of correlations (Mulders & Gelissen, 2021). Specifically, this code calculates the BF_{10} and BF_{01} between the null ($r_{AB} = r_{AC}$) and alternative ($r_{AB} > r_{AC}$) hypotheses. Finally, we confirmed that the correlations were not affected by age, sex, or corrected recognition score by performing hierarchical multiple regression analyses. All data are available from OSF (<https://osf.io/t3jr6/>).

Results

Descriptive Statistics

Descriptions of the Autobiographical Memory Test responses are shown in Table 2. The number of specific memory was $M = 3.84 \pm 2.46$ (38.8%), which is consistent with the findings of previous studies that applied Autobiographical Memory Test with minimal instructions to Japanese/East Asian populations (e.g., Matsumoto, Takahashi, & Kawaguchi, 2020; Takano, Mori, et al., 2017). The majority of categoric memories were without RP words ($M = 2.77 \pm 1.83$; 27.7%), but a considerable proportion of categoric memories with RP words was observed ($M = 1.01 \pm 1.08$; 10.1%).

The left column in Table 3 shows the mean responses in the MST test phase. Overall, the pattern of the results was similar to that of previous findings in a similar age group (Stark, Yassa, Lacy, & Stark, 2013). Participants correctly indicated most of the target stimuli as old ($M = 53.26 \pm 6.20$; 83.2%). In contrast, lure stimuli were less identified as similar ($M = 27.06 \pm 10.97$; 42.3%) and were erroneously recognized as old ($M = 28.02 \pm 9.92$; 43.8%).

Correlations

Table 2 illustrates the correlations between MST and Autobiographical Memory Test performance. The proportion of specific memories was significantly associated with the lure discrimination index ($r = .27$, $p = .008$; Figure 1 upper left panel) and the Bayes factor favored the significant correlation ($BF_{10} = 4.21$), but was not associated with the corrected

recognition score ($r = .09, p = .40$) and the Bayes factor favored the null hypothesis with no correlation ($BF_{01} = 5.47$). The results of the Bayes factor used to evaluate the equality of the correlations of specific memory with the lure discrimination index or corrected recognition score showed the anecdotal evidence for the alternative hypothesis ($BF_{10} = 1.45$) that the correlation between specific memory and lure discrimination index was greater than the correlation between specific memory and corrected recognition score. The correlation between the proportion of categoric memories and the lure discrimination index was not significant ($r = -.18, p = .088$). However, the proportion of categoric memories without RP words was negatively correlated with the lure discrimination index ($r = -.27, p = .008$; Figure 1 upper right panel) and the Bayes factor favored the significant correlation ($BF_{10} = 3.96$), whereas the proportion of categoric memories with RP words was not significant ($r = .12, p = .25$) and the Bayes factor favored the null hypothesis with no correlation ($BF_{01} = 4.00$). The results of the Bayes factor for testing the equality of correlations between categoric memories with or without RP words and the lure discrimination index favored the alternative hypothesis that the correlation between categoric memories without RP words and the lure discrimination index was stronger than the correlation between categoric memories with RP words and the lure discrimination index ($BF_{10} = 8.42$).

The proportion of specific memories recalled was negatively correlated with categoric memories without RP words ($r = -.67, p < .001$) and with RP words ($r = -.32, p = .002$). Recall of categoric memories without RP words was not correlated with that of categoric memories with RP words ($r = -.08, p = .45$). After evaluating the equality of the correlations between specific memory and categoric memories with or without RP words, the results favored the alternative hypothesis that the correlation between specific memory and categoric memory without RP words was lower than the correlation between specific memory and categoric memory with RP words (BF_{10} about 29).

Hierarchical Multiple Regression

A hierarchical multiple regression analysis was conducted to show that pattern separation uniquely predicted categoric memory without RP words and specific memory (Table 4). In Step 1, we entered age, sex, and corrected recognition score into the model. In Step 2, the lure discrimination index was entered. With the proportion of specific memories as the dependent variable, the overall model ($R^2 = .02, p = .60$) and the effects of age ($\beta = -.03, p = .80$), sex ($\beta = .11, p = .29$), and corrected recognition ($\beta = .08, p = .44$) were not significant at Step 1. In Step 2, the overall model was still nonsignificant ($R^2 = .09, p = .075$); however, the model was significantly improved ($\Delta R^2 = .07, p = .010$), and the effect of lure discrimination was significant ($\beta = .27, p = .010$). Using the proportion of categoric memories without RP words as the dependent variable, the overall model ($R^2 = .02, p = .55$) and the effects of age ($\beta = .02, p = .84$), sex ($\beta = -.13, p = .23$), and corrected recognition ($\beta = .09, p = .38$) were not significant in Step 1. However, in Step 2, the overall model reached significance ($R^2 = .11, p = .031$), a significant improvement in the model was observed ($\Delta R^2 = .09, p = .004$), and the effect of lure discrimination was also significant ($\beta = -.31, p = .004$).

