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A meta-analysis of false memory in healthy and pathological cognitive aging

Running head: false memory and aging

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Pre-registered and openness

The study protocol was pre-registered on the Open Science Framework (https://osf.io/v7g6q/?view_only=a2e4e544e3c741acaf12d6d2e4292042). The data and code supporting this meta-analysis are publicly available at (https://osf.io/h6n2q/?view_only=b26e6e41fa264a34be3eaf86f7b81c66).

Ethical approval

As this meta-analysis only used aggregated data extracted from previously published articles and no new data were collected from or about human participants, ethical approval was not required.

Abstract

Although there is a consensus about age-related impairments in true memory, the relationship between aging and false memory remains less clear. Both the Fuzzy-Trace Theory and the Activation-Monitoring Theory postulate possible effects of cognitive aging on the processes of encoding, consolidation, and retrieval. Yet, quantitative analyses of cognitive aging, both healthy (younger vs. older adults) and pathological (older adults vs. mild cognitive impairment, MCI/Alzheimer's disease, AD), on false memory have not been conducted. We meta-analyzed 150 articles with 414 independent effect sizes and found a robust aging effect of false memory, with older adults showing higher levels of false memory than younger adults in both spontaneous (Hedges' $g = 0.538$, 95% CI [0.432, 0.644]) and suggestion-induced false memory (Hedges' $g = 0.460$, 95%CI [0.255, 0.665]). MCI/AD patients showed significantly higher levels of spontaneous (Hedges' $g = 0.486$, 95%CI [0.053, 0.919]) but not suggestion-induced false memory (Hedges' $g = 0.608$, 95% CI [-0.286, 1.502]) than healthy older adults. For study and test phase, moderator analyses indicated that experimental material, modality, true memory, paradigm, type of test, and the retention interval significantly influenced aging effect on false memory. For general moderators, participants' age and education level were also significant. Our results underscore the importance of integrating the FTT and AMT to account for age differences in false memory across types. Both healthy and pathological cognitive aging increase susceptibility to false memory, and the decline in verbatim memory and monitoring functions, combined with hyperactivation during encoding, may

account for aging effect in false memory.

Keywords: false memory, older adults, cognitive status, Fuzzy-Trace Theory,

Activation-Monitoring Theory

Public Significance Statement

This meta-analytic review demonstrates that both healthy and pathological cognitive aging increase an individual's vulnerability to false memories. The findings of this study suggest that this augmented susceptibility may be derived from declines in verbatim memory and monitoring abilities, along with hyper-reliance on gist memory. Our results also underscore the importance of developing integrated false memory theories to account for aging differences on false memory under various circumstances.

Remembering past events is crucial in performing daily activities such as going to the grocery store or taking the correct type of medicine. Aging usually involves changes in memory performance, particularly in episodic memory, including decreased accuracy in true memory and increased rates of false memory (Balota et al., 2000; Light, 1991; Schacter et al., 1997). Although a substantial body of evidence indicates that older adults are more susceptible to different types of false memories than younger adults (e.g., Schacter et al., 1999; Schacter et al., 1997), the underlying aging mechanisms of this false memory effect remain unclear. Elucidating the relationship between aging and false memory could illuminate the cognitive mechanisms contributing to memory distortions in older adults. The aim of this article was to provide systematic evidence on the relationship between aging and false memory, as well as to uncover the key moderators underlying the aging effects on false memory. Furthermore, pathological cognitive aging—notably, mild cognitive impairment (MCI) and Alzheimer’s disease (AD)—is associated with distinct memory distortions beyond healthy aging. Another aim of this article was to test the direction and effect size of pathological false memory aging.

False Memory

False memory refers to the phenomenon when an individual mistakenly remembers details of an event that were not experienced (Bernstein et al., 2018; Brainerd & Reyna, 2005; Otgaar et al., 2018). False memories can be divided into two distinct categories based on the ways they are created: spontaneous false memory and suggestion-induced false memory (Bookbinder & Brainerd, 2016; Brainerd & Reyna,

2005; Liu et al., 2015; Otgaar et al., 2018; Tallman, 2020). Spontaneous false memory refer to false memories that are evoked by intrapersonal cognitive processes. The Deese/Roediger-McDermott (DRM; Deese, 1959; Roediger & McDermott, 1995) method is widely used paradigms to induce spontaneous false memory. Here, lists of associative words are presented (e.g., *vegetable, juice, berry, banana*), all of which are associated with the critical lure (i.e., *fruit*). On a subsequent memory test (e.g., recall, recognition) people frequently falsely remember the critical lure as having been presented in the original list.

Suggestion-induced false memory is usually created due to external suggestions (Otgaar et al., 2018; Tallman, 2020). Participants may be misled into remembering that an event occurred when it did not. A widely used method for inducing false memories is the misinformation paradigm (Brewin & Andrews, 2017; Otgaar et al., 2018). In this paradigm, participants are typically exposed to misleading post-event information, which produces false recollections (Brewin & Andrews, 2017). Other paradigms, such as memory conformity/social contagion, implantation, and imagination inflation (Bernstein et al., 2018; Brainerd & Reyna, 2005; Brewin & Andrews, 2017; Otgaar et al., 2018), show that suggestions from others or repeated imagination can also lead to the formation of false memories.

The relationship between spontaneous false memory and suggestion-induced false memory is a topic of keen interest in memory research. Several studies have investigated the association between false memories created by DRM paradigms and misinformation paradigms (see Table S1). While most studies have reported no

significant relationship between the two types of paradigms (Qin, 2008; Otgaar et al., 2011; Ost et al., 2013), others have suggested an association between misinformation and DRM false memory (Zhu et al., 2013; Bernstein et al., 2018). A recent two-experiment study spanning young and older adults reported no relationship between false memories in the misinformation, DRM, and memory conjunction tasks, supporting the view that different cognitive mechanisms underpin false memories in different paradigms (Devitt & Foster, 2025). This suggests that aging may affect the two types of false memory differently. Thus, we analyzed the effect of aging on these two types of false memory separately.

Theoretical Perspectives on False Memory in Older Adults

Fuzzy-Trace Theory

Fuzzy-Trace Theory (FTT, Brainerd & Reyna, 2002, 2005; Reyna & Brainerd, 1995) classifies mental representations of memory into two types: verbatim traces, which are detailed, vivid, and direct representations of past experiences; and gist traces, which capture the general meaning of a memory without its specific details (Draine & Greenwald, 1998; Greene & Naveh-Benjamin, 2023; Moravcsik & Healy, 1995). In spontaneous false memory tasks, FTT proposes that retrieval of verbatim and gist traces are opponent processes, playing different roles in false memory formation (Brainerd & Reyna, 2002, 2005; Reyna & Brainerd, 1995). Gist retrieval promotes false memories by facilitating the acceptance of semantically related lures, whereas verbatim retrieval suppresses false memories by enabling the retrieval of specific perceptual details (Reyna & Brainerd, 1995; Brainerd & Reyna, 1998).

