Aging and false memories: Comparing effects of item-relatedness and list position

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Abstract

Semantic false memories are traditionally more frequent from early list positions and thought to arise from presumed long-term memory stores whereas phonological false memories traditionally are more frequent from late list positions and thought to arise from presumed short-term memory stores. However, recent research with younger adults challenges this distinction, finding semantic and phonological false memories across stores and list positions (Atkins & Reuter-Lorenz, 2008; Dimsdale-Zucker et al., 2018; Flegal et al., 2010). Since aging is thought to differently influence integrity of short- and long-term memory, we compared performance between younger (YAs) and older (OAs) adults using a modified Deese-Roediger-McDermott paradigm to understand whether semantic and phonological memories depend on distinct or shared underlying memory stores. We examined false memory generation across age groups, list composition (semantic, phonological), and putative memory stores. OAs recalled fewer items than YAs, but both groups generated more phonological than semantic false memories. Notably, list position did not influence false memories in either YAs or OAs, suggesting false memory generation is driven by list composition rather than putative memory store. These findings challenge traditional views of memory organization by revealing shared cognitive processes, which transcend traditional memory system distinctions, underlie semantic and phonological false memories.

Introduction

Although colloquially we think of memory as a factual recapitulation of our experiences, extensive laboratory work has shown that, instead, memory is prone to distortions and confabulations (Loftus, 1997). These inaccuracies, which can be measured in the lab as false memories, underscore the dynamic and reconstructive nature of memory (Bartlett, 1993; Schacter, 2012). This fallibility of memory has been extensively studied using the Deese-Roediger-McDermott paradigm (DRM; Deese, 1959; Roediger & McDermott, 1995). The DRM paradigm is a verbal list-learning task designed to elicit false memories (for a review, see Gallo, 2010). In this task, participants study a list of words related to a central theme and later recall those words. A striking finding is that a significant number of participants falsely remember non-presented words related to the theme (e.g., if participants studied '*bed*', '*pillow*', '*dream*', '*nap*', they often falsely endorse seeing the word '*sleep*'). While false memories have traditionally been studied as failures of long-term memory (Gallo, 2013), an increasing body of research shows they can arise after relatively short delays and short lists of memoranda (e.g., Abadie & Camos, 2019; Atkins & Reuter-Lorenz, 2008; Coane et al., 2007; Dimsdale-Zucker et al., 2018; Festini & Reuter-Lorenz, 2013; Flegal et al., 2010). This raises important questions about the memory systems involved—particularly putative long- and short-term memory stores—in generating false memories. Here, we address this by examining how age-related changes, particularly those that traditionally are theorized to differentially affect long- and short-term memory systems (Brickman & Stern, 2009), can offer new insights into our understand of false memory as well as the structure of memory itself.

In the canonical DRM paradigm, participants study 12-to-15 words semantically related to a non-presented theme (e.g., words like '*bed*,' '*rest*,' and '*pillow*' are associated with the theme

'*sleep*'), which exceeds the capacity of short-term memory (Miller, 1956). After encoding, participants freely recall the studied items from memory or complete a recognition memory task in which they must decide if a presented item was previously studied. Research shows that false memories manifest in both free recall and recognition memory tasks, with participants erroneously recalling or endorsing non-presented words that are semantically related to the theme word (e.g., '*sleep*' in the example above; Deese, 1959; McDermott, 1996; McDermott & Roediger, 1998; Robinson & Roediger, 1997; Roediger & McDermott, 1995; Seamon et al., 1998; for a comprehensive review, refer to Gallo, 2013). These memory errors, or false memories, are thought to arise from the automatic activation of related semantic lexical networks during encoding, whereby studied words activate related but unstudied concepts and words from long-term memory stores. In turn, these activated items interfere during remembering, producing false memories (Roediger et al., 2001). Such memory errors reflect that memory is not a verbatim recording of past events, but, instead, a constructive process influenced by prior knowledge and associations (Roediger & McDermott, 1995; Schacter et al., 2007). Taken together, the finding that false memories occur in tasks involving list lengths that exceed short-term memory capacity as well as the role of semantic associations in generating false memories, support the idea that false memory is a long-term memory phenomenon.

However, this notion has been challenged by evidence demonstrating that false memories can occur even with shorter 3-item lists (Festini & Reuter-Lorenz, 2013) or 4-item lists and immediate testing with no retention delay, which fall within the capacity of short-term memory (e.g., Abadie & Camos, 2019; Atkins & Reuter-Lorenz, 2008; Coane et al., 2007; Dimsdale-Zucker et al., 2018; Flegal et al., 2010). For example, Atkins and Reuter-Lorenz (2008) found that participants falsely recognized semantically related lures after studying 4-item lists and

being tested within seconds of encoding. These results not only challenge the traditional view that false memories predominantly arise from long-term memory stores but also suggests that similar mechanisms may be at play during the generation of false memories from putative short- and long-term memory stores. Flegal and colleagues (2010) extended this work by testing false memories under both short- and long-term retrieval conditions. Participants studied 4-item lists and were tested either immediately after encoding each list (i.e., retrieval from short-term memory stores) or after a delay, once all the lists had been encoded, in a surprise memory test (i.e., retrieval from long-term memory stores). False memories occurred at similar rates in both conditions and, intriguingly, participants rated true and false memories as subjectively similar, regardless of whether their memory was tested in the short-term or long-term version of the task.

As such, while prior studies demonstrate that false memories arise under both short- and long-term retrieval conditions, evidence for the occurrence of false memories from both short- and long-term memory systems often involves different experimental designs to elicit false memories from each system. To address this, Dimsdale-Zucker and colleagues (2018) employed a modified serial position curve paradigm to investigate false memories across short- and long-term memory within a single task and recall window (see also Flegal et al. 2010) for use of a within-subjects design with identical study conditions across immediate and delayed tests). Unlike prior work using shorter lists of items, they use a modified variant of a serial position curve paradigm in which participants studied 12-item lists with three nested 4-item "sublists" (Glanzer & Cunitz, 1966; Murdock, 1962). Each sublist consisted of four words that were semantically related to a unique theme (e.g., *'hive', 'bumble,' 'sting,' and 'buzz'* are all semantically related to the theme *'bee'*). Within each 12-item list, the three subslists were unrelated to one another. They found that false memories occurred across all sublists, although

they were less frequent for the most recent sublist especially when the retention interval was unfilled. These findings support the idea that false memories can emerge from both short- and long-term memory stores.

However, much of the research on false memory has focused on semantic false memories, leaving open questions about the role of phonological similarity in generating false memories across short- and long-term memory systems. When items are recalled from the beginning of the list (i.e., from putative long-term memory stores), this is thought to be preferentially supported by gist- or meaning-based traces that are more resilient than fragile sensory coding that fades more rapidly (Brainerd & Reyna, 2002; Reyna & Brainerd, 1995). A consequence of this is an increased likelihood of semantic, as compared to sound-based or phonological, false memories. In contrast, when items are retrieved from the end of the list (i.e., putative short-term memory stores), phonological or acoustic information is more likely to be accessible (Baddeley & Hitch, 1974), which increases the likelihood of phonological errors (although this is contrasted by a greater likelihood of verbatim traces; Brainerd & Reyna, 2002; Reyna & Brainerd, 1995). Consistent with this distinction, studies demonstrate that items in the primacy position are predominantly susceptible to semantic errors (Craik & Levy, 1970), while items in the recency position are selectively susceptible to acoustic or phonological errors (Craik, 1968). Additionally, phonological false memories are more common when there is a short rather than a long delay between encoding and retrieval (Lim & Goh, 2019; McBride et al., 2019 but see Atkins & Reuter-Lorenz, 2008), likely reflecting retrieval from short-term memory stores (Coane et al., 2024). Thus, this research supports the idea that both types of false memories (semantic and phonological) may stem from different aspects of memory processing—semantic

errors from gist-based processing associated with the long-term memory system and phonological errors from verbatim traces associated with the short-term memory system.

However, not all research supports this view. While theory would predict that phonological false memories should primarily arise from short-term memory (particularly affecting the most recently studied items), Dimsdale-Zucker and colleagues (2018) found that phonological false memories occurred across all list positions, albeit their occurrence was rare. This suggests that phonological errors are not simply an artifact of the recency effect. The relatively few phonological false memories reported by Dimsdale-Zucker et al. (2018) is unsurprising given that the study lists were constructed on the basis of semantic similarity and were therefore intentionally biased to elicit semantic false memories. There is extant evidence that, when lists are constructed based on phonological, as compared to semantic similarity, that false memories can also occur in the phonological domain at similar rates as seen in semantically similar lists (e.g., recalling '*mat'* instead of '*cat'* or '*bat'*; (McBride et al., 2019; Sommers & Lewis, 1999; Watson et al., 2003). These findings suggest the intriguing possibility that a strict interpretation of phonological representations as falling within the purview of short-term memory stores (Baddeley, 1966, 1968) may need to be reconsidered.

Healthy aging can provide a potential lens through which to examine the differential access to verbatim and gist traces, which may underlie phonological and semantic and false memories, respectively. The semantic memory system, which is responsible for storing and recollecting general facts and knowledge about the self and the world (Tulving, 1972) remains relatively stable throughout the lifespan (Grady, 2012; Nyberg & Pudas, 2019; Salthouse, 2004). In contrast, the episodic memory system, which is responsible for recalling personal experiences and specific events (Tulving, 1972), becomes increasingly impaired with age. This decline in

episodic memory often leads to difficulties in the retrieval of specific contextual information (e.g., retrieving the time, place, or source of information; for a review of memory and aging, see Craik, 2023). As a result, older adults may preferentially rely on gist-based memory traces, drawing on general knowledge and abstracted information from their preserved semantic memory system, rather than on precise, verbatim details from their impaired episodic memory system. Accordingly, research consistently shows that older adults generally recall less than their younger counterparts (Brickman & Stern, 2009; Craik & Salthouse, 2011; Rönnlund et al., 2005) and their recollections tend to be more reliant on gist-based traces rather than perceptual, verbatim traces (Abadie & Camos, 2019; Brainerd et al., 2008; Grilli & Sheldon, 2022; Schacter et al., 1997). Furthermore, this shift toward a greater reliance on gist-based memory processing may also contribute to an increased susceptibility to false memories in older adults, particularly semantic false memories. Given that gist-based memory traces are more abstract and less detailed, they may create opportunities for older adults to incorporate erroneous information that aligns with their existing general knowledge, leading to semantic distortions. Consistent with this, research shows that younger adults generally outperform older adults on DRM tasks. Specifically, older adults correctly report fewer studied items and also report a greater number of semantic false memories as compared to younger adults (Balota et al., 1999; Budson et al., 2003; Dehon, 2020; Dennis et al., 2007; Norman & Schacter, 1997; Tun et al., 1998). This increase in false memories in older individuals appears to be resistant to additional control processes as even when cues are provided that inform individuals about the nature of the DRM paradigm, these cues either fail to reduce false memories or only partially mitigate them compared to young adults (McCabe & Smith, 2002).