Study 2

The results from Study 1 supported all hypotheses: pattern separation was associated with a high proportion of specific memories and was associated with a low proportion of categoric memories without RP words. In Study 2, we preregistered the design to replicate the findings of Study 1. Specifically, we formulated the following four hypotheses: the proportion of specific memories is positively associated with the lure discrimination index (Hypothesis 1), the proportion of categoric memories without RP words is negatively associated with the lure discrimination index (Hypothesis 2), the proportion of categoric memories with RP words is not associated with the lure discrimination index (Hypothesis 3), and these hypotheses are supported if we control for age, sex, general intelligence, and corrected recognition score

(Hypothesis 4). Further, we confirmed these hypotheses using a model-based analysis of MST. Although the MST indices such as lure discrimination index are useful because they a large body of research findings has accumulated, researchers have not clearly determined what cognitive process yields each response, namely, old, similar, and new (Leger & Gutchess, 2021). These use of parameters obtained from the model-based analysis can address this issue.

Participants

Based on the correlation between specific memories and lure discrimination index obtained in Study 1, the required sample size was estimated as $N = 105$ with the assumptions of $\alpha = .05$ and power $(1-\beta) = .80$. Considering that some data would have to be excluded for technical errors, we aimed to oversample participants and planned to stop the data collection until $N = 110$. In line with the preregistered design (<https://osf.io/yjxbt>)³, 110 Japanese undergraduate students recruited from Shinshu University participated in the face-to-face experiment. However, due to technical error, 7 participants' data were lost. Of the remaining data, 4 participants who met the predetermined exclusion criteria, which were the same as in Study 1, were excluded ($n = 4$: beyond ± 2.5 SD from the means of the MST response categories). Finally, the data obtained from 99 participants (42 males, 57 females, 18.93 ± 1.82 years old), which was unfortunately underpowered, were included in the analysis.

Japanese Adult Reading Test

The Japanese version of the National Adult Reading Test (JART) was used to measure

³ At the preregistration stage, we made a mistake in determining the sample size and calculated the required number of participants as $N = 102$. The correct number of participants was $N = 105$, as described in this paper.

general intelligence. The JART was developed by Matsuoka et al. (2006) and standardized for healthy individuals. This task asks participants to read 50 Japanese kanji characters. In this study, the number of correct responses was used for analysis.

Procedure

The procedure stayed unchanged from Study 1 except for the JART, which was added as a control for individual differences in general intelligence. The task order was counterbalanced, and participants followed the experimenter's instructions in a face-to-face format. After providing informed consent, participants completed all the tasks and received shopping voucher worth 1,000 JPY (approximately 10 USD) as compensation for their participation. For the Autobiographical Memory Test responses, the agreement of two independent raters was good for the traditional five categories (i.e., specific, categoric, extended, semantic, and omission; $k = .75$) and for the two categoric memory categories ($k = .88$)

Results

Descriptive statistics

The descriptives of the Autobiographical Memory Test responses are shown in Table 5. Among the Autobiographical Memory Test trials, specific memory accounted for $M = 4.42 \pm 2.18$ (44.7%). Consistent with Study 1, more categoric memories without RP words ($M = 2.11 \pm 1.17$; 21.6%) than with RP words ($M = 1.41 \pm 1.36$; 14.3%) were observed.

The right column of Table 3 shows the mean responses recorded in the MST test phase. Generally, consistent with Study 1, participants correctly specified most of the target stimuli as old ($M = 55.34 \pm 5.38$; 86.5%), but fewer identified lure stimuli as similar ($M = 30.69 \pm 10.05$; 47.9%) and erroneously recognized lure stimuli as old ($M = 26.18 \pm 8.85$; 40.9%).