As for suggestion-induced false memory, verbatim traces of original information might compete with verbatim traces of post-event misinformation. In the misinformation paradigm, participants first encode an event. Then, they receive contradictory misinformation and are subsequently tested on their memory of the event. Throughout these phases, participants should store both verbatim and gist traces of the original information and misinformation. Although the gist representations are probably shared between the original and the misinformed events, verbatim traces differ. During memory tests, verbatim and gist retrieval function similarly to spontaneous false memory, but new verbatim details of misinformation, as well as overlapping gist shared with the original details, contribute to suggestion-induced false memory (Brainerd et al., 2000; Reyna & Brainerd, 1998). The presentation of misinformation reinforces the gist trace of original events, thereby increasing participants' susceptibility to accept schema-consistent false details. On the other hand, such misinformation implants new verbatim traces of the surface details, interfering with the retrieval of original verbatim traces through trace competition. Critically, misinformation not only introduces new verbatim traces, but also weakens access to original details through retroactive interference, amplifying errors.

Studies using the conjoint recognition model (Brainerd et al., 2022; Stahl & Klauer, 2008; Xiao et al., 2015) and the dual retrieval model (Brainerd et al., 2014; Chang, 2019) suggest that the development of verbatim and gist memory varies across the lifespan. Specifically, verbatim memory declines in older adults, whereas gist memory remains relatively stable (Abadie et al., 2021; Brainerd & Reyna, 2002,

2005; Greene et al., 2022; Reyna & Brainerd, 1995). Meanwhile, accelerated verbatim memory decline in MCI/AD (Foldi, 2011; Hudon et al., 2006), combined with relatively preserved gist memory (Budson et al., 2003; Deason et al., 2017), would be expected to magnify false memory in pathological cognitive aging, particularly for semantically driven lures.

Activation-Monitoring Theory

According to Activation-Monitoring Theory, memory involves two critical processes: activation and monitoring (AMT, Gallo & Roediger, 2002; Roediger et al., 2001). In spontaneous false memory paradigms (e.g., the DRM paradigm), activation of a node in the implicit associative network can spread through semantic networks from presented items (e.g., "orange") to non-presented critical lures (e.g., "fruit"). For suggestion-induced false memory, a similar account of AMT called Associative-Activation Theory (AAT) was proposed by Howe and colleagues (Howe et al., 2009; Otgaar et al., 2013, 2016, 2017) is used to explain false memories beyond word-list tasks to other tasks, positing that processing a word or concept results in an immediate and parallel spread of activation to related concept nodes in a person's knowledge base (i.e., mental lexicon; Anderson, 1983; Collins & Loftus, 1975). Misleading information can activate memory networks of an original event through semantic or contextual associations, causing the integration of these misinformation details. Furthermore, AMT posits that monitoring processes are a key factor in minimizing memory errors (Roediger et al., 2001). If participants fail to judge an item as activated by internally generated activation spreading or suggested information (i.e., source

monitoring failure), the item will be incorrectly recognized as having been presented, leading to false memories.

As people age, activation spreads more widely and becomes less efficient due to slower processing speeds (Diamond et al., 2000; Dywan et al., 1992; Jongman & Federmeier, 2022; Salthouse, 1996). However, the breadth and depth of semantic activation may be maintained or even hyperactivated (Park et al., 2002; Kave & Halamish, 2015; Park et al., 2002; Verhaeghen, 2003). Thus, older adults can show comparable performance to younger adults in word association and semantic priming effect (Burke & Peters, 1986; Madden, Pierce, & Allen, 1993; Campbell & Davis, 2024). Meanwhile, age-related deficits have also been found in source monitoring (Colombel et al., 2016; Dehon & Brédart, 2004; Devitt & Schacter, 2016; Gallo & Roediger, 2003; Kurkela & Dennis, 2016). The brain regions associated with false memory retrieval are the prefrontal cortex (PFC) and medial temporal lobe (MTL; Chamberlain et al., 2022; Dennis et al., 2014; Dennis et al., 2008; Royet et al., 2011; Tsukiura, 2014). Reduce activation in the PFC (Devitt & Schacter, 2016; Mitchell & Johnson, 2009; Tsukiura, 2014) and MTL (Addis & Schacter, 2008; Straube, 2012) in older adults may reflect a decline in retrieval-related processes for monitoring conflicts between true and false memories. Meanwhile, relative to healthy older adults, individuals with MCI/AD, exhibit nonspecific associative activation (e.g., hyper-priming effect; Giffard et al., 2001; Ober & Shenaut, 1995) and impaired source monitoring (Dodson et al., 2011; MacDuffie et al., 2012), making them more suggestible and less able to reject intruded lures, which in turn could elevate false

memory rates.

The Framework of the present meta-analysis

Although gist extraction (as conceptualized FTT) and associative activation (as posited by AMT) share several similarities, they also diverge in fundamental ways. Associative strength reflects the co-occurrence frequency of linguistic elements in natural language use, whereas gist strength captures the semantic richness of connections between encoded items and false memory targets (Brainerd et al., 2020, 2024). Brainerd's (2020, 2024) critical tests—designed to disentangle mean gist strength (MGS) from mean backward associative strength (MBAS)—reveal that MGS and MBAS vary independently and the gist mechanism of fuzzy-trace theory and the associative mechanism of activation monitoring theory operate in parallel. Thus, false memories emerge through two dissociable yet interactive pathways: (1) an associative pathway driven by spreading activation in semantic networks (AMT), and (2) a gist-based pathway governed by thematic coherence and schema-driven reconstruction (FTT). Their relative dominance is modulated by task demands (e.g., semantic vs. perceptual focus), developmental stage (e.g., age-related shifts in verbatim-gist competition), and retrieval dynamics (e.g., monitoring efficiency). This dual-pathway framework resolves theoretical discussions by positioning AMT and FTT as complementary rather than competing accounts.

Based on the theoretical accounts of false memory and their relationship with aging, we have developed a theoretical framework for guiding our meta-analysis in order to understand the effects of aging on false memory (see Figure 1). According to

FTT, increases in false memories among older adults are partly due to age-related declines in verbatim memory and a greater reliance on gist (Grilli & Sheldon, 2022; Reagh et al., 2020), while AMT highlights slower associative activation and impaired monitoring (Chamberlain et al., 2022; Dehon & Brédart, 2004; Devitt & Schacter, 2016; Gallo & Roediger, 2003). In addition, several variables need to be taken into account when considering the aging effect on false memory. As Figure 1 illustrates, we categorized moderators into those primarily affecting study, test, and general factors. Taking these moderators into account allows for a more nuanced understanding of the complex relationship between false memory and aging when comparing spontaneous and suggestion-induced false memory.

----- *Figure 1* -----

Potential Moderators

More than ten moderators were coded for each type of false memory: 14 for spontaneous false memory and 11 for suggestion-induced false memory (see the Methods section). Based on false memory theories and relevant empirical evidence, we present below the key moderators that may play a role in the relationship between aging and false memory, from study phase, test phase, and general perspectives.