Additionally, aging is known to be associated with declines in sensory processing, including reductions in vision and hearing, with research showing that the degree of these sensory declines is linked to rates of cognitive decline (Roberts & Allen, 2016). Several hypotheses have been proposed to explain how these age-related changes in sensory processing may affect performance on cognitive tasks (for review, see Monge & Madden, 2016). One well-supported hypothesis is the information degradation hypothesis, which posits that sensory degradation leads to errors during perceptual processing, ultimately resulting in poor performance on higher-order cognitive tasks that may not necessarily be perceptual in nature (Schneider & Pichora-Fuller, 2000). Following this, one possibility is that declines in sensory processing contribute to the higher rates of false memories observed in older adults. Consistent with this, research indicates that older adults experience declines in memory precision, particularly the ability to discriminate between perceptually similar stimuli (Ferguson et al., 1992; Korkki et al., 2020; Stark et al., 2013; Toner et al., 2009; Yassa et al., 2011).This decline in memory discrimination may in turn contribute to difficulties in accurately recalling specific details and distinguishing between similar items, thus leading to falsely remembering an item that is similar to something they were originally presented with. As such, declines in auditory processing could make it particularly difficult for older adults to discriminate between items that are phonologically similar.

Furthermore, cognitive operations involved in post-retrieval monitoring—such as evaluating the relevance of retrieved information to the goal of retrieval (Rugg, 2004)—also become less effective with increasing age (Henkel et al., 1998; Johnson et al., 1993). Such monitoring processes are essential for verifying the veracity of retrieved information. In the context of the DRM paradigm, such monitoring failures may contribute to the increased

susceptibility of older adults to false memories. In other words, deficits in post-retrieval monitoring processes could increase the likelihood that older adults are unable to monitor and reject a falsely remembered item that is similar to one they were originally presented with, thereby leaving them more prone to false memories in general (Dehon, 2020; Gallo & Roediger, 2003; Mitchell & Johnson, 2009).

In a related line of work, there is also evidence indicating that older adults also generate overall more false memories in working memory tasks relative to younger adults (Jantz et al., 2021). One possible cognitive mechanism contributing to increased false memories in older relative to younger adults is the age-related decline in rehearsal processes (Naveh-Benjamin & Cowan, 2023). Pirolle and colleagues (2025) demonstrated that the rate of rehearsal is positively associated with performance on working memory tasks, such that limiting the opportunity to rehearse leads to a higher incidence of false memories.

Thus, these age-related changes in sensory as well as cognitive function make older adults an ideal population for examining the differential contributions of putative short- and long-term memory stores to the generation of semantic and phonological false memories. Given that older adults tend to exhibit preserved semantic relative to episodic memory, they may rely more heavily on gist-based processing. As a result, they may be especially prone to semantic false memories, particularly for items presented early in a list. Alternatively, this shift toward gist-based processing may not reflect preserved semantic function per se but rather may be a consequence of reduced access to item-specific or sensory-based representations, which support verbatim memory and can be used to reject false information (Dennis et al., 2008). Such reductions may stem from weaker initial encoding (Glisky et al., 2001) or difficulties in binding contextual details (Naveh-Benjamin, 2000; Old & Naveh-Benjamin, 2008) which can thusly

limit the availability of cues needed to reject false information. In contrast, phonological false memories, which involve misremembering the sound or structure of words (e.g., recalling a similar-sounding word that was not presented), tend to be associated with short-term memory processes, and are more prevalent for items presented toward the end of a list where verbatim traces remain the strongest. As such, aging may influence not only the type of false memories (e.g., semantic vs. phonological) but also how these memory errors are distributed across list positions, suggesting that certain types of false memories may be more likely to occur at specific list positions as a function of age. Understanding these patterns can provide valuable insights into the differential roles of short- and long-term memory in the generation of false memories.

To provide a rigorous test of whether semantic and phonological false memories occur across list positions putatively associated with short- and long-term memory stores, we modified the paradigm used by Dimsdale-Zucker and colleagues (2018) and constructed lists where words either shared semantic or phonological associations with a non-presented theme (e.g., for the theme '*sleep*,' study lists may have been '*bed'*, '*nap'* … [semantic]; '*keep'*, '*reap'* … [phonological]; see **Appendix A**). We recruited younger and healthy older individuals to study these word lists. We hypothesized that this design would allow us to examine false memory generation across list positions both within individuals (i.e., examining differences in semantic vs. phonological false memories across list positions) and between age groups (i.e., comparing performance between younger and older adults). In Experiment 1, younger adults (YAs) and older adults (OAs) were presented with a series of word lists through simultaneous visual and auditory presentation. In Experiment 2, we replicated this in an OA-only sample shown word lists with visual-only presentation.

We used a similar design to Dimsdale-Zucker (2018) in which each studied list consisted of three sublists, with each sublist containing four words. Critically, in the present investigation, for half of the trials, the words in each sublist were *semantically* related to a non-presented theme word (e.g., '*bed'*, '*nap'*, '*awake'*, '*doze'* for the lure word '*sleep'*). For the other half of the trials, the four words in each sublist were *phonologically* related to a theme word (e.g., '*leap*, '*steep*, '*bleep*, '*heap* for the lure word '*sleep'*). This design intended to create a bias toward the generation of either semantic or phonological false memories, depending on the trial type. A key strength of this design was that it allowed us to assess false memories at all list positions under the same study conditions and recall window. Following the bimodal (i.e., visual and auditory) encoding phase in which participants were presented with words, participants were instructed to freely recall the studied words, and the number of semantic and phonological errors were assessed. To determine if our findings in OAs from Experiment 1 were influenced by the added support of presenting stimuli in two modalities, the stimuli in Experiment 2 were presented in a single modality (visual only) and focused on an OA sample, while all other procedures remained the same.

Based on extant theories, we hypothesized two possible patterns of results. First, based on accounts that posit memory for early and late study positions is supported by different underlying memory stores (Barnhardt et al., 2006; Brainerd & Reyna, 2002; Deese & Kaufman, 1957; Glanzer & Cunitz, 1966; Murdock, 1962; Reyna & Brainerd, 1995), we anticipated that semantic false memories would be more frequent for items presented in the early list positions—reflecting strong gist traces but relatively weaker verbatim traces. In contrast, we hypothesized that phonological false memories would be more likely for items presented at the end of the list where both gist and verbatim traces are presumed to be strong. Furthermore, we predicted that

OAs would exhibit a stronger tendency to generate semantic rather than phonological false memories, even for items presented at later list positions, reflecting age-related declines in memory precision (i.e., relative preservation of gist-level memory representations and decline of verbatim traces). Alternatively, if representations for early and late sublists instead rely on shared underlying memory stores and processes (Jonides et al., 2008; Nairne, 2002; Öztekin et al., 2010), we instead expected to observe semantic and phonological false memories across list positions and age groups. Specifically, we hypothesized that even if there were differences in the number of false memories from different sublist positions (e.g., more veridical and therefore fewer false memories from the most recent positions), that there would be no observable differences in the type of false memories—semantic or phonological—from these different sublists for both YAs and OAs. Altogether, this study aims to contribute to the ongoing discussion about the dual- versus single-store nature of underlying memory stores that can support both successful and erroneous memory performance, thereby providing new insights into our theoretical understanding of the phenomenon of false memories and the structure of memory itself.

Methods

Experiment 1

Participants. Native English speakers, free from any reported neurological or psychological disorders, and naïve to the stimulus set were recruited for this study. 48 Boston College undergraduate students (30 = female) participated either for course credit (0.5 credits/half hour) or cash ($5/half hour). All participants completed a battery of neuropsychological assessments that included the Mini-Mental State Examination (MMSE; Folstein et al., 1975), the Shipley Institute of Living Scale (SILS; Shipley, 1986), and the FAS (total, perseverations, and

intrusions) to evaluate cognitive function, memory, and verbal fluency. The Digit Symbol Substitution Test, Digits Forward, and Digits Backward tasks were used to assess processing speed and working memory. The Wisconsin Card Sorting Test (WCST) was administered to measure executive function and cognitive flexibility. The Beck Anxiety Inventory (BAI) and Beck Depression Inventory (BDI; Beck et al., 1996) were used to evaluate levels of anxiety and depression. Six participants were excluded for scores greater than 10 on the BDI leaving a remaining sample of 42 participants (25 = female; $Mean_{age}$= 19.34 years, SD_{age}= 0.99 years; see **Table 1** for neuropsychological assessment data).

An additional sample of 46 healthy, community dwelling seniors (aged 59 and up) were recruited from the Greater Boston area and compensated with cash ($5/half hour) for their participation. One participant was excluded for scores greater than 10 on the BDI (Beck et al., 1996) and an additional 3 participants withdrew themselves following the practice citing task difficulty and personal concerns about memory abilities precluding completion of the task. Results presented below are from the remaining 42 older participants (27 = female; $Mean_{age}$= 76.31 years, SD_{age}= 6.70 years; see **Table 1** for neuropsychological assessment data).

Materials. One 12-item list was presented on each of 46 trials (see **Appendix A**). Words were printed on a computer screen while a computerized voice simultaneously read the words aloud. Each list was composed of three sublists where each sublist contained four words that were all related to a common non-presented theme word (see **Appendix B**). On half of the trials, associates were related to the theme semantically (see **Figure 1B**) and for the other half of trials phonologically (see **Figure 1B**). Order of semantic and phonological trials was pulled randomly for each participant. Semantic versus phonological relationship of list items was counterbalanced

across participants such that each triplet was only presented once in either the semantic or phonological condition for each participant. Additionally, the order of sublists in each list were counterbalanced so that each theme occurred in each presentation position (primacy, middle, recency) equally often across participants.