Correlations

Table 5 illustrates the correlations between MST and Autobiographical Memory Test performance in Study 2. As predicted in Hypothesis 1, the proportion of specific memories was positively correlated with the lure discrimination index ($r = .32, p = .001$; Figure 1 lower left panel) and the Bayes factor favored the significant correlation (BF_{10} about 25). The proportion of specific memories was not associated with the corrected recognition score ($r = -.01, p = .89$) and the Bayes factor favored the null hypothesis with no correlation ($BF_{01} = 7.88$). The results of the Bayes factor used to evaluate the equality of the correlations of specific memory with the lure discrimination index or corrected recognition score favored the alternative hypothesis that the correlation between specific memory and lure discrimination index was greater than the correlation between specific memory and corrected recognition score (BF_{10} about 16). Consistent with Hypotheses 2 and 3, the lure discrimination index was negatively correlated with the proportion of categoric memories without RP words ($r = -.39, p < .001$; Figure 1 lower right panel) and the Bayes factor favored the significant correlation (BF_{10} about 386); however, the lure discrimination index was not associated with the proportion of categoric memories with RP words ($r = .13, p = .20$) and the Bayes factor favored the null hypothesis with no correlation ($BF_{01} = 3.56$). The results of the Bayes factor for testing the equality of the correlations between categoric memories with or without RP words and the lure discrimination index favored the alternative hypothesis that the correlation between categoric memories without RP words and the lure discrimination index was stronger than the correlation between categoric memories with RP words and the lure discrimination index (BF_{10} about 154).

The proportion of specific memories recalled was negatively correlated with that of categoric memories without RP words ($r = -.76, p < .001$) and with RP words ($r = -.30, p = .002$). Recall of categoric memories without RP words was not correlated with that of

categoric memories with RP words ($r = -.16, p = .11$). After evaluating the equality of the correlations between specific memory and categoric memory with or without RP words, the results favored the hypothesis that the correlation between specific memory and categoric memory without RP words was lower than the correlation between specific memory and categoric memory with RP words (BF_{10} about 2363).

Hierarchical regression analysis

A hierarchical regression analysis was performed to examine Hypothesis 4 (Table 4). In Step 1, the control variables (age, sex, general intelligence, and corrected recognition) were entered into the model, and in Step 2, the lure discrimination index was entered. For predicting specific memory, in Step 1, the overall model ($R^2 = .14, p = .007$) and the effect of general intelligence ($\beta = .32, p = .002$) were significant, whereas the effects of age ($\beta = .19, p = .053$), sex ($\beta = .04, p = .70$), and corrected recognition ($\beta = -.06, p = .51$) were not significant. In Step 2, there was a significant improvement in the model ($\Delta R^2 = .06, p = .009$), and the overall model was also significant ($R^2 = .20, p < .001$). The lure discrimination significantly predicted the proportion of specific memories ($\beta = .27, p = .009$). For predicting categoric memories without RP words, in Step 1, the overall model ($R^2 = .13, p = .012$) and the effects of age ($\beta = -.23, p = .020$) and general intelligence ($\beta = -.24, p = .017$) were significant, whereas the effects of sex ($\beta = -.14, p = .15$) and corrected recognition ($\beta = .07, p = .47$) were not significant. In Step 2, there was a significant improvement in the model ($\Delta R^2 = .12, p < .001$), and the overall model was also significant ($R^2 = .25, p < .001$). The lure discrimination significantly predicted the proportion of categoric memories without RP words ($\beta = -.38, p < .001$).

Modeling Analysis

We conducted a model-based analysis to provide an additional test of the main

findings. We used a recently developed model of the MST (Lee, Villarreal, & Stark, 2022), based on the multinomial processing tree framework for modeling recognition memory (Erdfelder et al., 2002; Snodgrass & Corwin, 1988). The general goal of multinomial processing tree models is to explain observed response behavior in terms of an underlying set of inter-dependent cognitive processes represented as probability trees. The structure of the trees corresponds to assumptions about the cognitive processes involved in producing behavior, and the probabilities associated with each branch of a tree correspond to parameters representing cognitive variables.