Moderators in study phase

Modality and material

In the initial study by Roediger and McDermott (1995), word lists were presented to participants auditorily, resulting in a significant false memory effect. Subsequent studies have also examined false memory visually. Smith et al. (1998) found that

switching the modality from auditory to visual effectively reduced false recall and false recognition of critical lures, with false recall being most sensitive to the presentation modality. Young adults used visual details to distinguish the items on the lists from the critical items, while visual presentation of word lists did not reduce false memories in older adults compared to auditory presentation (Butler et al., 2010; Gras et al., 2011; Smith et al., 2005), suggesting that visual presentation may improve source monitoring in younger adults, but not in older adults. For the misinformation paradigm, the procedure typically involves visual encoding to induce false memories, but other modalities have been used as well (Chatburn et al., 2017). For example, Dijkstra and Moerman (2012) examined the effects of different encoding patterns on false memory in a misinformation paradigm in which participants heard, observed, or acted out a series of events. Participants had better true memories in the act out condition, while the acceptance of misinformation was lowest in the auditory condition. Ulatowska, Olszewska, and Hanson (2016) transformed the event encoding phase of the misinformation paradigm into video, picture, written narrative, and auditory narrative, with the misinformation and memory test presented in written form. Participants in the written and auditory modes had fewer suggestive false memories than those in the video and picture modes, and that these effects of stimulus presentation may also be age dependent.

List length and number of lists

The length of word lists used in the DRM paradigm has been found to be related to false memory generation. Research by Robinson and Roediger (1997) found that

increasing the list length resulted in higher rates of false recall and false recognition. Askey et al. (2018) conducted a study using DRM word lists of varying lengths to examine false memories in older adults. Their results showed that the proportion of correctly recalled words decreased as the list length increased, and longer lists increased the likelihood of retrieving critical lures. Moreover, older adults exhibited larger list length effects: as the number of associates per DRM list increased, so did their retrieval of critical lures, which increased more steeply compared to young adults. One possible explanation for false memories in DRM is the spreading activation principle, whereby longer lists may lead to multiple activations of the critical lures (Collins & Loftus, 1975). Lists with stronger semantic associations to critical lures also evoke more false memories than lists with weaker associations, as a result of spreading activation between associations in semantic memory (Gallo & Roediger, 2002; Newbury & Monaghan, 2019). From the FTT perspective, for shorter word lists, verbatim traces may be easier to retain because they contain less textual detail. For longer lists, gist traces may be more critical because they help capture the core meaning of the lists.

Misinformation approaches

Campbell et al. (2007) proposed that the presentation of misleading information influences memory performance due to differences in encoding. Stoll (2021) found that the way misinformation is introduced can affect false memory differently. Participants in the direct interview condition (questions that directly query the misleading detail) showed higher misinformation endorsement compared with the

indirect interview condition (questions that presupposed the misinformation) and the narrative condition (the misinformation embedded in a written account of the witnessed video). In a study by LaPaglia and Chan (2013), participants watched a video and then received a statement or question containing misleading information. The results indicated that presenting misinformation through a statement increased susceptibility to false memory. This effect is known as retrieval-enhanced suggestibility (RES), where initial recall tests can draw attention to specific parts of the narrative, thereby reinforcing the encoding of misinformation from the narrative (Chan & Langley, 2011; Meluso, 2011; Thomas et al., 2010). According to FTT, different ways of misinformation may lead to different levels of storage of verbatim traces and gist traces. The depth of processing of misleading information may directly affect the subsequent formation of false memories. The strength and retention of memory traces is largely determined by the nature of the stimuli. Shallow (structural) processing involves only surface features of the stimuli, whereas deep (semantic) processing is a more meaningful process that allows more time and space to elaborate and imagine the stimuli (Greene et al., 2022). Meanwhile, for AMT, different ways in which misleading information is implanted through textual narratives versus questioning or interviews may affect participants' monitoring of information sources (Horry et al., 2014; LaPaglia & Chan, 2019).

Moderators in test phase

Interval between encoding and retrieval

The effect of the interval between encoding and retrieval on gist and verbatim

memory is complex. Gist memory tends to last longer, while verbatim memory is more prone to rapid forgetting (Ahmad et al., 2017; Brainerd & Reyna, 2002). Gist memory is generally more stable and durable than verbatim memory and it is relatively less susceptible to the passage of time. Older and younger adults may exhibit different effects of time on verbatim and gist memory traces. Because older adults rely more on gist memory than younger adults (Brainerd et al., 2009), age differences in memory were magnified after long delays due to a disproportionate decline in verbatim compared to gist memory in older adults (Fandakova et al., 2020; Memon et al., 2003).

Type of tests

Recall relies more on intentional memory search, whereas recognition relies on both recollection and familiarity (Tsuji & Imaizumi, 2022; Yonelinas et al., 2010). According to the FTT, recollection requires considerable effort to extract specific memory details, whereas recognition judgments based on familiarity are fast, automatic processes that do not require conscious retrieval of contextual information. Recall may place more emphasis on the recollection process, whereas recognition places emphasis on familiarity as well, or familiarity of the extracted gist of the information. In recognition tasks, people may be more likely to select options that look familiar without necessarily capturing the gist of the information. According to the AMT, monitoring cues are activated during recognition tests when words are presented to participants. These cues facilitate the suppression of related but unseen words, reducing the likelihood of false recognition. However, during recall tests, such

monitoring cues are not available, leading to the activation of more related words and resulting in a higher incidence of false memories in recall tests compared to recognition tests. Studies have shown that recall declines more with age, compared to recognition (Craik & McDowd, 1987; Danckert & Craik, 2013; Rhodes et al., 2019). Furthermore, a meta-analysis conducted by Fraundorf et al. (2019) on aging and recognition memory showed that older adults had lower identification accuracy and tended to have more liberal response criteria (i.e., a greater tendency to label items as new) compared to younger adults. These findings suggest that test type may play a moderating role in the aging effect on false memory.

Response bias

Potential age differences in false memory may not solely be due to a decline in their memory discriminability, but rather to differences in response criteria compared to younger counterparts. Older adults have shown reduced discrimination accuracy and a more liberal response criterion (Fraundorf et al., 2019; Meusel et al., 2012; Rotello & Macmillan, 2007). The question of whether this liberal response bias in older adults is merely a result of their reduced discrimination ability warrants further investigation. Three recognition indices were coded in the current study: True Recognition (studied items judged as "old" items); False Recognition (lures judged as "old" items); Foil Recognition (foil items as be "old" items). False alarms to foil items are commonly used as the baseline false alarm rate in recognition memory tests and are typically subtracted from the hit rate to calculate "corrected" recognition index. Thus, in age-related false memory studies, the results on unrelated items are also of

concern.

True memory

The observed age differences in false memory may not only be due to reduced memory discriminability, but also be related to changes in true memory mechanisms. As other studies have found, older adults were less likely to correctly recall studied items and more likely to falsely recall highly related but unstudied items than younger adults (Butler et al., 2004; Lee et al., 2012; Schacter et al., 1997). Older adults show reduced neural engagement in the MTL and left ventrolateral prefrontal cortex (VLPFC) during encoding - regions critical for item-specific processing that support item-specific encoding, while age-related increases in the superior temporal gyrus (STG) have also been associated with subsequent false memories (Dennis et al., 2007, 2008). This neural divergence suggests that age-related enhancement of false memory does not result from passive memory degradation, but from an active shift towards gist-based processing at the expense of perceptual specificity. Consequently, age differences in false memory cannot be fully understood without simultaneously examining true memory performance.