Sublists represent a subset of 128 lists taken from previously published work on semantic false memories in STM (Flegal et al., 2010). These lists were supplemented with additional themes taken from neutral associates published in Kensinger and Corkin (2003) and associates were selected from the University of South Florida (USF) Free Association Norms (Nelson et al., 2004) following similar procedures as previous work (Flegal et al., 2010) to yield a total of 138 themes that were organized into 46 possible triplets. Audio files for each word were culled from the Linguistic Data Consortium at UPenn (http://www.ldc.upenn.edu/). Additional stimuli not available from this dataset were constructed in Lips (http://mac-free.com/download/Lips.html) using the "Victoria" voice and further edited in Audacity (http://audacity.sourceforge.net/).

Table 1.

Neuropsychological assessment data

	Experiment 1		Experiment 2
	YA	OA	OA
MMSE	29.43 *(0.83)*	28.76 *(1.36)*	29.16 *(0.71)*
Shipley	32.57 *(2.82)*	35.93 *(3.04)*	36.59 *(3.20)*
Digits symbol	46.79 *(6.80)*	33.21 *(7.67)*	40.50 *(14.97)*
Digits forward	11.57 *(1.99)*	10.88 *(2.37)*	11.23 *(2.37)*
Digits backwards	8.02 *(1.98)*	8.62 *(2.72)*	8.18 *(2.26)*
Digits total	19.63 *(3.23)*	20.12 *(4.72)*	19.30 *(4)*
BAI	6.95 *(6.02)*	4.18 *(4.27)*	3.33 *(3.82)*
BDI	3.05 *(2.37)*	3.43 *(2.83)*	3.15 *(3.19)*
FAS (total)	48.81 *(8.44)*	47.26 *(15.99)*	47.48 *(14.61)*
FAS (perseverations)	1.33 *(0.58)*	1.76 *(2.09)*	2.61 *(2.24)*
FAS (intrusions)	-	-	0.18 *(0.54)*
WCST (categories)	-	5.24 *(1.32)*	5.32 *(1.16)*
WCST (errors)	-	5.45 *(4.57)*	4 *(3.83)*
WCST (perseverations)	-	2.85 *(2.94)*	2.93 *(3.17)*
Mental control	-	24.21 *(5.21)*	26.84 *(6.25)*
Arithmetic	-	14.95 *(3.41)*	14.93 *(4.19)*

Notes. Standard deviation indicated in parentheses; missing FAS data in YA was due to data handling errors by the experimenter (HDZ). WCST, Mental Control, and Arithmetic were not administered to YA.

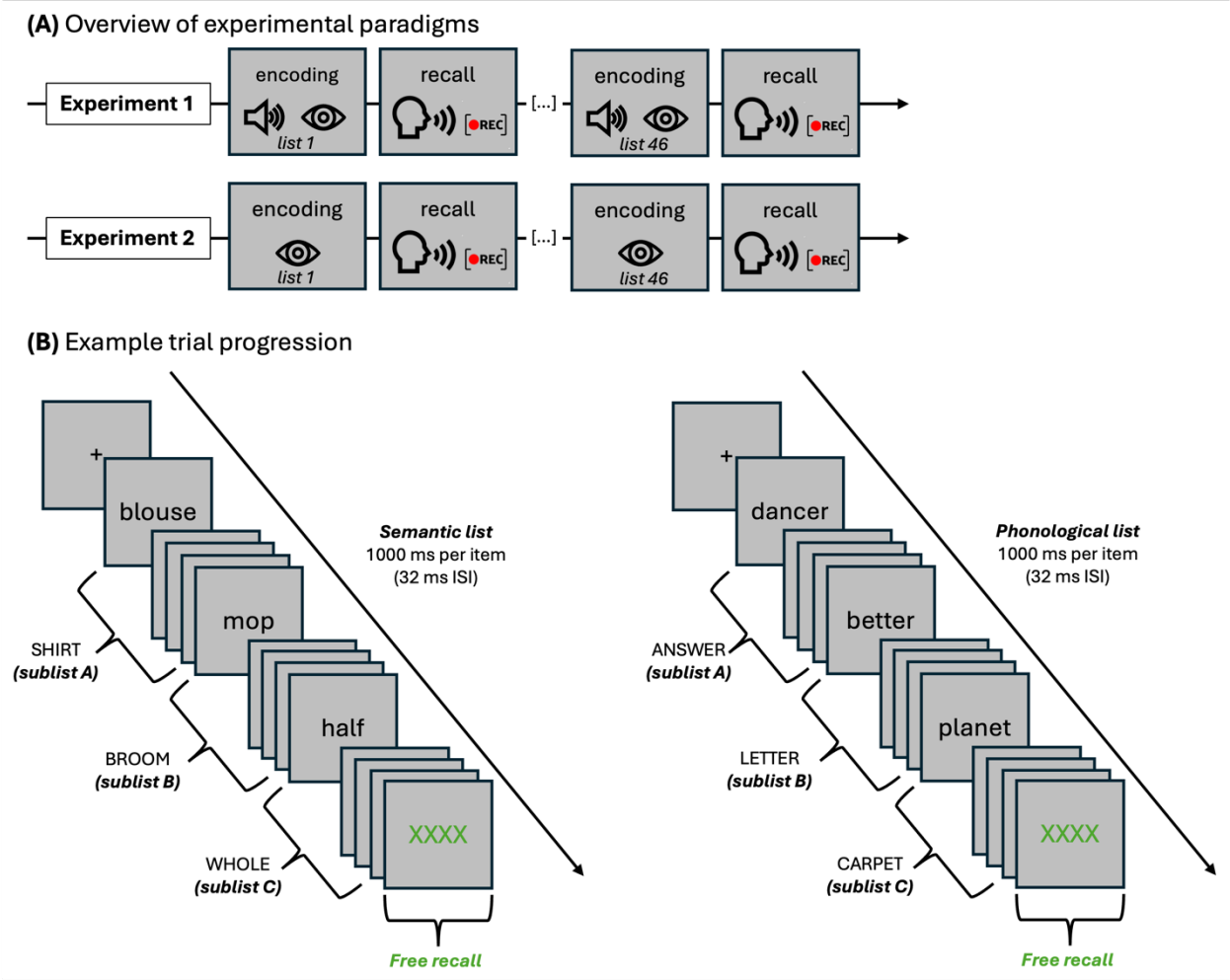

Figure 1. (A) Overview of experimental paradigms used in Experiment 1 and Experiment 2. **(B)** Example trial progression for semantic and phonological lists.

Procedure. Participants gave written consent in accordance with the Boston College IRB. The experimenter explained the memory task and then participants completed five practice trials before proceeding through the remaining 46 task trials. Experimenters remained in the room and transcribed audio responses on laptop computers. Audio responses were additionally recorded using an Olympus WS-210s voice recorder to allow for later analysis. Following the memory task, participants were given feedback about the task, completed neuropsychological tasks, and were debriefed as to the purpose of the study.

Words were presented serially at a rate of 1000 ms per word (after Bartha et al., 1998) with 32 ms between words. Timing and presentation were controlled using ePrime 2.0 software (Psychology Software Tools, Pittsburgh, PA). Stimuli appeared in black Courier New font on a silver background. Presentation of the 12 words was followed by a row of five green "X"s that served as the recall cue and remained the screen for the duration of the free recall. Participants were required to take a minimum of 30 seconds to freely recall the words aloud. Participants pressed the space bar to advance to the next set of words which began 1000 ms later.

Data analysis. In addition to the experimenter's in-room transcriptions, a second experimenter transcribed each audio file. A third coder resolved discrepancies between these transcriptions. Incorrect responses were classified as (1) *semantic:* associates listed in the USAF norms as related to the theme word or judged as related in meaning to the memory set by a trained coder, (2) *phonological:* related in sound to the theme word, (3) *within trial repeats*: the second instance of a correct or error response, (4) *between trial repeats:* items presented on one of the two previous trials, (5) *unrelated*: not related in meaning or sound to the theme, and (6) *non-words and mispronunciations* (see Atkins & Reuter-Lorenz, 2008 for similar scoring

procedures). Throughout the manuscript, degrees of freedom of the ANOVAs were corrected using the Geisser-Greenhouse method to adjust for violations of sphericity, resulting in non-integer values for the degrees of freedom and Tukey's HSD (Honestly Significant Difference) was used to ensure accurate pairwise comparisons.

Results

Total number of recalled words (combined correct and false)

A repeated measures ANOVA with condition (semantic, phonological) and sublist (A, B, C) entered as a within-subjects factor and age group (YA, OA) specified as a between-subjects factor indicated a significant main effect of age group ($F(1, 82) = 34.66$, $p < 0.001$, $\eta^2_p = 0.30$) such that YAs recalled overall a greater number of words as compared to OAs (see **Table 2** for numeric values). There was a significant main effect of condition ($F(1, 82) = 134.82$, $p < 0.001$, $\eta^2_p = 0.62$) showing that participants recalled a greater number of words in the semantic relative to the phonological condition. The main effect of sublist was also significant ($F(1.63, 133.56) = 297.56$, $p < 0.001$, $\eta^2_p = 0.79$). Participants recalled a greater number of words in Sublist A compared to Sublist B ($t(82) = 2.49$, $p = 0.04$); however, they recalled significantly fewer words in Sublist A compared to Sublist C ($t(82) = -16.55$, $p < 0.001$). Additionally, participants recalled significantly fewer words in Sublist B compared to Sublist C ($t(82) = -23.83$, $p < 0.001$). This analysis also revealed a significant interaction effect between age group and condition ($F(1, 82) = 35.97$, $p < 0.001$, $\eta^2_p = 0.31$). Both YA ($t(82) = -12.45$, $p < 0.001$) and OA ($t(82) = -3.97$, $p = 0.001$) participants reported a greater number of words in semantic compared to phonological trials, though the magnitude of this effect was stronger in YAs. None of the other effects—specifically, the interactions between age group and sublist, condition and sublist, nor the three-

way interaction between age group, condition, and sublist—reached statistical significance (all *p*-values > 0.05). See **Figure C1A** in **Appendix C** for an illustration of the data.

Table 2.

Total number of recalled words (correct and false combined; means with standard deviation in parentheses) split by age group, list type, sublist, and experiment.