Figure 2 shows the three probabilistic trees used in the Lee et al (2022) model of the MST. Each tree corresponds to a different stimulus type: old, new, or lure. In the tree for old stimuli, the parameter ρ represents the probability of a studied item being remembered. If the item is remembered, it is assumed the participant will respond "old". If the item is not remembered (with probability $1 - \rho$) the participant is assumed to guess "old" with probability γ^o , guess "similar" with probability γ^s , or guess "new" with probability γ^n . These guessing parameters are constrained so that $\gamma^o + \gamma^s + \gamma^n = 1$. In the tree for new stimuli, the parameter ψ represents the probability of remembering that the item was not studied. If this occurs, it is assumed that the participant responds "new", otherwise the same guessing probabilities γ^o , γ^s , and γ^n determine their decision. For lure stimuli, the first processing step is an attempt to remember the similar item that was studied. If that item is remembered it is compared to the item presented on the test trial and there is a probability δ_l that the two are successfully discriminated. Successful discrimination leads to a "similar" response, but a failure to discriminate leads to an "old" response. If the relevant studied item is not remembered, the guessing probabilities determine the decision.

The simplest form of this model assumes that there are independent $\delta_1, \dots, \delta_5$ discriminability probabilities for the five different levels of lure in the MST. However, Lee et

al (2022) introduce an extended hierarchical model that links the different discriminability parameters using a logistic function. In particular, they assume that

$$\delta_l = 1/(1 + \exp(-\beta(\frac{l}{n_l + 1} - \tau))).$$

where τ is a threshold parameter that determines what level of lure participants are first able to discriminate, and β is a slope parameter that corresponds to how reliably participants discriminate. Overall, this hierarchical version of the model has two key parameters of interest for the current research questions. One is the ρ parameter, which measures the ability of people to remember relevant items from training. The other is the τ parameter, which measures their ability to make fine-grained distinctions between lure and studied stimuli. Thus, the translation of our key hypotheses to the context provided by the model is that ρ , as a measure of basic remembering, is not expected to correlate with the three AMS measures: specific memory, categoric memory without RP words, and category memory with RP words. The τ threshold, in contrast, as a measure of the ability to distinguish between similar stimuli, is expected to show the same pattern of correlations as the lure discrimination index.

We implemented the hierarchical version of the Lee et al (2022) model in JAGS (Plummer, 2003), which is a scripting language for graphical models that facilitates the use of Bayesian computational sampling methods of inference (Lee & Wagenmakers, 2013). A posterior predictive analysis showed that the model was descriptively adequate for our data. That is, the model was able to describe the patterns of responding for old, new, and each type of lure stimuli at the level of individual participants. The details of the JAGS implementation and the posterior predictive check are provided in the supplementary information.

Figure 3 shows the patterns of correlation between the ρ parameter in the top row and the τ parameter in the bottom row against each of the three AMS measures in columns. The main panel shows the parameter and test scores for each participant as a blue circle, with

error bars indicating interquartile ranges for the posterior distributions of the parameters and measures. (The posterior distributions for the AMS measures are based on a simple binomial model of the number of observations out of the total number of trials for each measure). The inset panels show as a yellow curve the posterior distribution of the correlation coefficient between the parameter and measure across all participants. Also shown as a dotted line is a uniform prior on the correlation coefficient. The difference between the prior and posterior distributions allows the estimation of Bayes factors testing whether or not the correlation is significantly different from zero, using the Savage-Dickey method (Wetzels, Grasman, & Wagenmakers, 2010).

The results in Figure 3 show that the memory parameter ρ does not correlate with any of the AMS measures. The Bayes factors all favor the null hypothesis of no correlation, with values of 8, 11, and 10, for specific memory, categoric memory without RP words, and categoric memory with RP words, respectively. Meanwhile, the τ threshold measure of discrimination sensitivity shows a similar pattern of correlation as the lure discrimination index. The correlation of τ with categoric memory without RP words is clear, with a Bayes factor of 40 favoring a significant correlation which is estimated at 0.35. The correlation of τ with the categoric memory with RP words measure has a Bayes factor of 4 in favor of the null hypothesis of no correlation. These two results are exactly as predicted. The final result is more ambiguous. The correlation of τ with the specific memory measure is 1.6 in favor of a significant correlation. This is best interpreted as a lack of evidence for either conclusion. That is, it is unclear whether the correlation is significant or not. The mean correlation of -0.20, however, is in the right direction.