General moderators

Paradigm

Two common methods used to study spontaneous false memory are the category method and the DRM paradigm. In the category method, participants are presented with a list of words that belong to a common category (e.g., fruits; Brainerd & Reyna, 2007; Knott & Dewhurst, 2007). In the DRM paradigm, participants are exposed to a

series of words related to a specific topic or concept. Participants are then asked to recall or recognize these words. Both the category method and the DRM paradigm lead to the formation of false memories, albeit via different mechanisms: the category method induces false memories via shared lexical items within a category, whereas the DRM paradigm induces false memories via shared semantic themes (Coane et al., 2021). Older adults may rely more on gist processing, prioritizing the general meaning of word lists over precise verbatim details in the DRM paradigm. When dealing with category-based lists, similarly, they may organize information into categorical frameworks, with greater emphasis placed on the categorical relationships than on the verbatim details. Beyond these two paradigms, a small number of studies on spontaneous false memory have adopted other tasks such as visual scene recognition, inference-based errors, conjunction errors, and boundary extension illusions, which can also elicit false memories without external suggestion (Brainerd et al., 2008; Otgaar et al., 2013, 2018; Toffalini et al., 2019).

Suggestion-induced false memory occurs via various paradigms, such as the misinformation paradigm and the imagination inflation paradigm. Misleading information from others is often presented in a context that obscures its true nature. In contrast, imagination inflation suggests participants to repeatedly imagine something that never occurs, and thus lacks the rich contextual cues associated with actual experiences or external information (Baran & Niedzwienska, 2003; Dudek & Polczyk, 2024; Garry & Polaschek, 2000). Because older adults have deficits in recalling detailed information, their dependency on gist processing may lead them to easily

integrate misleading information into their memory representations. In addition, they often struggle to accurately monitor the source of their memories. In the imagination inflation paradigm, despite the absence of contextual cues, older adults may still prioritize gist processing, focusing on the overall meaning or theme of the imagined events (Arndt, 2012; Bays, 2011).

Continuum age in each age group

For studies that have compared younger adults with older adults in different age groups, differences between these studies may be due to sample selection and biological aging (e.g., different studies might have a different age range for older and younger adults respectively). False memories may differ along a continuum of age within each age group.

Education level

In addition, education is another individual variable that has been associated with memory performance. Studies have reported compensatory effects of education on age-related cognitive decline. For example, research has shown that highly educated older adults tend to employ more effective strategies in memory tasks than older adults with lower levels of education (Troyer, 2001; McDougall et al., 2010). On the other hand, older adults with lower levels of education may rely on additional frontal cortex functioning to compensate for dysfunction in other areas of the brain (Haut et al., 2005).

Country and culture

Cultural background reflects and shapes an individual's memory experience. It

can influence participants' patterns of memory association, leading to different patterns of false memory. For instance, in a study by Lee et al. (2008) using the DRM paradigm, the lexical co-occurrence rate was significantly correlated with false recall and recognition for Chinese participants, but not for American participants. Similarly, Schwartz et al. (2014) found that Americans made more classification errors than Turks, while Turkish subjects falsely recalled more non-category-related list words than Americans did. Furthermore, Wang et al. (2022) found cultural differences in false memory using the DRM paradigm, where Europeans were more likely to form self-referential false memories than East Asians. These studies indicate how cultural differences may affect the susceptibility of different populations to false memories.

Year of publication

The decline effect refers to the observation that the effect sizes decrease as time passes since the initial publication of an effect (Pietschnig et al., 2019). Strategic research and submission behaviors, selective reporting, and p-hacking may lead to this effect (e.g., Simonsohn et al., 2014). Therefore, the year of publication was also coded.

The Present Meta-Analysis

Currently, there are several narrative reviews focusing on false memory in older adults, suggesting that cognitive aging is often associated with increased susceptibility to false memory (Jacoby & Rhodes, 2006; Koutstaal & Schacter, 1997, 2013). Although previous meta-analyses (e.g., McCabe et al., 2009), have provided important evidence regarding age differences in false memory, they have primarily

focused on a single paradigm (e.g., DRM), without systematically comparing age effects across different types of false memory. Our study offers several new contributions. First, to the best of our knowledge, this is the first study to use a comprehensive three-level meta-analytic approach to systematically compare age effects across both spontaneous and suggestion-induced false memory paradigms. Our analysis explicitly contrasts these two types, allowing us to clarify whether and how age-related effects differ by paradigm. Second, based on the theories of false memory (i.e., FTT, AAT, and AMT), we have comprehensively coded the potential moderators for spontaneous and suggestion-induced false memory, respectively. From study phase, test phase, and general perspectives, we examined the significant moderators that may account for the variation in the age effect on false memory. Third, the present study also examined the effect of pathological cognitive aging on false memory, that is, false memories in older adults with MCI and AD. Patients with MCI/AD have a higher incidence of memory distortions and false memories (Gallo et al., 2010; Howe & Akhtar, 2020). Some studies suggest that false memory may serve as an early indicator of MCI and AD (Hildebrandt et al., 2009; Schmid et al., 2013). However, some studies have found that the patients showed lower level of endorsement for unstudied lure items than healthy older adults (Budson et al., 2006; Gilet et al., 2017; Waldie & Kwong See, 2003). Indeed, while there are numerous studies that have examined false memory in MCI/AD, there appears to be a dearth of systematic research that has comprehensively examined differences in false memory across cognitive status (i.e., healthy cognitive aging vs. MCI/AD). We quantitatively

compared false memory across cognitive statuses by contrasting healthy older adults with individuals with MCI/AD. This allows us to determine if age-related patterns extend to pathological aging or if MCI/AD has a distinct false memory profile.

In summary, the present study aimed to answer the following questions: (1) Are there age-related differences (older vs. younger adults) in spontaneous and suggestion-induced false memory, respectively, and if so, are there differences between these two age effects? (2) Are there cognitive status differences (healthy cognitive aging vs. MCI/AD) in spontaneous and suggestion-induced false memory, respectively, and if so, are there differences between these two cognitive status effects? (3) What are the moderators that might explain the variation in the age effect on different types of false memory? We expected that older adults and MCI/AD might be more susceptible to false memory; the differences in age effects between spontaneous and suggestion-induced false memory would be exploratory without expected directions; several moderators might explain the variation in the age effect from study phase, test phase, and general perspectives motivated by FTT and AMT theories, in elucidating the aging effect on false memory.

Method

Preregistration and openness

This study adhered to the guidelines outlined in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA; Page et al., 2021; see Table S2). In addition, the meta-analysis has been registered online on August 8, 2022 in the

Open Science Framework (OSF). Of note, we have updated the pre-registration in the OSF on September 10, 2024, and both the updated and original versions are available in the OSF for transparency:

https://osf.io/v7g6q/?view_only=a2e4e544e3c741acaf12d6d2e4292042 (Anonymous, 2022). The update was undertaken to clarify terminology, broaden the study population, and document the repeated search process. These changes were made in the interest of transparency and rigor. Both the updated version and the original preregistrations are publicly available on OSF to ensure full transparency. The summary of the update is available in the supplementary materials. The data, metadata, and R-script ("metafor" package; Viechtbauer, 2010) are also available in the OSF: https://osf.io/h6n2q/?view_only=b26e6e41fa264a34be3eaf86f7b81c66 (Anonymous, 2025).