		Experiment 1	
Semantic trials		Younger adults	Older adults
	A	2.32 *(0.59)*	1.53 *(0.69)*
	B	2.25 *(0.52)*	1.27 *(0.58)*
	C	3.46 (0.39)	2.85 *(0.91)*
Phonological trials			
	A	1.73 *(0.57)*	1.32 *(0.69)*
	B	1.73 *(0.40)*	1.22 *(0.53)*
	C	3.08 *(0.45)*	2.66 *(0.88)*
		Experiment 2	
Semantic trials			Older adults
	A	-	1.94 *(0.56)*
	B	-	1.14 *(0.45)*
	C	-	2.37 *(0.76)*
Phonological trials			
	A	-	1.47 *(0.54)*
	B	-	0.92 *(0.45)*
	C	-	2.23 *(0.66)*

Note. Only older adults were tested in Experiment 2.

Table 3.

Raw means of correct words and false memories recalled (standard deviation in parentheses) split by age group, list type, sublist, and experiment.

Experiment 1			
Correct responses			
Semantic trials		Younger adults	Older adults
	A	2.14 *(0.55)*	1.36 *(0.67)*
	B	1.98 *(0.51)*	1.15 *(0.57)*
	C	3.39 *(0.41)*	2.78 *(0.91)*
		Phonological trials	
	A	1.55 *(0.51)*	1.13 *(0.63)*
	B	1.56 *(0.36)*	1.05 *(0.49)*
	C	2.91 *(0.47)*	2.49 *(0.87)*
False memories			
Semantic trials		Younger adults	Older adults
	A	0.18 *(0.15)*	0.17 *(0.11)*
	B	0.17 *(0.12)*	0.12 *(0.10)*
	C	0.07 *(0.07)*	0.07 *(0.06)*
Phonological trials			
	A	0.17 *(0.14)*	0.19 *(0.14)*
	B	0.16 *(0.10)*	0.17 *(0.12)*
	C	0.17 *(0.11)*	0.17 *(0.10)*
Experiment 2			
Correct responses			
Semantic trials			Older adults
	A	-	1.77 *(0.57)*
	B	-	1.03 *(0.42)*
	C	-	2.29 *(0.75)*
Phonological trials			
	A	-	1.30 *(0.51)*
	B	-	0.82 *(0.39)*
	C	-	2.09 *(0.63)*
False memories			
Semantic trials			Older adults
	A	-	0.18 *(0.15)*
	B	-	0.11 *(0.08)*
	C	-	0.09 *(0.07)*
Phonological trials			
	A	-	0.18 *(0.11)*
	B	-	0.10 *(0.08)*
	C	-	0.14 *(0.10)*

Note. Only older adults were tested in Experiment 2.

Correct responses

To account for the overall differences in the total number of items recalled between YAs & OAs, we re-scored the number of correct responses as a proportion of total recalled items. This approach—commonly used when analyzing data across difference age groups (e.g., Khanna & Cortese, 2009; McGuire et al., 2015; Sugrue & Hayne, 2006)—enables us to remove age-related differences in overall recall rates. For completeness, we report raw descriptive statistics of the number of correct and false memory responses without this scoring correction in **Table 3**. Additionally, we computed and report serial position curves (Murdock, 1962) to examine the probability of correct responses as a function presentation position. These curves revealed a recency effect such that there was a greater probability to correct responses from the last list position relative to the first and middle lists (see **Figure 2**); this was replicated with statistical analyses (reported below).

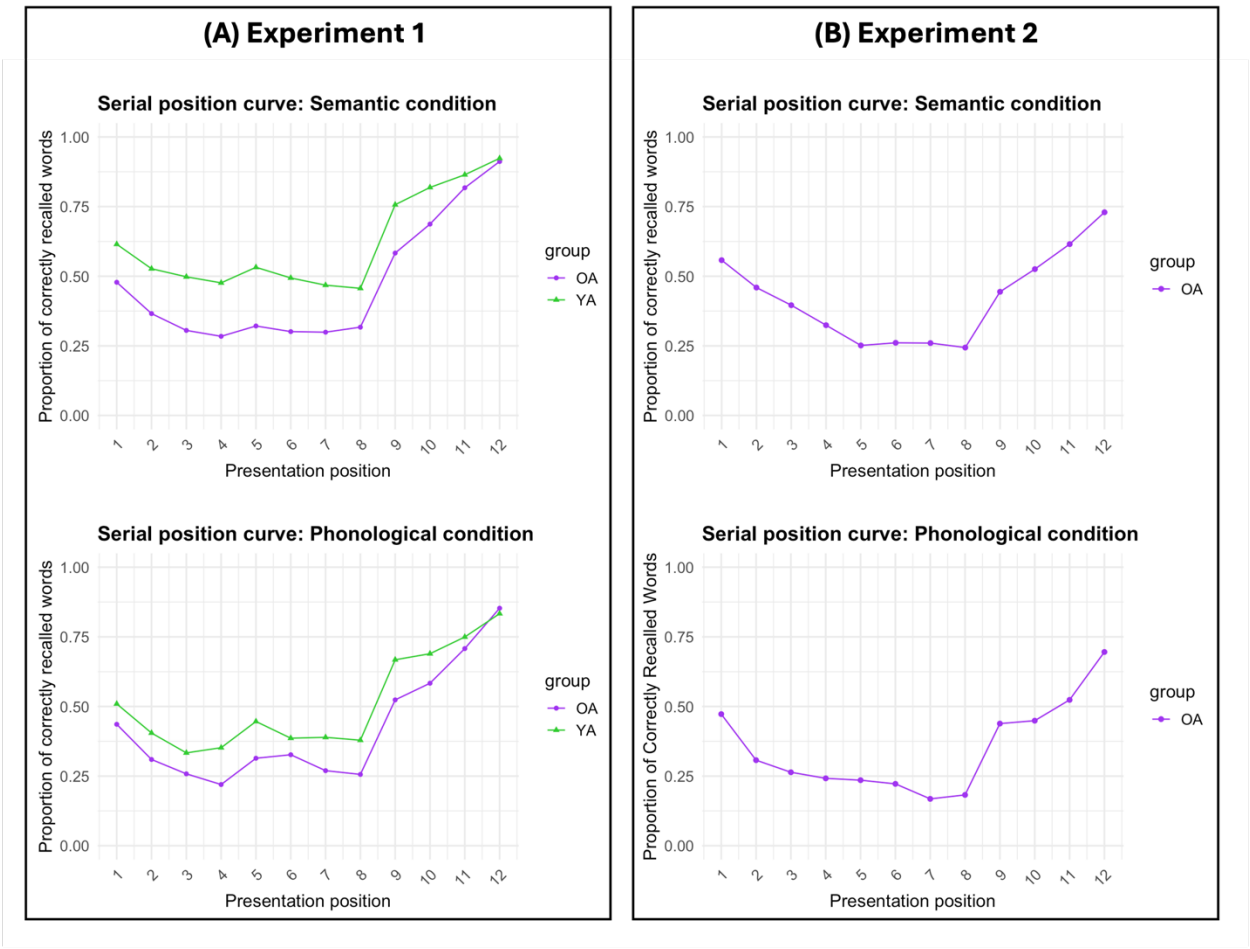

Figure 2. Serial position curves (correct responses) as a function of condition (semantic, phonological) for **(A)** Experiment 1 and **(B)** Experiment 2 (only older adults were tested in Experiment 2).

A repeated measures ANOVA was conducted with condition (semantic, phonological) and sublist (A, B, C) entered as within-subjects factors and age group (YA, OA) as a between-subjects factor. There was a significant main effect of age group ($F(1, 82)= 5.03$, $p = 0.028$, $\eta^2_p = 0.06$) such that YA reported a greater proportion of correct words relative to OA ($t(82) = -2.24$, $p = 0.03$). The main effect of condition was also significant ($F(1, 82) = 21.85$, $p < 0.001$, $\eta^2_p = 0.21$) such that there was a greater proportion of correctly recalled words in the semantic relative to the phonological condition ($t(82) = 4.67$, $p < 0.001$). Lastly, there was a significant main effect of sublist ($F(1.93, 158.26) = 69.62$, $p< 0.001$, $\eta^2_p = 0.46$) indicating significant differences

between sublists A and C ($t(82) = -9.86$, $p < 0.001$) and sublist B and C ($t(82) = -11$, $p < 0.001$) while no significant differences were found between sublists A and B ($t(82) = -0.55$, $p = 0.85$). That is, participants reported a greater proportion of correct words in sublist C relative to both sublists A and B. All other effects, notably including an interaction between condition, sublist, and age, did not reach the threshold for statical significance (all $p > 0.05$). See **Table 4** for descriptive statistics and **Figure C2A** in **Appendix C** for an illustration of the data. Thus, although we observed *numerically* greater memory for the earliest presented items in the list, we failed to find a statistically significant primacy effect.

Table 4.

Proportion of correct words recalled (standard deviation in parentheses) split by age group, list type, sublist, and experiment.

		Experiment 1	
Semantic trials		Younger adults	Older adults
	A	0.92 *(0.06)*	0.83 *(0.24)*
	B	0.92 *(0.05)*	0.85 *(0.25)*
	C	0.98 *(0.02)*	0.91 *(0.25)*
Phonological trials			
	A	0.90 *(0.07)*	0.81 *(0.23)*
	B	0.91 *(0.05)*	0.81 *(0.24)*
	C	0.94 *(0.04)*	0.87 *(0.25)*
		Experiment 2	
Semantic trials			Older adults
	A	-	0.90 *(0.08)*
	B	-	0.90 *(0.06)*
	C	-	0.96 *(0.03)*
Phonological trials			
	A	-	0.87 *(0.07)*
	B	-	0.89 *(0.09)*
	C	-	0.94 *(0.04)*

Note. Only older adults were tested in Experiment 2.

False memories

A repeated measures ANOVA was conducted with condition (semantic, phonological) and sublist (A, B, C) entered as within-subjects factors and age group (YA, OA) entered as the between-subjects factor. This analysis revealed a significant main effect of group ($F(1, 82) = 5.03$, $p = 0.03$, $\eta^2_p = 0.06$) such that, on average, OAs had an increased proportion of false memories as compared to YAs ($t(82) = 2.24$, $p = 0.03$). There was a significant main effect of condition ($F(1, 82) = 21.85$, $p < 0.001$) indicating an overall greater proportion of false memories in the phonological relative to the semantic condition ($t(82) = -4.67$, $p < 0.001$). There was a significant main effect of sublist ($F(1.93, 158.26) = 69.62$, $p < 0.001$, $\eta^2_p = 0.46$), establishing significant differences between sublist A and sublist C ($t(82) = 9.86$, $p < 0.001$), as well as between sublist B and sublist C ($t(82) = 11$, $p < 0.001$). Both sublists A and B showed higher proportions of false memories compared to sublist C. No other significant effects were found, notably including with age (all $p > 0.05$). See **Table 5** for descriptive statistics and **Figure 3A** for an illustration of the data.