Discussion

Decades of research has identified a number of psychological mechanisms underlying

AMS (autobiographical memory specificity; Sumner, 2012; Williams et al., 2007). It remains, however, unclear whether pattern separation, an essential component of episodic memory, is associated with AMS. The present study examined this association using the MST (mnemonic similarity task; Kirwan & Stark, 2007) and the Autobiographical Memory Test with minimal instruction (Debeer et al., 2009). The results showed that individuals with higher pattern separation (as assessed by the lure discrimination index) retrieve more specific autobiographical memories. Furthermore, as a novel classification, categoric memory was separated into memories with and without RP words. As predicted, we found that categoric memories without RP words were selectively associated with lower lure discrimination index. These findings were strengthened by the use of cognitive modeling for the MST as we found a consistent significant effect of the parameter τ , representing the ability to distinguish between similar stimuli. Note that in a replication study conducted in-person and individually (Study 2), pattern separation was uniquely associated with higher AMS even after controlling for general intelligence and corrected recognition scores.

As mentioned earlier, the literature has shown that (nonautobiographical) episodic memory details are supported by both source/associative memory and pattern separation (Stevenson et al., 2020), and this finding would be applicable to AMS. The present study suggests that AMS may be relevant for pattern separation. To retrieve and report a specific past event, it is necessary not only to recollect the source memory, but also to discriminate overlapping features of events and retrieve the event-specific context. Note that since recognition can be based on familiarity and is not a sufficient indicator of source and associative memory (Yonelinas et al., 2010), the lack of association between corrected recognition score and AMS does not negate their contribution to AMS.

Another important piece of evidence from the literature on episodic memory is that pattern separation depends not only on retrieval but also on encoding (Stark et al., 2019). While AMS research has focused on memory retrieval (Sumner, 2012), individual differences

or conditions at the encoding are probably also responsible for AMS. Pattern separation may allow us to encode and retain the unique aspects of each event, thereby discriminating from general memories into event-specific knowledge during retrieval. Examining AMS using a paradigm with controlled encoding of autobiographical memory (e.g., Cabeza et al., 2004) may address this research question.

In light of the categoric memory results, we propose distinguishing between categoric memories indicating the repetition, regularity, and frequency of an event(s) and one indicating a lack of temporal context (Figure 4). Following the operationalization of Renoult et al. (2016), we classified categoric memories depending on the word use concerning repetitions and frequency of events. We regarded the presence of RP words as an indication that a categoric memory contains a high level of abstract representation because these words represent knowledge formed by the summarization of multiple similar events (Barsalou, 1988). In contrast, categoric memory without RP words can be understood as half a specific memory – a memory that describes an event(s) but critically lacks temporal specificity. The former type of categoric memory corresponds to autobiographical facts in the sense of Renoult et al. (2016) whereas the latter corresponds to repeated events. Importantly, these two types of categoric memory did not correlate with each other, and therefore, are two different constructs. Specific memory was negatively correlated with both categoric memories, and particularly strongly correlated with categoric memory without RP words. These correlations are partially attributed to the task design of the Autobiographical Memory Test as it calculates how many memories are recalled among 10 memories. Nevertheless, the strong negative correlation between specific memory and categoric memory without RP words may indicate that they are counter-constructs. Specific memories may be recalled if the temporal context can be recovered, whereas categoric memories without RP words may be recalled if the temporal context cannot be recovered. On the other hand, the correlation between specific memory and categoric memory containing RP words is relatively weak, indicating that this

type of categoric memory is a different component from episodic memory, and may reflect semanticized abstract representations as we assumed.

The classification of types of categoric memory allows us to develop an integrative model of autobiographical memory structures. Renoult et al.'s (2012) model of autobiographical memory structures proposed that personally relevant general and semantic memories can be divided into the following three categories: self-knowledge, autobiographical facts, and repeated events. The model places repeated events proximate to episodic memory, whereas self-knowledge and autobiographical facts are close to semantic memory. However, their classification of general and semantic memories appears to have a complex taxonomy (Renoult et al., 2012, 2016, 2020). We somewhat tentatively based our classification of categoric memories on the operationalizations of Renoult et al. (2016), but this classification may be interpreted differently from Renoult et al. (2012 and 2020). They defined repeated events as recalling common elements of multiple episodes in one's personal past, and this definition includes not only categoric memory without RP words but also categoric memory with RP words. Renoult et al. (2020) also proposed that autobiographical facts are essentially semanticized, experience-far memories, but some of these are experience-near and include spatiotemporal contextual information. In turn, the present study showed that a simple taxonomy following the operationalization of Renoult et al. (2016) could be useful for general memory classification. The comparison of two types of categoric memory in relation to the lure discrimination index supported the presence of categoric memory that is closer to specific memory but lacks temporal context, and categoric memory that is closer to semantic memory and contains high levels of abstract representations. Specifically, low pattern separation may be associated with a lack of the temporal information necessary for episodic memory (i.e., when an event occurred), resulting in the report of categoric memory without RP words. In contrast, the lack of correlation between pattern separation and categoric memory with RP words suggests that these categoric memories are underpinned by

semanticized abstract representations rather than faulty episodic memory. This simple taxonomy would be the crossroads of AMS research and personal semantic research.