Search strategy

A comprehensive systematic search was conducted from August 8, 2022, to April 30, 2024. With no limitations on the publication date of the articles, to identify potentially relevant studies for inclusion. The following electronic databases were searched: EBSCO, PubMed, Science direct, Web of Science, ProQuest, Wiley, and Google Scholar. The keywords included in topic search were *false memory* AND *older adults* OR *cognitive impaired older adults*. See supplementary material, for a complete list of search terms.

Inclusion and exclusion criteria

The inclusion criteria for studies were as follows: (a) written in English or

Chinese, (b) published in peer-reviewed scientific articles or master's or doctoral theses, (c) using quasi-experimental or experimental designs reporting qualitative results, (d) employing spontaneous or/and suggestion-induced false memory paradigms (e.g., DRM lists, category-based lists, misinformation effect, and imagination inflation), (e) compared younger and older adults (YA vs. OA) or older adults with cognitive impairment (OA vs. MCI/AD). Of note, studies or experiments that exclusively focused on a single age group were excluded.

Study selection

Figure 2 shows the study selection flowchart. Through the screening process, 150 articles were included. Some of these articles included multiple experiments. A total of 414 independent effect sizes were examined across these studies. Study selection and subsequent data extraction were performed by S.Y.H. and independently reviewed by H.Z.X.

----- *Figure 2* -----

Quality of the study

We evaluated the study quality using an adapted version of the Physiotherapy Evidence Database (PEDro) scale (Moseley et al., 2002; max score = 9). Studies scoring 7 or above were classified as having a low risk of bias, signifying higher quality. Conversely, studies with scores of 6 or below were deemed to have a high risk of bias, suggesting potentially lower quality and greater susceptibility to bias (See the supplementary materials for each study's score and characteristics).

Data extraction

Following the guidelines proposed by Lipsey and Wilson (2001), we calculated standardized effect sizes (Hedges' g) for group differences in false memory (younger vs. older adults, and older adults vs. MCI/AD) in both spontaneous and suggestion-induced paradigms. Positive effect sizes indicated greater susceptibility to false memory in older adults (vs. younger adults) or in cognitively impaired older adults (vs. older adults), while negative effect sizes indicated the opposite. If there were data for more than one age group that fell within our defined age parameters, the data were merged and a single effect size was computed. That is, if there were data available for both young old (60-70 years) and old old (70-80 years), we combined the data and calculated a single effect size; if there were data for participants with mild cognitive impairment (MCI) and Alzheimer's disease (AD), we combined the data and computed a single effect size. Where necessary, effect sizes were estimated from graphs (GetData Graph Digitizer tool; Digitizer, 2020) test statistics (p , t , or F , *etc.*), or by contacting authors; studies without accessible data were excluded ($n = 11$)

Data coding

In order to examine potential sources of variability in aging and false memory and better understand the factors that may influence the results across different studies, the following variables were systematically coded. Across paradigms, we collected information on author, title, journal, and publication year, as well as participants' nationality and cultural background, mean age, and education years within each experiment. In addition, we coded data about the study design, including

the modality of material (auditory, visual, or auditory + visual), and the type of test conducted (recall, recognition, or recognition following recall).

In specific paradigms, for the spontaneous false memory studies, the type of materials used (e.g., words, pictures), the number of lists learned, the response to studied items and new items, and the number of words in each list were coded. For the suggestion-induced false memory studies, we coded how the initial materials were presented (e.g., video, slides/photographs, story), methods for the misinformation (e.g., recall test, narrative, photographs, confederate), and interval time between encoding and retrieval.

Three-level analysis

Traditional meta-analytic techniques do not account for non-dependent effect sizes intercorrelations, potentially leading to an overestimation of the overall effect size (Lipsey & Wilson, 2001). In contrast, three-level meta-analytic methods are better equipped to handle these dependencies and retain information from the same study: participants (Level 1) contribute to individual effect sizes (Level 2), which, in turn, constitute larger units referred to as studies (Level 3; Cheung, 2014; Van den Noortgate et al., 2015). This approach enhances the effectiveness of statistical tests compared to traditional methods (Assink & Wibbelink, 2016). Primary effects, heterogeneity, moderating effects, publication bias, and sensitivity analyses were assessed in the present study using three-level random effects models. Additionally, we applied a traditional random effects model to verify the robustness and consistency of the results (see supplementary materials).

Wald tests were performed to determine the confidence interval for the combined effects and the level of variability, known as heterogeneity (Viechtbauer, 2005). We fitted a three-level meta-analysis model to each data set using restricted maximum likelihood (REML) estimation. In assessing moderating effects, we included moderating variables as covariates in the three-level meta-analytic model to estimate the magnitude of the moderated effects. To ensure the representativeness of the moderating effect results, the categorical moderating variables were defined in accordance with Card (2015), with each variable require at least five effect sizes ($k \geq 5$) for a robust and reliable analysis.

Publication bias and sensitivity analysis

To address and mitigate publication bias, several strategies were implemented in the present study. We employed the funnel plot, Egger's test, and the trim and fill method to assess and correct for publication bias. To investigate the influence of each individual study on the overall estimation of effect size and to identify extreme studies, Baujat plots, Influence Diagnostics plots, and Graphic Display of Heterogeneity (GOSH) plots were performed. For details on our approach and results see the supplementary.

Results

(1) YA vs. OA

Table 1 shows the main effect and heterogeneity in the random effect model and three-level model, respectively. For spontaneous false memory, older adults were

significantly more susceptible than younger adults ($g = 0.538$, 95% CI [0.432, 0.644], $p < .001$) of the 240 independent effect sizes from 147 studies. Homogeneity analysis revealed that the sample was not homogeneous at a greater probability than chance due to sampling error ($Q(239) = 1147.611$, $p < .001$). An examination of the variability of the study variance at Level 3 revealed a significant contrast between the complete and the reduced models ($p < .001$). The full (three-level) model showed a better fit compared to the reduced model. Moreover, analysis of within-study variance (Level 2) also showed a noteworthy difference between the complete and reduced models ($p < .001$), indicating substantial within-study variability in the effect sizes. We calculated the I^2 statistic to assess the proportion of variance at each level of the model. The results indicated that 16.279% of the variance was due to sampling error, 15.102% was due to within-study variance, and 68.619% was due to between-study variance.

For suggestion-induced false memory, older adults were more susceptible to misinformation than younger adults ($g = 0.460$, 95%CI [0.255, 0.665], $p < .001$) of the 118 independent effect sizes from 83 studies. Homogeneity was significant ($Q(117) = 1194.827$, $p < .001$). Further examination of the variability of the study variance at level 3 ($p < .001$) and within study variance at level 2 ($p < .001$) both revealed significant contrasts. The results indicated that 7.591% of the variance was due to sampling error, 36.704% was due to within-study variance, and 55.705% was due to between-study variance.