Table 5.

Proportion of false memories (standard deviation in parentheses) split by age group, list type, sublist, and experiment.

		Experiment 1	
Semantic trials		Younger adults	Older adults
	A	0.08 *(0.06)*	0.17 *(0.24)*
	B	0.08 *(0.05)*	0.15 *(0.25)*
	C	0.02 *(0.02)*	0.09 *(0.25)*
Phonological trials			
	A	0.10 *(0.07)*	0.19 *(0.23)*
	B	0.09 *(0.05)*	0.19 *(0.24)*
	C	0.06 *(0.04)*	0.13 *(0.25)*
		Experiment 2	
Semantic trials			Older adults
	A	-	0.10 *(0.08)*
	B	-	0.09 *(0.06)*
	C	-	0.04 *(0.03)*
Phonological trials			
	A	-	0.13 *(0.07)*
	B	-	0.11 *(0.09)*
	C	-	0.06 *(0.04)*

Note. Only older adults were tested in Experiment 2.

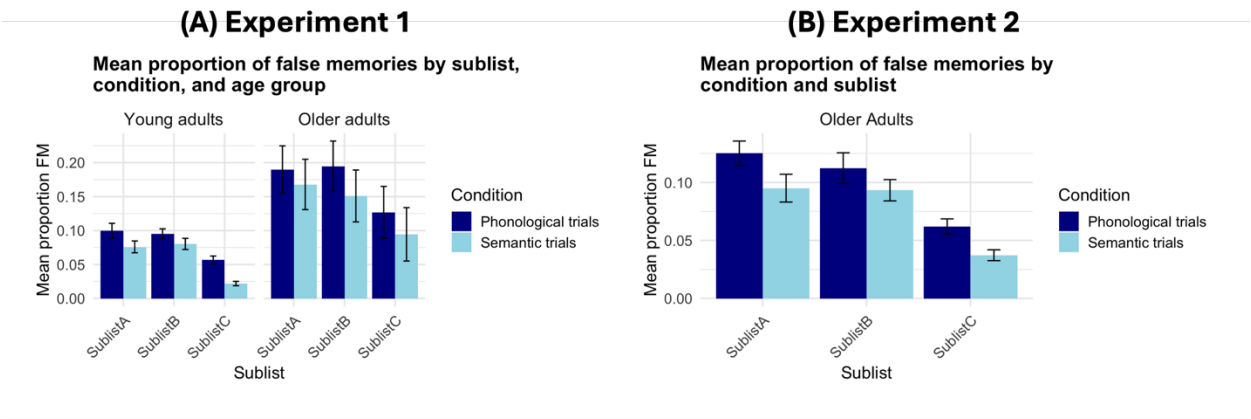

Figure 3. (A) Average proportions of false memories recalled as a function of age group (YA, OA), condition (semantic, phonological), and sublist (A, B, C). **(B)** Average proportions of false memories recalled as a function of condition (semantic, phonological), and sublist (A, B, C). In the semantic condition, false memories refer to semantic false memories, while in the phonological condition, they refer to phonological false memories. Only older adults were tested in Experiment 2. Error bars indicate standard error of the mean.

Interim summary 1

In Experiment 1, we examined performance on an adapted version of the DRM paradigm, focusing on the effects of list type (semantic vs. phonological) and sublist position (A, B, C) between age groups (YAs and OAs). Our findings revealed several key patterns across both age groups: All participants, irrespective of age, recalled a higher proportion of correct words in the semantic condition compared to the phonological condition, with this effect being more pronounced in YAs. A recency effect was also observed, as all participants recalled a higher proportion of correct words from sublist C, regardless of age or condition. Furthermore, all participants generated a lower proportion of false memories from sublist C, suggesting that verbatim traces may have been more robust and thus better able to counteract gist traces from this most recent sublist (Brainerd & Reyna, 2002; Reyna & Brainerd, 1995).

Interestingly, and in violation of our *a priori* hypothesis, both groups exhibited similar patterns of false memory production. That is, despite OAs remembering fewer items overall relative to YAs, all participants generated a higher proportion of false memories in the phonological relative to the semantic condition and had similar distributions of false memories across the sublists (fewest false memories from the most recent C sublist than either sublist A or B). This finding contradicts the prediction that OAs would be more prone to phonological errors, especially from the most recent C sublist, as compared to YAs, and suggests that false memory production is similar across age groups.

Our findings also challenge the view that the nature of false memories is strictly tied to a specific memory store, suggesting instead that the types of false memories generated are more closely related to the properties of the studied lists. To further investigate whether the surprising finding of comparable performance observed in OAs and YAs was influenced by the multimodal

presentation of stimuli (i.e., both visual and auditory), we conducted Experiment 2, focusing solely on OAs in which we presented words visually only. If the enhanced encoding from the multimodal presentation in Experiment 1 masked age-related differences, we expected that removing auditory cues would reduce memory performance in OAs.

Experiment 2

Methods

Participants. A sample of 47 healthy, community dwelling seniors (aged 59 and up) were recruited from the Greater Boston area and compensated at a rate with cash ($5/half hour) for their participation. Three participants were excluded: 2 participants were excluded for having an MMSE score less than 28 and 1 participant was excluded due to errors during data collection. Results presented below are from the remaining 44 older participants (26 = female; $Mean_{age}$= 72.5 years, SD_{age}= 7.11 years; see **Table 1** for neurological assessment data).

Materials. All materials were identical to those used in Experiment 1.

Procedures. All procedures were identical to those in Experiment 1, with the exception that stimuli were presented visually only, rather than presented both visually and auditorily.

Data analysis. All analyses were identical to those in Experiment 1.

Results

Total number of recalled words (combined correct and false)

A repeated measures ANOVA with condition (semantic, phonological) and sublist (A, B, C) entered as within-subjects factors was conducted on the overall number of words recalled, regardless of correct or FM status. This analysis revealed, first, a significant main effect of condition ($F(1, 43) = 105.33$, $p < 0.001$, $\eta^2_p = 0.7$) showing that participants recalled on average a greater number of words in the semantic relative to the phonological condition ($t(43) = 10.26$, p

< 0.001). Second, there was a significant main effect of sublist (F(1.37, 58.80) = 59.13, p < 0.001, η^2_p = 0.58). Pairwise comparisons indicated that participants recalled significantly more words in Sublist A compared to Sublist B (t(43) = 7.29, p < 0.001). Conversely, they recalled significantly fewer words in Sublist A compared to Sublist C (t(43) = -3.90, p < 0.001). Additionally, they recalled significantly fewer words in Sublist B as compared to Sublist C (t(43) = -13.12, p < 0.001). Lastly, this analysis revealed a significant interaction effect between condition and sublist (F(1.96, 84.15) = 7.39, p < 0.001, η^2_p = 0.15). Pairwise comparisons indicated that within all three sublists (A: t(43) = 7.32, p < 0.001; B: t(43) 3.81, p < 0.001; C: t(43) = 2.68, p = 0.01), participants recalled more words in the semantic relative to the phonological condition. See **Table 2** for detailed descriptive statistics and **Figure C1B** in **Appendix C** for an illustration of the data.

Correct responses

A repeated measures ANOVA with condition (semantic, phonological) and sublist (A, B, C) specified as within-subjects factors was conducted. While the interaction between the factors was not significant (F(1.66, 71.34) = 0.26, p = 0.73, η^2_p = 0.01), the analysis revealed a significant main effect of condition (F(1, 43) = 16.23, p < 0.001, η^2_p = 0.27). Participants recalled a greater proportion of correct words in the semantic relative to the phonological condition (t(43) = 4.03, p < 0.001). Additionally, the main effect of sublist (F(1, 98, 85.04) = 26.18, p <0.001, η^2_p = 0.38) was significant. While there was no significant difference in the proportion of correctly recalled words between sublist A and B (t(43) = -0.77, p = 0.73), participants recalled a significant lower proportion of correct words in sublist A relative to sublist C (t(43) = -6.94, p < 0.001) as well as a significantly lower proportion of correct words in sublist

B relative to sublist C ($t(43) = -5.85$, $p < 0.001$). See **Table 6** for descriptive statistics and **C2B** for an illustration of the data.

False memories

A repeated measures ANOVA with condition (semantic, phonological) and sublist (A, B, C) entered as within-subjects factors was conducted. This analysis revealed a main effect of condition ($F(1, 43) = 16.23$, $p < 0.001$, $\eta^2_p = 0.27$) such that participants reported a greater proportion of false memories in the phonological relative to the semantic condition ($t(43) = -4.03$, $p < 0.05$). The main effect of sublist was also significant ($F(1.98, 85.04) = 26.18$, $p < 0.001$, $\eta^2_p = 0.38$). Pairwise comparisons showed that while there was no significant difference in the proportion of false memories between sublists A and B ($t(43)$ 0.77, $p = 0.73$), sublist C had a significantly lower proportion of false memories compared to both sublists A ($t(43) = 6.94$, $p < .001$) and B ($t(43) = 5.85$, $p < .001$). Lastly, the interaction between the factors was not significant ($F(1.66, 71.34) = 0.26$, $p = 0.81$, $\eta^2_p = 0.01$). See **Table 5** for detailed descriptive statistics and **Figure 3B** for an illustration of the data.

Interim summary 2:

In Experiment 2, we focused our investigation solely on OAs and replicated key findings from Experiment 1: First, OAs recalled a higher proportion of correct words in the semantic condition compared to the phonological condition, mirroring the pattern observed in Experiment 1. A recency effect was also evident, as in Experiment 1, with OAs recalling a higher proportion of correct words from sublist C. When analyzing false memory production, OAs generated a higher proportion of phonological false memories compared to semantic false memories. Additionally, a higher proportion of false memories were observed from sublist A relative to sublist C, complementing the finding that more items were correctly recalled from the end of the

presented lists supporting the recency effect seen in correct recall, and from sublist B relative to sublist C; however, there was no interaction between the types of false memories generated and list position.