Recent autobiographical memory research has suggested that episodic memory has two important components: *temporal specificity* (when an event occurred – on a particular day and time) and *scene recall* (reliving, vividness, and beliefs in the accuracy of autobiographical memory; cf. scene construction; Hassabis & Maguire, 2007) (Rubin, Deffler, & Umanath, 2019; Rubin, 2020). Temporal specificity is conceptually the same as AMS. Empirical evidence suggests that scene recall is poorly correlated with temporal specificity (Rubin et al., 2019; Rubin, 2020) and that its typical property, vividness, is poorly related to autobiographical or episodic memory specificity (Cooper & Ritchey, 2022; Habermas & Diel, 2013; Matsumoto et al., 2022). These findings can be interpreted as scene recall is involved in not only specific but also general categoric memories. For example, we can recall, without episodic memory, the scene of the path we walked to high school everyday. Thus, the association between memory specificity and pattern separation, would not be alternatively explained by memory properties associated with scene recall, such as vividness. As a potential future research topic, specific memory and the subtypes of categoric memory proposed in the present study could be distinguished by the involvement of temporal specificity and scene recall. Specifically, categoric memories without RP words may be characterized by a lack of temporal specificity and the presence of scene recall, whereas categoric memories with RP words may lack temporal specificity (but accompanied by frequency information) and also lack scene and sensory perceptual details. Specific memory would include both temporal specificity and scene recall (Rubin et al., 2019; Rubin, 2020). In hierarchical model of autobiographical memory, sensory-perceptual detail fades as one moves from a hierarchy of specific memories to an abstract hierarchy (Conway & Pleydell-Pearce, 2000; Renoult et al., 2012; Williams et al., 2007), and thus a reasonable approach would be to separate the contrasts in the hierarchy within categoric memory by the shading of scenes.

In addition to the discussion described above, it would be interesting to distinguish between the two types of categoric memories either in terms of other behavioral measures or neural substrates or by incorporating natural language processing (Takano et al., 2017, 2018, 2019). One hypothesis is that categoric memory without RP words involves a relatively long latency, indicating truncated generative retrieval (Eade et al., 2006), whereas categoric memory with RP words involves a relatively short latency, indicating direct (associative) retrieval (Matsumoto et al., 2020). Another possibility is that categoric memory with RP words is rated higher in event frequency than categoric memory without RP words. Categoric memory is known to be characterized by the frequency of events in one's life (Barsalou, 1988; Williams & Dritschel, 1992), but as variance among these events has been noted, we may be able to discriminate the semantic and episodic nature of categoric memory by the subjective rating of frequency.

Since previous studies have shown that lure discrimination index is a useful marker of hippocampal function (Stark et al., 2019), the present study potentially contributes to the neural account of AMS. Recently, growing cognitive neuroscientific research on autobiographical memory (Cabeza & St. Jacques, 2007; Svoboda, McKinnon, & Levine, 2006) and AMS (Young et al., 2012) have provided neural accounts (for a review, Barry et al., 2018). However, surprisingly, researchers have not clearly determined whether the hippocampus is involved in AMS, including general categoric memory. Previous studies have confirmed that the hippocampus underlies the encoding and retrieval of specific autobiographical memories (Barry & Maguire, 2019; Gilboa & Moscovitch, 2021; Moscovitch et al., 2016; Squire, Genzel, Wixted, & Morris, 2015) as well as general categoric memories (Addis et al., 2004; Gilboa & Moscovitch, 2021; Holland, Addis, & Kensinger, 2011; Renoult et al., 2012; St-Laurent, Moscovitch, Levine, & McAndrews, 2009; Young et al., 2012). A possible explanation for these findings is that components of autobiographical memory retrieval involving the hippocampus, such as the generation of a conceptual frame

(Conway, 2009; Irish & Piguet, 2013) and visuospatial imagery (Addis et al., 2004), overlap between specific and general categoric memories. Although the present study is limited to behavioral assessments, examining the hippocampus based on the functions of each subregion will facilitate the elucidation of the mechanism of AMS.