Publication bias and sensitivity analysis

The funnel plots revealed that several effect sizes deviated from the expected distribution (Figure S1). Egger's test results were significant, indicating the presence of publication bias in both the spontaneous false memory ($z = 8.955, p < .001$) and suggestion-induced false memory ($z = 3.809, p < .001$) studies (see Table S7).

After conducting a thorough analysis of spontaneous and suggestion-induced false memory, sensitivity analyses identified three outlier conditions in spontaneous false memory: effect sizes from Bialystok et al. (2020) bilingual condition and Evrard et al. (2018) ascending and descending condition (see Figure S2); and free recall condition in Bulevich's (2007) thesis (see Figure S3), in suggestion-induced false memory. After the removal of these outliers, the overall effect sizes for spontaneous false memory remained significant ($g = 0.493, 95\%CI [0.410, 0.576], p < .001$), as well as the heterogeneity results ($Q(233) = 905.538, p < .001$); Also, the overall effect sizes for suggestion-induced false memory remained significant ($g = 0.435, 95\%CI [0.239, 0.630], p < .001$), as well as the heterogeneity results ($Q(116) = 1118.056, p < .001$). The forest plots of the effect sizes are shown in Figure 3.

----- Figure 3 -----

(2) OA vs. MCI/AD

For the spontaneous false memory studies, MCI/AD were more susceptible than cognitively normal older adults ($g = 0.486, 95\% CI [0.053, 0.919], p = .029$), measured by Hedges' g of the 48 independent effect sizes from 30 studies, and significant heterogeneity was observed ($Q(47) = 594.992, p < .001$). The examination

of the variability of the study variance at Level 3 ($p < .001$) revealed significant contrasts but within study variance at Level 2 ($p = 0.142$). We calculated the I^2 statistic to assess the proportion of variance at each level of the model. The results indicated that 5.277% of the variance was due to sampling error, 44.253% was due to within-study variance, and 50.470% was due to between-study variance.

For the suggestion-induced false memory studies, the effect size was not significant ($g = 0.608$, 95% CI [-0.286, 1.502]), based on a total of the 8 independent effect sizes from 8 studies, and the forest plots of the effect sizes are shown in Figure 4. Homogeneity was significant ($Q(7) = 71.788$, $p < .001$). An examination of the variability of study variance at Level 3 revealed no significant contrast between the complete and the reduced models ($p \approx 1.000$), nor did an analysis of the within-study variance (Level 2; $p \approx 1.000$). We calculated the I^2 statistic to assess the proportion of variance at each level of the model. The results indicated that 8% of the variance was due to sampling error, 46% was due to within-study variance, and 46% was due to between-study variance. However, given the small effect size, the wide confidence interval, and the limited number of included studies ($n = 8$), these results should be interpreted with caution.

Publication bias and sensitivity analysis

Upon inspection on the funnel plots, we observed that several effect sizes deviated from the expected distribution and Egger's test showed significant publication bias for spontaneous false memory ($z = 3.469$, $p < .001$) and significant for suggestion-induced false memory studies ($z = 3.715$, $p < .001$; see Table S7).

For spontaneous false memory, after removing the outlier (Howe et al. (2024)), the overall effect sizes for spontaneous false memory between MCI/AD and OA were marginally significant ($g = 0.333$, 95%CI [-0.003, 0.668], $p = .052$), and the forest plots of the effect sizes are shown in Figure 4. For suggestion-induced false memory, sensitivity analysis was not performed due to the small number of independent effect sizes included (Figure 4).

----- *Figure4* -----
 ----- *Table 1* -----

(3) Spontaneous vs. Suggestion-Induced False Memory

To examine the differences between the effect sizes for spontaneous and suggestion-induced false memory, we conducted a Q -test to compare the two types of false memory. For YA vs. OA, the Q -test show no significant differences between the effect sizes for the two types of false memory ($Q = 0.222$, $p = .638$). For OA vs. MCI/AD, the Q -test results also showed no significant differences between the effect sizes for the two types of false memory ($Q = 0.546$, $p = .460$). These results indicated that the effect of age and cognitive status was similar for the two types of false memory.

(4) Moderators

Spontaneous false memory moderators

Table 2 shows the results of moderating analyses for spontaneous false memory. For the effect of age (YA vs. OA), material, true memory, interval time between encoding and retrieval and paradigm were significant moderators of spontaneous false

memory creation; for the effect of cognitive status (OA vs. MCI/AD), the continuous age, country and MMSE of AD/MCI, publication years, and material were significant moderators (Figure S5-S8).

Study phase related moderators

Material

The materials used in the studies were coded into words and pictures. For the effect of age, pictures exhibiting a significantly larger difference between younger and older adults than words ($\beta = 0.442$, 95%CI [0.241, 0.643], $p < .001$). Similarly, the effect was also found for cognitive status differences ($\beta = 1.086$, 95%CI [0.268, 1.905], $p = .010$).

Modality

The encoding modality (coded as visual, auditory, or a combination of the two) did not significantly moderate the age effect difference in the effect of age ($F(2, 234) = 2.736$, $p = .067$), or cognitive status ($F(2, 44) = 0.503$, $p = 0.608$).

List length and number of lists

Neither list length nor the number of lists significantly affected age differences (list length: $\beta = 0.012$, 95%CI [-0.006, 0.030], $p = .207$; number of lists: $\beta = 0.004$, 95%CI [-0.002, 0.010], $p = .160$). Similarly, neither list length nor number of lists significantly affected cognitive status differences (list length: $\beta = -0.078$, 95%CI [-0.164, 0.009], $p = .076$; number of lists: $\beta = 0.033$, 95%CI [-0.051, 0.118], $p = .435$).

Test phase-related moderators

Interval time between encoding and retrieval

Retention interval (short delay < 1 hour vs. long delay > 24 hour) significantly moderated age effect, $F(1, 226) = 15.268, p < .001$), suggesting that as the delay increases, the age effect increases. The number of studies examining interval time between 1 hour and 24 hours was too small for the moderator analysis ($k = 3$). Given the small number of effect sizes for each interval type, interval moderation was not examined for differences in cognitive status.

Type of test

No significant differences were observed between recall, recognition, and recall plus recognition on the aging effect of false memory ($F(2, 234) = 1.442, p = .239$). There was also no significant cognitive status effect difference between recall, recognition, and the combined measures ($F(2, 44) = 2.559, p = .089$).

Response bias

The Hedges' g of false alarm rates for the new stimuli (the mean difference in the proportion of old responses to new items) between younger and older adults was 0.257 (95% CI [0.154, 0.360], $p < .001$). That is, older adults were more likely to endorse perceptually novel foils as "old" stimuli compared to young adults. However, the response to the new item did not moderate the age effect ($F(1, 102) = 2.397, p = .125$). For cognitive status, the difference was not significant ($g = 0.384$, 95% CI [-0.826, 1.593], $p = .519$). As moderator, it was not significant either for differences in cognitive status effect ($F(1, 24) = 0.528, p = .474$).