However, one notable pattern across the two experiments was that OAs exhibited numerically higher performance (i.e., increased accurate recall) in Experiment 2 than in Experiment 1. Although there were some demographic differences between the samples—e.g., OAs in Experiment 1 were somewhat older than those in Experiment 2—these are unlikely to fully account for the observed differences in recall performance. Instead, it appears that the bimodal (i.e., simultaneous auditory and visual) presentation format used in Experiment 1 may have been unexpectedly detrimental for OAs. While prior research suggests that multimodal presentation of information can enhance task performance in older adults (for a review, see De Dieuleveult et al., 2017), it is possible that the bimodal presentation in this case introduced additional processing demands that negatively affected OA performance on our task. Nevertheless, the patterns observed in Experiment 2 were largely consistent with those found in Experiment 1. This aligns with other research showing that presenting visual stimuli, with or without auditory input, results in similar effects on learning and memory recall in healthy older adults (Constantinidou & Baker, 2002).

Discussion

This study examined the role of putative short- and long-term memory systems in the generation of false memories, focusing on how age-related changes to these processes can inform our understanding of the nature of false memories produced. Using a modified version of the DRM paradigm (see Dimsdale-Zucker et al., 2018), we tested the idea that certain list positions might be associated with an overrepresentation of specific types of false memories (semantic vs.

phonological). We addressed this question in a healthy OA sample to examine how age-related changes in mnemonic processing and reliance on and access to verbatim versus gist traces might influence the generation and nature of false memories. Our findings revealed both age-related differences as well as surprisingly shared patterns of memory performance: While OAs remembered fewer items overall, as well as fewer studied items compared to YAs, the pattern of false memories generated was strikingly similar across age groups. Notably, both OAs and YAs were more likely to generate phonological rather than semantic false memories and the relative rate of these errors did not interact with sublist position or age. We found a largely similar pattern of results in Experiment 2 in an exclusively OA sample when we restricted presentation of items to written format only, removing the potential additional support of the bimodal presentation used in Experiment 1. Once again, OAs generated a greater number of phonological as compared to semantic false memories, irrespective of list position. Critically, we also failed to find an interaction between sublist and list type, suggesting that semantic and phonological false memories can arise from all list positions. Altogether, our findings suggest that the nature of false memories is not, as the traditional view suggests, tied to the memory store from which they originate, but, instead, may be related to properties of the studied items in a list. This has important theoretical implications, challenging prevailing assumptions about the role of memory systems in the generation of false memories and underscoring the need to reconsider the mechanisms underlying false memories.

Given the striking age group similarities in the types of false memories and the sublist from which they originated, it is important to explore the factors that may have contributed to the generation of these false memories. One idea, posited by Fuzzy Trace Theory (FTT; Brainerd & Reyna, 2002; Reyna & Brainerd, 1995), suggests that information is simultaneously stored as

both a verbatim and a gist representation. The verbatim representation captures specific surface-level details of encoded information while the gist representation captures the general meaning and semantic content of the encoded information. For veridical memory, both the verbatim and gist representations are strong, facilitating accurate recall. However, as verbatim traces decay over time, individuals are thought to rely increasingly on gist representations, which, while more durable, are also more prone to errors, and, consequently, may contribute to the generation of false memories. In our data, both YAs and OAs exhibited more veridical memories for the most recent as compared to the first sublist. This is consistent with FTT's prediction that verbatim traces are stronger for recently presented items, thereby supporting more accurate recall.

However, another prediction that extends on FTT is that semantic false memories should be more frequent for items presented at the beginning of a list, as these items are likely supported by gist representations, which are more prone to distortions related to broader semantic content (Craik & Levy, 1970). In contrast, phonological false memories should be more frequent for items presented at the end of the list, where the verbatim representation, particularly of fragile surface-level information such as acoustic or phonological details, is strongest (Craik, 1968). In lists that maximized the opportunity to form either semantic or phonological representations of studied items, we found that both semantic and phonological false memories could be generated from all list positions. Thus, the absence of an interaction between list type (semantic, phonological) and sublist position in the current study suggests that the differences in the nature of false memories (i.e., semantic vs. phonological) may not be solely attributable to differential reliance on putative short-term versus long-term memory stores during recall. Instead, other cognitive factors that operate across all sublist positions may play a role in the generation of false memories.

One such factor that may be position-invariant is source monitoring—i.e., the ability to accurately recall the context in which information was first learned (Johnson et al., 1993). Source monitoring is crucial for distinguishing between different memory sources, such as differentiating between information learned from a list of words and information generated internally (e.g., recognizing that you saw the word '*cat*' on a list, rather than having thought of the word *'cat'* after seeing the word *'bat'* on the list). These source monitoring operations seem to be supported in large part by the prefrontal cortex (Johnson et al., 1993; Mitchell & Johnson, 2009). Research with YAs has shown increased activity in prefrontal cortical regions in the short-term memory variant of the DRM paradigm (Atkins & Reuter-Lorenz, 2011), further suggesting these regions may play an important role in mitigating false memory generation.

Although both age groups likely used source monitoring to adjudicate studied from falsely recalled items, OAs demonstrate known deficits in source monitoring (Chalfonte & Johnson, 1996; Dehon & Brédart, 2004; Hashtroudi et al., 1989; Johnson et al., 1993; Mitchell et al., 2003; Mitchell & Johnson, 2009; Spencer & Raz, 1995) likely due to both structural and functional changes in frontal and core memory regions (Fjell et al., 2013; Salat et al., 2004). To address potential concerns regarding age-related declines in executive control, we assessed our OA participants using a battery of standardized neuropsychological measures (see **Table 1**), allowing us to at least partially mitigate concerns about deteriorations in executive control processing. Nevertheless, cognitive deficits in aging are multifactorial in nature and may reflect a complex interplay of factors beyond what our tests may have captured. For instance, the overall poorer memory performance in OAs may also be related to age-related impairments in memory discrimination (Korkki et al., 2020; Leal & Yassa, 2014; Stark et al., 2013), inhibitory control (Hasher et al., 1999), and working memory deficits (Babcock & Salthouse, 1990; D'Esposito &

Postle, 2015; Grady et al., 2006; Mattay et al., 2006). Relative to YAs, OAs exhibit greater difficulty in discriminating between externally and internally generated information (i.e., identifying whether a word was heard or thought about; Hashtroudi et al., 1989). Age-related deficits in source monitoring are particularly pronounced when the information being judged is highly similar. For instance, OAs struggle to accurately identify which of two speakers spoke, especially when the speakers are similar, such as in the case of two female voices (Ferguson et al., 1992). Other work shows that increased overlap in the features of the judged information or items interferes with the ability to distinguish between memory sources (Henkel et al., 1998). In the present study, both the semantic and phonological conditions were designed to induce false memories through the presentation of similar items, either conceptually related in the semantic condition or acoustically similar in the phonological condition. Importantly, our findings suggest that these mechanisms are unlikely to operate differently for semantic versus phonological false memories, indicating that shared cognitive processes contribute to both types of memory errors.

The Activation-Monitoring Framework (AMF; Roediger et al., 2001) provides another possible parsimonious theoretical explanation for our findings (for a detailed discussion, see Chang & Brainerd, 2021). The AMF suggests that words may be connected by properties such as semantic or lexical networks as well as other properties such as acoustic or phonological features (Roediger et al., 2001). Accordingly, false memories arise through the automatic activation of related concepts, alongside source monitoring errors that lead individuals to misattribute the source of their memories[1]. This framework underscores how memory retrieval can be influenced by semantic associations and prior knowledge (Gallo & Roediger, 2003), as well as phonological

[1] Of note, these types of source monitoring errors are thought to stem from recollection-based processes—such as recall-to-reject and the distinctiveness heuristic (Gallo et al., 2006)–rather than from general executive control mechanisms as described by Johnson et al., (1993). However, the design of the present study was not intended to directly test the influence of these specific monitoring processes.

similarity (Baddeley, 1964; Conrad, 1963; Wickelgren, 1965). Collins & Loftus (1975) demonstrated that semantic false memories emerge through spreading activation within semantic lexical networks, leading to the intrusion of semantically related but incorrect memories. Similarly, phonological similarity can lead to false memories by creating interference during recall, as demonstrated by Marmurek et al. (2006), who report that phonological false memories arise through misattributions based on acoustic similarity. Taken together, our findings emphasize that false memories, whether semantic or phonological, emerge from shared processes. More broadly, this work provides a more integrated understanding of false memories and highlights the importance of considering both phonological and semantic influences on memory retrieval within a unified theoretical framework of false memory.

Another possibility that could help to understand the group-level differences in the overall level of false memories are the differences observed in veridical memory rates. That is, verbatim traces can play a dual role by both supporting veridical memory, but also counteracting gist-based traces that can support false memories (Brainerd & Reyna, 2002; Reyna & Brainerd, 1995). In Experiment 1, we observed a significant main effect of age group on both correct responses *and* false memories. Although these age group effects did not interact with list type or sublist position, it does still raise the possibility that the differences observed in false memories could be explained by the differences in veridical memory performance. Furthermore, this relative increase in the proportion of responses that were false memories was also driven in part by lower recall of items overall in OAs (both veridical and false memories) compared to their younger counterparts. This aligns with previous findings that have reported overall reduced episodic memory even in cognitively healthy OAs (Brickman & Stern, 2009; Craik & Salthouse, 2011; Rönnlund et al., 2005). When focusing on correctly recalled items, OAs also recalled a

lower proportion of correct items than YAs, consistent with prior research using the DRM paradigm in aging samples (Balota et al., 1999; Budson et al., 2003; Dehon, 2020; Dennis et al., 2007; Norman & Schacter, 1997; Tun et al., 1998). Although we tried to mitigate the impact of these group-level output differences by using proportion scoring (Khanna & Cortese, 2009; McGuire et al., 2015; Sugrue & Hayne, 2006), it could still be that differences in overall levels of false memories between age groups can at least be partially explained by differences in verbatim traces and concomitant veridical memory (c.f., Atkins & Reuter-Lorenz, 2008).

Importantly, even when using a proportion scoring to account for age-related differences in total output, there were no significant interactions between age and false memories with sublist position. Instead, we saw striking commonalities: Both YAs and OAs made more false memories in the phonological relative to the semantic condition and were more likely to make false memories from the A and B than C sublist. These findings challenge the hypothesis that OAs are more prone to semantic errors as compared to YAs due to their presumed reliance on gist-based memory traces (Abadie & Camos, 2019; Brainerd et al., 2008; Grilli & Sheldon, 2022; Schacter et al., 1997). Instead, our findings suggest that false memory generation may be more influenced by factors such as the properties of the studied list rather than age-related memory alterations.