Poor pattern separation has been observed in depression (Shelton & Kirwan, 2013), schizophrenia (Kraguljac et al., 2018), and advanced age (Toner et al., 2009). Independently, reduced AMS has been observed in these populations (Kwok et al., 2021; Ros et al., 2018; Williams et al., 2007). Individuals in these classes are also known to have hippocampal atrophy and decreased hippocampal neurogenesis (Campbell et al., 2004; Videbech & Ravnkilde, 2004; Adriano, Caltagirone, & Spalletta, 2012; Bettio, Rajendran, & Gil-Mohapel, 2017). Although the present study did not target those populations, poor pattern separation may underlie the reduced AMS observed in those individuals. Examining which of these categoric memories are abnormal would provide insights into a pathological condition of the autobiographical memory structure.

AMS can be improved by repeated training to recall specific memories, which is known as Memory Specificity Training (MeST; Barry, Sze, & Raes, 2019; Raes, Williams, & Hermans, 2009), and the MeST has some effect on improving mental health including depression and posttraumatic stress disorder (Barry et al., 2019; Moradi et al., 2014). It has long been a question as to what process variables explain the effects of MeST on the improvements of AMS and mental health (Barry et al., 2021). Some of the improvement of AMS may be obtained through improvements in pattern separation because the MeST includes an exercise in focusing on the unique aspects of events (Raes et al., 2009). One future direction is to explore whether the effects of MeST and its family on improving AMS and mental health are mediated by improved pattern separation. Perhaps, a pattern separation training intervention might improve AMS, which would benefit patients, as they would not need to face negative autobiographical memories, unlike the MeST.

As a limitation, it should be noted that reduced AMS cannot be explained by pattern separation alone. In particular, executive control and regulatory processes (functional avoidance) could influence AMS (Williams et al., 2007). Furthermore, although we did not use emotional and self-relevant stimuli in this study, these stimuli may activate dysfunctional schemas, especially in patients with depression, and then induce categoric memory based on abstract representations (Matsumoto et al., 2020). Memory characteristics such as vividness and accuracy may provide additional information to differentiate between specific memory and the subtypes of categoric memory. Another limitation of this study is the correlational design, which means that causality can only be inferred. Nevertheless, this study contributes to the body of research identifying the mechanisms by which autobiographical memory contributes to mental health, why autobiographical memory is impaired, and the development of an integrative model of autobiographical memory structures.

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Table 1. Examples of categoric memories with and without RP words

With RP words

When I was in secondary school, I practiced **almost every day** to win more in my club activities.

I **often** fell asleep during school lessons

I am **always** worried about what people think of me

Many times I forgot to do errands that my parents asked me

These days, when I finish my university assignments, I have nothing else to do.

Without RP words

I studied for the university entrance exam

I had a bad attitude in high school. I was reading in class with impunity.

I passed the time by watching Amazon Prime Video.

I had difficulty explaining things well.

I have experienced difficulties in carrying on a conversation.

Table 2. Correlations between pattern separation, recognition memory, and autobiographical memory specificity in Study 1

<i>Variables</i>	<i>M</i>	<i>SD</i>	1.	2.	3.	4.	5.	6.	7.
1. LDI	0.29	0.20							
2. Corrected recognition	0.79	0.11	.20 *						
3. Proportion of SM	0.39	0.25	.27 **	.09					
4. Proportion of CM	0.38	0.20	-.18	.00	-.77 ***				
5. without RP words	0.28	0.18	-.27 **	.08	-.67 ***	.86 ***			
6. with RP words	0.10	0.11	.12	-.15	-.32 **	.44 ***	-.08		
7. Proportion of EM	0.12	0.09	-.23 *	-.05	-.18	-.10	-.18	.09	
8. Proportion of SA	0.11	0.15	-.08	-.13	-.51 ***	-.03	.06	-.13	-.17

LDI = Lure discrimination index; SM = Specific memory; CM = Categorical memory; EM = Extended memory; SA = Semantic association.