True memory

True memory for the studied item showed a significant age difference ($g = -0.388$, 95% CI $[-0.546, -0.230]$, $p < .001$). This means that compared to younger people older people are less likely to recall studied items. Age effect response to studied items significantly moderated the age effect in false memory ($F(1, 205) = 4.472$, $p = .036$). For cognitive status, the difference for studied items was also significant ($g = -1.181$, 95% CI $[-1.475, -0.886]$, $p < .001$), but as moderator was not significant ($F(1, 33) = 2.032$, $p = .163$). Specifically, greater age-related decline in true memory was associated with greater age-related increase in spontaneous false memory.

General moderators

Paradigm in the studies was coded as DRM, category, and others (e.g., visual scenes, inference errors). Moderation analyses revealed significant differences between these paradigms ($F(2, 234) = 11.755$, $p < .001$). The category-based paradigm ($\beta = 0.370$, 95%CI $[0.196, 0.544]$, $p < .001$) and the others paradigm ($\beta = 0.513$, 95%CI $[0.180, 0.845]$, $p = .003$) showed significantly larger age effect than the DRM paradigm, while there was no significant difference between category and other paradigms ($\beta = 0.142$, 95%CI $[-0.210, 0.495]$, $p = .427$). For differences in cognitive status, moderator analyses revealed no significant differences between these paradigms ($F(2, 44) = 0.466$, $p = .631$).

Other general variables, i.e., continuous age, sex, and education of younger and older adults, as well as country, culture, and year of publication, did not moderated the

variability of the aging effect on false memory ($ps > .05$). However, for cognitive status, the age of MCI/AD ($F(1, 43) = 10.581, p = .002$), year of publication ($\beta = 0.047, 95\%CI [0.005, 0.090], p = .030$), MMSE ($F(1,37) = 5.164, p = .029$) and country ($F(2, 38) = 4.631, p = .016$) were significant predictors of variability in effect size, while other variables were not significant predictors of effect size variability ($ps > .05$).

In summary, materials, paradigms, true memory, and the time interval between encoding and retrieval played significant moderating roles in the aging effects observed in spontaneous false memory (Figure 5). That is, under condition of higher true memory, picture materials (vs. words), the categorical paradigm (vs. the DRM paradigm), and a longer retrieval delay, the false memory discrepancy between older adults and younger adults was significantly larger.

----- *Figure 5* -----
 ----- *Table 2* -----

Suggestion-induced false memory moderators

Table 3 shows the results of the moderation analysis for suggestion-induced false memory. For the effect of age (YA vs. OA), modality, material, type of test, age, and education level of older adults were significant moderators of suggestion-induced false memory; however, for the effect of cognitive status (OA vs. MCI/AD), no further analysis of the moderator effects was conducted due to the small number of effect sizes included in this sample (Figure S9-S10).

Study phase-related moderators

Material

Materials in studies on suggestion-induced false memory were coded as video, slides/photographs, and story. Type of materials was a significant moderator on the age effect of false memory ($F(2, 88) = 3.248, p = .044$). Compared with slides/photos, age effect differences were significantly smaller with the story ($\beta = 0.845, 95\%CI [0.178, 1.511], p = .041$), whereas videos did not show a comparable reduction ($\beta = 0.663, 95\%CI [0.057, 1.269], p = .065$), indicating that age effect in false memories were smaller when a story was used as the encoding material.

Modality

Included studies were coded as visual or combined visual and auditory, and auditory was excluded as $k = 2$. Modality significantly moderated age effect ($F(1, 86) = 6.532, p = .012$), such that an age effect was only observed in the visual combined auditory condition ($g = 0.651, 95\%CI [0.394, 0.908], p < .001$), but not in the visual-only condition ($g = 0.154, 95\%CI [-0.132, 0.441], p = .288$).

Methods of misinformation

The methods of misinformation (narrative, question, and photograph) did not significantly moderate the age effect ($F(2, 86) = 0.317, p = .729$).

Test phase-related moderators

Interval time between encoding and retrieval

Interval time was coded as less than 1 hour (short delay) and more than 24 hours (long delay), and the number of effect size for the interval between 1 and 24 hours

was too small ($k=1$) to analysis. Retention interval did not significantly moderate age effect in suggestion-based false memory ($F(1, 95) = 0.454, p = .502$).

Type of tests

The type of memory test (recall vs. recognition) significantly influenced the age effect sizes ($F(1, 114) = 3.911, p = .050$): recognition showed an age effect ($g = 0.602, 95\%CI [0.345, 0.859], p < .001$), while recall did not ($g = 0.212, 95\%CI [-0.082, 0.506], p = .156$).

General moderators

Paradigm was coded as the misinformation paradigm and others (e.g., imagination inflation and memory conformity). The results showed that the paradigm used did not have a significant influence on the age effect ($F(1, 115) = 0.015, p = .902$). Moreover, the age of the older adults ($\beta = 0.057, 95\%CI [0.006, 0.108], p = .027$) and the age of the young adults ($\beta = 0.074, 95\%CI [0.014, 0.133], p = .015$) were significant predictors of effect size variability. Older adults with more years of education had significantly smaller age effect sizes, $\beta = -0.374, 95\%CI [-0.540, -0.207], p < .001$. While the years of education of the young adults was not significant, $F(1, 63) = 0.042, p = .837$. These results suggest that years of education of older adults may play an important role in reducing the age effect in false memory, but not for young adults. All the other potential moderators including sex, country, and year of publication, were not significant ($ps > .05$).

In summary, our results showed that aging effects in suggestion-induced false memory are influenced by material, modality, misinformation approaches, and type of

tests (see Figure 6). Specifically, presenting information in visual combined auditory (vs. visual only), using slides or videos (vs. story), and recognition (vs. recall) increases age differences.

----- *Figure 6* -----

----- *Table 3* -----

Discussion

While there is consensus on the age-related decline in true memory, the relationship between aging and false memory has been questioned (Jacoby & Rhodes, 2006; Pansuwan et al., 2020; Zhang et al., 2016). Here, we conducted the meta-analysis on the aging effect in both spontaneous and suggestion-induced false memory between younger and older adults, as well as differences in different cognitive status (older adults vs. MCI/AD). Three-level meta-analysis showed that older adults were significantly more susceptible to both spontaneous and suggestion-induced false memory than younger adults, while the age effect of both types of false memory was comparable. Meanwhile, there was no significant difference between older adults and MCI/AD in suggestion-induced false memory, but a significant difference was observed in spontaneous false memory.

These findings highlight the crucial role of age and neurocognitive status on susceptibility to false memories. The robustness of the findings was further tested using sensitivity analyses and random effects models, and the pattern of results was consistent. Furthermore, moderation analyses revealed that variables related to study

phase, test phase, and general perspective play an important role in theoretical and methodological insights into the age effect in false memory. In the following sections, we discuss these findings in the extent of FTT and AMT, consider methodological implications, limitations and suggest future avenues for research on false memory in aging.