Other work outside of the domain of aging also suggests that list similarity is an important factor for the generation of false memories (for an in-depth review, see Coane et al., 2021). For example, studies have shown that manipulating associative strength—the degree to which words co-occur in language—can strongly induce false memories (Kumar, 2021). In this case, similarity is based on conceptual links between words (e.g., '*cat',* '*dog'*, and '*bird'* have a high associative strength because they are all domestic animals). Another factor is categorical

similarity which refers to the degree to which items belong to the same category (e.g., '*apple'*, '*banana'*, and '*orange'* all belong to the category of fruits; Buchanan et al., 1999). Further studies have explored orthographic or phonological similarity, finding that false memories can also be induced when words share similar spelling or pronunciation. For instance, Sommers and Lewis (1999) presented participants with 15-item lists and found that lists containing words with greater phonological similarity (e.g., '*fat'*, '*that'*, '*cab'* for the word '*cat'*) led to more false memories. This effect was attenuated when phonological similarity was reduced (e.g., '*can'*, '*coat'*, '*scat'*, '*cash'* for the word '*cat'*).

The work reported here adds to this literature by demonstrating that list characteristics can fundamentally shape memory errors and the generation of false memories, irrespective of age. Most critically, our data shows that, when items are presented in a way that encourages phonological errors, both YAs and OAs are equally susceptible to these types of memory distortions. This finding builds upon previous research by Dimsdale-Zucker (2018), who demonstrated that phonological errors can occur at all list positions. Importantly, the current study extends this work by showing that this effect occurs within the same participants, across age groups, and under the same study conditions.

Another important feature of the list characteristics in the paradigm used here is the combination of a long, supra-span list—typically used to isolate memory representations from separate short- and long-term memory stores (Murdock, 1962)—with nested sublists that allow for more precise tagging of early, middle, and late study positions (adapted from Dimsdale-Zucker, et al., 2018). One goal of this list organization was to look at the relative predominance of both veridical and false memories from different list positions. Elevated memory for more recent items, the recency effect, has traditionally been interpreted as relying on short-term

memory stores (Murdock 1962). In our study, we observed a recency effect across both age groups, as YAs and OAs recalled a greater proportion of correct words from the end of studied lists (sublist C) compared to words from the beginning (sublist A) or middle (sublist B) positions, aligning with prior research showing a recency effect (Deese & Kaufman, 1957; Glanzer & Cunitz, 1966; Howard et al., 2006; Murdock, 1962). The reported recency effect has significant implications for our understanding of the temporal dynamics of memory retrieval. The presence of a recency effect in both age groups suggests that more recently encountered information remains more accessible, possibly due to reduced interference or decay compared to items encountered at longer delays (Glanzer & Cunitz, 1966; Murdock, 1962). Additionally, the reported recency effect was complemented by the finding that the proportion of false memories was lowest for items presented at the end of the list. (sublist C), in comparison to those from the beginning (sublist A) or middle (sublist B) positions. These results suggest that recent items are not only more accurately recalled but also less likely to result in false memories, possibly because they are stored as more accessible verbatim traces, minimizing effects of interference and decay. This pattern indicates that the cognitive mechanisms underlying the recency effect remain functional across both age groups, despite the age-related differences in overall memory performance. In other words, even though OAs may experience declines in memory abilities, such as recalling fewer total items, their ability to exhibit the recency effect to the same degree as YAs indicates that the specific memory processes underlying this phenomenon remain relatively intact across the lifespan.

From a theoretical perspective, our findings challenge the traditional notion that semantic and phonological false memories emerge from distinct memory stores and exert differential effects on the recency and primacy effects (Craik, 1968; Craik & Levy, 1970). Classically,

semantic and phonological false memories have been understood as arising from separate memory stores—semantic false memories being attributed to the activation of related meanings or concepts stored in long-term memory, and phonological false memories to the activation of similar-sounding words or phonetic features stored in short-term memory. Our results suggest that semantic and phonological false memories do not differentially arise from putative short- and long-term memory stores. By this token, our findings imply that the cognitive mechanisms responsible for false memories might be more similar across these two types of memory systems than previously thought. That is, both semantic and phonological false memories may arise through common underlying cognitive processes, including the activation of related concepts and the misattribution of source information. This challenges the traditional dual-store perspective of memory (Atkinson & Shiffrin, 1968; Glanzer & Cunitz, 1966) and aligns more closely with the idea that memory is a fluid and interconnected system, where different types of information (e.g., phonological and semantic) are not processed or stored in isolation across different memory systems but rather coexist in a unified memory store (Jonides et al., 2008; Nairne, 2002); however see Forsberg et al., 2025 for recent evidence suggesting an alternative perspective.

In conclusion, this study provides important insights into the nature of false memory generation across the lifespan. Our findings demonstrate that while OAs exhibit overall declines in veridical episodic memory performance and an increased susceptibility to false memories, their relative propensity to generate semantic versus phonological false memories based on list properties and list context remains similar to that of YAs. These findings challenge the notion that semantic and phonological false memories operate via entirely separate storage mechanisms and support the idea that common underlying cognitive processes drive these distortions.

Data availability statement: The data and analysis scripts that support the findings of this study are available on https://github.com/dzmemoryandcontextlab/FMOA.git.

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Appendix A. The forty-six possible study lists used in Experiments 1 & 2

buy-forever-nose	snake-blood-flash	sweet-doctor-pitch
bread-dirt-funny	whiskey-baby-handle	rough-morning-draw
church-man-urge	chain-vote-lesson	fog-basement-shake
finish-girl-process	beautiful-sleep-heaven	long-sneeze-train
site-boring-teeth	sheet-job-chair	rent-dance-fail
logic-sink-horse	high-math-dense	pen-annoy-hydrogen
shirt-broom-whole	hold-thief-boom	waiter-muscle-trash
window-give-impact	chaos-smart-height	slow-butterfly-justice
clam-fruit-data	smell-present-fence	king-bee-mine
focus-many-alone	back-roof-city	building-square-decrease
admission-ring-river	trip-basket-argue	marry-shovel-plain
soap-pig-nut	scale-fate-lie	army-dry-speaker
gas-piano-opinion	act-corn-hawk	atom-stress-hint
adult-anger-needle	black-cold-again	cheese-flag-lose
rain-mix-plaster	answer-letter-carpet	pan-bake-cabbage
rock-movie-saloon		

Appendix B. The 138 theme words in alphabetical order and their possible phonological and semantic associates used in Experiments 1 & 2

Theme	Phonological associates	Semantic associates
act	tract, tact, pact, enact	drama, pretend, portray, perform
admission	mission, nutrition, audition, condition	ticket, enter, in, school
adult	result, consult, insult, fault	grown, mature, responsible, kid
again	remain, detain, sustain, obtain	twice, never, stop, repeat
alone	prone, clone, lone, zone	solo, isolated, lonely, one
anger	stranger, linger, danger, finger	fury, enrage, rage, mad
annoy	soy, deploy, joy, employ	irritate, bother, aggravate, disturb
answer	sweater, center, setter, better	stamp, mail, mailbox, envelope
argue	value, revenue, rescue, pursue	complain, debate, disagree, agree
army	calmly, smarmy, fondly, darkly	soldier, navy, marines, infantry
atom	awesome, custom, bottom, blossom	neutron, molecule, proton, nucleus
baby	maybe, flabby, lobby, hubby	crib, diaper, carriage, infant
back	plaque, crack, track, quack	front, spine, behind, forward
bake	lake, mistake, fake, brake	oven, cook, broil, cake
basement	department, experiment, confident, element	underground, attic, downstairs, cellar
basket	jacket, ticket, cricket, picket	laundry, waste, wicker, picnic
beautiful	careful, hopeful, plentiful, dutiful	gorgeous, ugly, pretty, lovely
bee	three, free, flee, see	reign, queen, crown, throne
black	snack, slack, track, smack	gray, white, coal, brown
blood	bud, thud, spud, flood	vampire, vein, donor, plasma
boom	zoom, fume, assume, consume	bomb, sonic, bang, explosion
boring	soaring, scoring, wearing, roaring	dull, lecture, interesting, exciting
bread	head, pled, tread, read	rye, butter, toast, loaf
broom	plume, room, bloom, resume	mop, sweep, dustpan, witch
building	ending, finding, holding, forbidding	structure, construction, empire, blocks
butterfly	multiply, ally, apply, supply	moth, cocoon, insect, wing
buy	why, bye, guy, sly	sell, store, purchase, spend
cabbage	voyage, foliage, package, village	sauerkraut, patch, slaw, lettuce
carpet	cabinet, summit, planet, helmet	red, floor, magic, rug
chain	cane, contain, pain, brain	whip, bicycle, necklace, link
chair	pair, lair, fair, stair	table, swivel, rocking, recliner
chaos	moss, cross, toss, floss	hectic, havoc, confusion, anarchy
cheese	these, breeze, tease, please	swiss, cheddar, mouse, cracker
church	purge, surge, scourge, merge	preacher, cathedral, steeple, temple
city	witty, bitty, pity, ditty	urban, suburb, town, metropolis
clam	swam, cram, glam, exam	mussel, chowder, shell, oyster
cold	fold, sold, bold, old	hot, shiver, artic, frigid
corn	born, worn, torn, adorn	husk, field, flake, cob
dance	glance, advance, enhance, chance	song, ballet, aerobics, ballerina
data	debater, later, beta, crater	analysis, computer, information, entry
decrease	niece, fleece, cease, crease	lower, reduce, less, increase
dense	dispense, hence, defense, commence	thick, stupid, forest, dumb
dirt	divert, alert, flirt, hurt	grime, soil, filth, mud
doctor	roster, lobster, proctor, blotter	stethoscope, nurse, physician, surgeon
draw	thaw, jaw, claw, flaw	crayon, scribble, sketch, paint
dry	pry, fly, deny, cry	moist, thirst, desert, towel
fail	nail, rail, sail, bail	pass, succeed, try, flunk
fate	hate, late, bate, mate	luck, death, destiny, life