*** $p < .001$, ** $p < .01$, * $p < .05$.

Table 3. The mean proportion of each response in the Mnemonic Similarity Task

		Study 1		Study 2	
		<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Target	Old	0.83	0.10	0.86	0.08
	Similar	0.11	0.07	0.10	0.07
	New	0.06	0.06	0.04	0.04
Lure	Old	0.44	0.16	0.41	0.14
	Similar	0.42	0.17	0.48	0.16
	New	0.14	0.09	0.11	0.07
Foil	Old	0.04	0.05	0.02	0.03
	Similar	0.13	0.09	0.09	0.06
	New	0.83	0.11	0.88	0.07

Table 4. Hierarchical regression analyses of the proportions of specific memories and categoric memories without RP words (lacking temporal context)

	<i>Variables</i>	<i>Coefficients</i>	<i>SE</i>	β	<i>p</i>	<i>Model information</i>
<i>Study 1</i>						
<i>DV = Specific memory</i>						
Step 1	(Intercept)	0.20	0.26		.43	$R^2 = .02, p = .60.$
	Age	0.00	0.01	-.03	.80	
	Sex	0.06	0.05	.11	.29	
	Corrected recognition	0.18	0.24	.08	.44	
Step 2	LDI	0.35	0.13	.27	.01	$R^2 = .09, p = .07.$
						$\Delta R^2 = .07, p = .010.$
<i>DV = Categoric memory without RP words</i>						
Step 1	(Intercept)	0.20	0.19		.28	$R^2 = .02, p = .55.$
	Age	0.00	0.00	.02	.84	
	Sex	-0.05	0.04	-.13	.23	
	Corrected recognition	0.15	0.17	.09	.38	
Step 2	LDI	-0.29	0.10	-.31	.004	$R^2 = .11, p = .03.$
						$\Delta R^2 = .09, p = .004.$
<i>Study 2</i>						
<i>DV = Specific memory</i>						
Step 1	(Intercept)	-0.24	0.29		.41	$R^2 = .14, p = .007.$
	Age	0.02	0.01	.19	.053	
	Sex	0.02	0.04	.04	.70	
	JART	0.01	0.00	.32	.002	
	Corrected recognition	-0.12	0.18	-.06	.51	

Step 2	LDI	0.30	0.11	.27	.009	$R^2 = .20, p < .001.$ $\Delta R^2 = .06, p = .009.$
<hr/>						
<i>DV = Categorical memory without RP words</i>						
Step 1	(Intercept)	0.85	0.25		< .001	$R^2 = .13, p = .012.$
	Age	-0.02	0.01	-.23	.02	
	Sex	-0.05	0.04	-.14	.15	
	JART	-0.01	0.00	-.24	.017	
	Corrected recognition	0.11	0.15	.07	.47	
Step 2	LDI	-0.35	0.09	-.38	< .001	$R^2 = .25, p < .001.$ $\Delta R^2 = .12, p < .001.$

Note. LDI = Lure Discrimination Index.

Table 5. Correlations between pattern separation, recognition memory, and autobiographical memory specificity in Study 2

<i>Variables</i>	<i>M</i>	<i>SD</i>	1.	2.	3.	4.	5.	6.	7.	8.
1. LDI	0.37	0.20								
2. Corrected recognition	0.83	0.12	.31 **							
3. Proportion of SM	0.45	0.22	.32 **	-.01						
4. Proportion of CM	0.36	0.21	-.27 **	.10	-.86 ***					
5. without RP words	0.22	0.18	-.39 ***	.05	-.76 ***	.76 ***				
6. with RP words	0.14	0.14	.13	.10	-.30 **	.51 ***	-.16			
7. Proportion of EM	0.17	0.09	-.14	-.23 *	-.26 **	-.18	.04	-.33 ***		
8. Proportion of SA	0.02	0.06	-.02	.07	-.23 *	-.04	.07	-.15	.00	
9. JART	33.04	6.68	.29 **	.17	.31 **	-.22 *	-.23 *	-.03	-.22 *	-.02

LDI = Lure discrimination index; SM = Specific memory; CM = Categorical memory; EM = Extended memory; SA = Semantic association; JART = Japanese Adult Reading Test.

*** $p < .001$, ** $p < .01$, * $p < .05$.

Study 1

Study 2

Figure 1. Scatterplots and correlations of autobiographical memory specificity, lure discrimination index, and corrected recognition score

Figure 2. The multinomial processing tree model of the MST developed by Lee et al (2022).

Figure 3. The correlation between the ρ memory and τ threshold parameters and the AMS measures of specific memory, categoric memory without RP words, and categoric memory with RP words. The main panels show the parameter and measure means for each participant as blue markers, with error bars showing the interquartile range of the credible interval. The inset panels show the posterior distribution of the correlation coefficient as yellow curves. CM = categoric memory.

Figure 4. Dual framework for explaining nonspecific, general categoric memories.