fence	suspense, whence, intense, immense	yard, wire, gate, barrier
finish	diminish, nourish, flourish, tarnish	end, done, complete, start
flag	tag, lag, rag, bag	pole, stripes, checkered, banner
flash	cash, ash, bash, clash	light, lightning, bright, camera
focus	bonus, locus, crocus, caucus	attention, concentrate, blur, lens
fog	frog, clog, bog, dog	mist, smog, haze, unclear
forever	clever, server, lever, endeavor	eternity, always, endless, infinity
fruit	cute, mute, suit, commute	citrus, pear, berry, kiwi
funny	money, puny, runny, sunny	comedian, humor, hilarious, clown
gas	mass, amass, class, brass	oil, fuel, station, petroleum
girl	twirl, hurl, swirl, whirl	dress, dolls, female, boy
give	live, active, elective, olive	take, generous, charity, share
handle	candle, vandal, sandal, scandal	suitcase, care, door, drop
hawk	walk, stalk, chalk, squawk	bird, eagle, dove, prey
heaven	eleven, leaven, heathen, seven	angel, hell, god, earth
height	fight, right, night, tight	intelligent, wise, knowledge, genius
high	rely, sigh, defy, why	jump, elevate, tower, low
hint	tint, lint, mint, quint	guess, suggestion, clue, secret
hold	told, gold, scold, mould	grip, grasp, keep, carry
horse	source, endorse, enforce, concourse	gallop, saddle, pony, colt
hydrogen	conclusion, burgeon, region, occasion	write, pencil, marker, quill
impact	compact, contact, exact, abstract	hit, crash, car, curtain
job	blob, knob, mob, snob	occupation, career, task, employment
justice	armistice, solstice, service, practice	courts, truth, lawyer, liberty
king	sing, ding, fling, bring	sting, bumble, buzz, hive
lesson	parson, lessen, fasten, listen	teacher, teach, learn, school
letter	dancer, romancer, prancer, enhancer	reply, solution, question, response
lie	pie, dye, tie, ply	untruthful, dishonest, fib, deception
logic	tragic, optic, allergic, garlic	thought, reason, sense, philosophy
long	strong, gong, wrong, throng	far, short, distance, hair
lose	confuse, choose, cruise, accuse	gain, find, defeat, win
man	tan, van, fan, can	handsome, make, lady, woman
many	granny, zany, nanny, penny	few, plenty, several, much
marry	tarry, ferry, wary, starry	engage, hitch, wed, single
math	heath, hath, bath, path	equation, algebra, arithmetic, calculus
mine	line, nine, wine, fine	yours, selfish, possession, me
mix	affix, fix, six, nix	blend, stir, integrate, combine
morning	charming, disarming, dawning, lining	early, dawn, dew, evening
movie	gravy, savvy, wavy, groovy	popcorn, film, theater, cinema
muscle	hassle, castle, rustle, tassel	strength, weights, tone, flex
needle	paddle, betle, meddle, handle	thread, injection, syringe, haystack
nose	rose, pose, chose, prose	face, throat, ear, big
nut	strut, hut, gut, cut	squirrel, almond, pecan, cashew
opinion	onion, minion, dominion, pavilion	fact, choice, bias, view
pan	an, ran, lifespan, ban	pot, fry, skillet, dish
pen	ten, hen, when, then	air, helium, peroxide, oxygen
piano	rhino, soprano, domino, volcano	organ, keyboard, ivory, guitar
pig	rig, jig, gig, fig	sty, hog, sow, pork
pitch	rich, which, ditch, itch	catch, throw, ball, baseball
plain	sprain, crane, sane, grain	ordinary, plaid, simple, fancy
plaster	pastor, blaster, master, caster	wall, concrete, cement, cast
present	lenient, absorbent, rodent, omniscient	past, future, absent, gift
process	compress, profess, progress, address	way, elimination, procedure, system

rain	vain, pain, main, wane	hail, storm, umbrella, puddle
rent	dent, extent, bent, sent	own, lease, apartment, monthly
ring	thing, cling, swing, spring	bell, diamond, jewelry, phone
river	sliver, driver, giver, quiver	bridge, stream, creek, flow
rock	block, smock, lock, clock	stone, solid, boulder, roll
roof	aloof, spoof, proof, goof	shingle, tin, tar, ceiling
rough	enough, fluff, stuff, gruff	tough, coarse, smooth, sandpaper
saloon	cartoon, baboon, lagoon, balloon	beer, drink, cowboy, bar
scale	ale, pale, stale, whale	pound, balance, weigh, measure
shake	quake, wake, opaque, steak	hands, vanilla, wiggle, milk
sheet	seat, cheat, sleet, meet	pillow, paper, blanket, cover
shirt	assert, squirt, overt, insert	bouse, sleeves, collar, shorts
shovel	gavel, marvel, level, bevel	dig, spade, rake, pail
sink	pink, blink, kink, think	drain, float, faucet, bathroom
site	quite, polite, unite, kite	area, place, camp, location
sleep	leap, steep, bleep, heap	bed, nap, awake, doze
slow	glow, grow, crow, blow	turtle, fast, snail, sluggish
smart	tart, cart, heart, dart	tall, basketball, feet, length
smell	cell, spell, dwell, swell	scent, whiff, aroma, stench
snake	sake, stake, ache, make	slither, serpent, reptile, rattle
sneeze	wheeze, squeeze, freeze, ease	allergy, tissue, cough, handkerchief
soap	scope, slope, microscope, cope	lather, suds, bubble, shower
speaker	beaker, sneaker, seeker, weaker	sound, guest, stereo, microphone
square	rare, spare, snare, scare	triangle, circle, shape, round
stress	bless, assess, confess, chess	anxiety, pressure, tension, strain
sweet	heat, street, beet, sheet	bitter, sugar, honey, sour
teeth	beneath, wreath, sheath, heath	gums, braces, tongue, mouth
thief	chief, brief, relief, grief	robber, burglar, bandit, crook
train	lane, slain, stain, attain	track, engine, railroad, caboose
trash	stash, flash, mash, dash	garbage, dump, rubbish, debris
trip	clip, drip, flip, chip	baggage, travel, journey, vacation
urge	perch, birch, search, lurch	convince, impulse, need, persuade
vote	afloat, dote, note, boat	ballot, campaign, election, register
water	hater, gator, traitor, skater	server, waitress, food, tip
whisky	frisky, sticky, tricky, risky	scotch, gin, bourbon, rum
whole	sole, role, goal, mole	half, all, part, piece
window	bravado, meadow, shadow, avocado	curtain, shutter, pane, sill

Appendix C

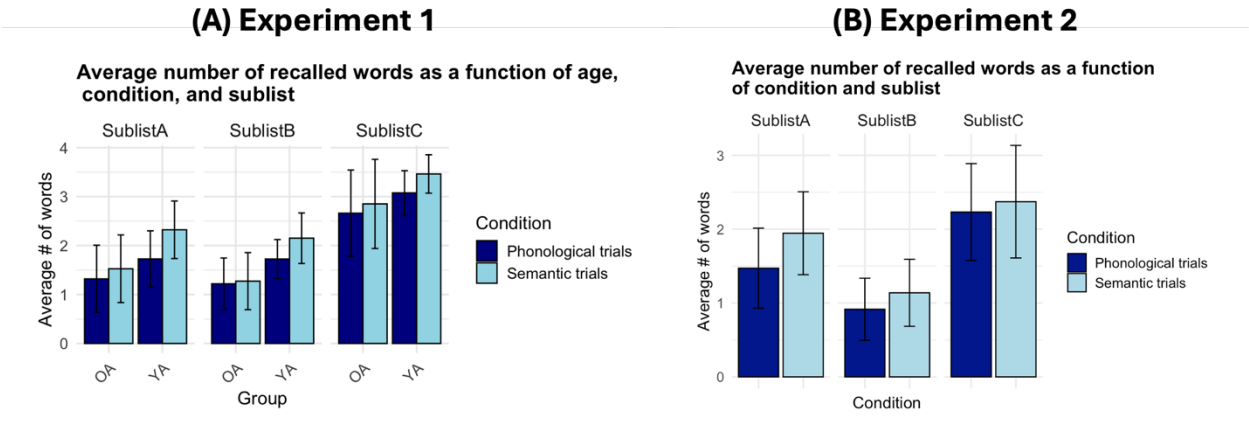

Figure C1. (A) Average number of words (correct and false) recalled by young adult (YA) and older adult (OA) participants as a function of condition (semantic, phonological) and sublist (A, B, C). **(B)** Average number of words recalled by OA participants as a function of condition (semantic, phonological) and sublist (A, B, C). Only older adults were tested in Experiment 2. Error bars indicate ±1 standard deviation from the mean.

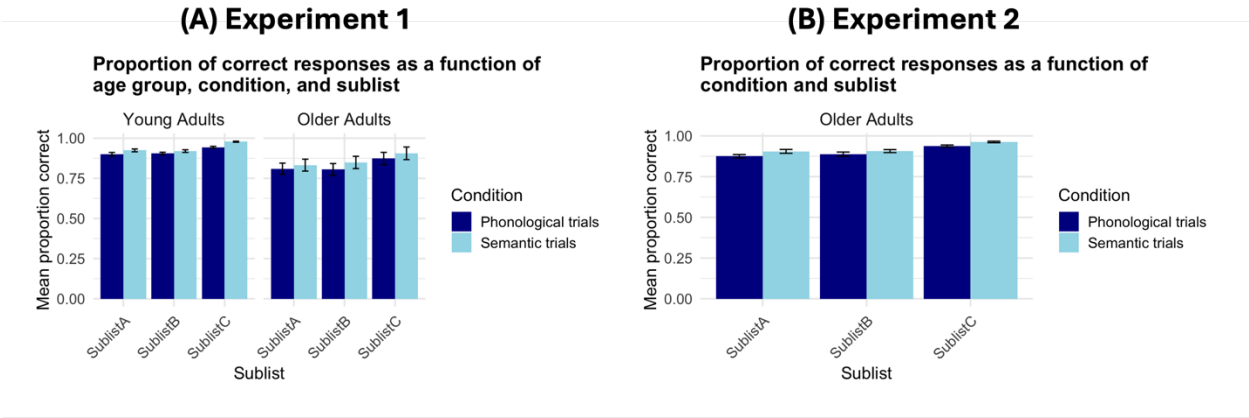

Figure C2. (A) Average proportions of correct responses recalled as a function of age group (YA, OA), condition (semantic, phonological), and sublist (A, B, C). **(B)** Proportion of correctly recalled words by older adult (OA) participants as a function of condition (semantic, phonological) and sublist (A, B, C). Only older adults were tested in Experiment 2. Error bars indicate standard error of the mean.