Aging Effect on False Memory

We conducted an indirect comparison to assess whether there were false memory type-based differences in age-related effects between spontaneous and suggestion-induced false memory. The results indicated that there were no significant age-related differences in false memory that could be attributed to the choice of false memory types. Older adults were significantly more susceptible to spontaneous and suggestion-induced false memory than younger adults. According to the FTT, older adults tend to rely on gist traces more than verbatim traces. This reliance increases spontaneous false memory and makes older adults more susceptible to external cues, leading to suggestion-induced false memory. The AMT suggests that age-related declines in source monitoring and attentional control can cause “hyper-binding,” which makes it harder for older adults to distinguish between internal and external information sources (Campbell & Davis, 2024). In people with MCI or AD, both verbatim or gist memory can be significantly impaired, they also exhibit further declines in monitoring ability (Dodson et al., 2011; MacDuffie et al., 2012). According to the AMT, false memories arise from inadequate monitoring of activated memory information. Older adults, especially those with MCI or AD, have further

weakened monitoring abilities, making it harder to distinguish true from false information and increasing their susceptibility to both spontaneous and suggestion-induced false memory (Dodson et al., 2011; MacDuffie et al., 2012). Of note, while our meta-analysis was theoretically motivated by FTT and AMT, the method itself is grounded in effect sizes of age differences. Thus, the results cannot directly test the two theories in certain aspects. Our findings also do not falsify either theory. Instead, we attempted to explain the aging mechanisms of false memories by integrating the two theories' perspectives.

Aging Mechanisms underlying Spontaneous vs. Suggestion-Induced False Memory

Our results also aimed to explore the potential differences between spontaneous and suggestion-induced false memory. Although the Q-tests revealed no significant differences in the overall magnitude of age effects between spontaneous and suggestion-induced false memory, the moderators explaining the variation in the aging effect for these two types of false memories were different, suggesting the presence of different intrinsic mechanisms underlying each type of false memory (see Figure 7).

----- *Figure 7* -----

Spontaneous false memory

For study phase-related moderators, materials played significant moderating roles in the aging effects observed in spontaneous false memory, and similar patterns were observed when comparing cognitive status. Specifically, age-related and cognitive-

status differences were greater with picture materials (vs. words), suggesting that enriching the specificity of memory experiences during encoding may increase the aging effect and cognitive status effect of false memory. Specifically, compared to word materials, pictures tend to be more discriminable and distinctive during visual processing (Schacter et al., 1999; Smith & Hunt, 2020; Wang et al., 2018), pictures reduced false memory for both age groups, but the reduction was larger in younger adults than in older adults, and smallest in MCI/ADs. This pattern indicates that declines in verbatim memory and monitoring with normal aging—and their further impairment in MCI/AD—limit the extent to which pictorial distinctiveness suppresses false memory.

For test phase-related moderators, true memory and the retention interval moderated the aging effect on false memory. Older adults showed lower true memory than younger adults, and higher true memory was associated with greater age differences in spontaneous false memory creation. Task conditions that strengthened memory (e.g., high semantic relatedness or familiarity-based tests) increased both hits and gist-based false alarms. Since older adults rely more on gist and less on verbatim or source monitoring, improved true memory may be accompanied by more false alarms to lures, leading to larger age differences in false memory. This pattern suggests that conditions supporting better true memory also amplify age-related reliance on gist-based processing. For younger adults, their false memories decrease with long delays, but an age-related hyper-activation or gist extraction may compensate for the time decay effect, allowing older adults' false memories to sustain.

After long delays, false memory decreased for younger adults, whereas it remained unchanged for older adults, thereby increasing the age differences.

In summary, four potential mechanisms in the aging effect of false memory: age-related increase in activation, age-related decrease in monitoring, age-related increase in gist extraction, and age-related decrease in verbatim traces (see Figure 7). These mechanisms often interact across conditions, spontaneous false memory is less likely to occur when true-memory performance is relatively high and in tasks involving pictorial materials, and long-delay tests, which may suppress false memory reports in younger adults. In contrast, older adults may not benefit from the false memory suppression effect, leading to an increase in age-related differences in false memory.

Suggestion-induced false memory

Our results showed that the aging effect in suggestion-induced false memory is influenced by modality, material, misinformation approach, and type of tests. For the study phase related moderators—modality and material—presenting information in visual and auditory formats and using slides or videos (vs. story) increases age differences. Memory specificity suppressing the false memories of younger adults for spontaneous false memory, but memory specificity increases the aging effect on suggestion-induced false memory by increasing the false memories of older adults. Rich materials and multimodalities can provide a scaffold to “hook” the misinformation relative to the existing memory, helping older adults to incorporate it, which reflect an age-related decline in monitoring. Finally, test type was also a significant moderator: older adults had significantly more suggestion-induced false

memory than younger adults when using a recognition test, but not when using a recall test. Recognition depends on both recollection and familiarity, whereas recall relies more retrieval specific details (Tsuji & Imaizumi, 2022; Yonelinas et al., 2010). Older adults tend to have more liberal response bias and weaker monitoring to reject of misinformation (Fraundorf et al., 2019).

General moderators

In terms of general moderators, paradigms, age, years of education, and MMSE scores all affected false memory as predicted. Compared to the DRM paradigm, the categorical paradigm decreased false memory in both younger and older adults, but the reduction was greater in younger adults, resulting in a larger age difference. The DRM paradigm, with greater semantic and associative overlap between critical lures and list items, promotes more false memory overall. Semantic priming research shows that semantically related pairs (e.g., cat - dog) produce stronger priming effects than categorical pairs (e.g., sheep - dog; Hutchison, 2003). Older adults exhibit excessive associations, or “hyper-binding,” due to decreased attention control (Hasher & Zacks, 1988; Campbell & Davis, 2024). Our results showed that the paradigm significantly moderated the effect of age on spontaneous false memory, but not on suggestion-induced false memory. As the overall magnitude of the age-related effect did not differ between the two types of false memory, this pattern may suggest greater variability across spontaneous false memory paradigms (e.g., DRM, category, and other tasks). One possible explanation is that DRM lists entail stronger semantic overlap between studied items and critical lures. This overlap amplifies gist-based processing and

disproportionately engages the age-related reliance on gist. In contrast, suggestion-induced paradigms (e.g., misinformation, imagination inflation, and conformity) share common post-event suggestion and source-monitoring demands that exhibit less systematic variation in semantic relatedness. The age-related differences in false memory became more pronounced with increased age, especially for suggestion-induced false memory. As people age, memory functions tend to decline, including the ability to monitor sources. However, higher education and MMSE scores in older adults can effectively compensate for the effect of age on false memory (Abadie et al., 2021; Gallo et al., 2019). Education, as an important component of cognitive reserve, is a protective factor against cognitive decline with age (Nyberg & Pudas, 2019). Highly educated older adults tend to use more effective strategies in memory tasks (Troye, 2001; McDougall et al., 2010; Le Carret et al., 2003; Shadlen et al., 2005).

Taken together, these findings suggest that, although ageing confers a generalized vulnerability to false memories across paradigms, the mechanisms through which this vulnerability emerges differ. Therefore, it is still useful to distinguish between spontaneous and suggestion-induced false memory, not because the size of the age effect differs overall, but because the mechanisms that give rise to these errors may vary across paradigms. This perspective also explains why some studies have found only small or negligible age differences in false memory, namely under conditions that reduce reliance on gist or minimize monitoring demands.

Limitations and future directions

Although the present meta-analysis of age-related false memory included as

many studies and moderators as possible, it did not exhaust all false memory paradigms and moderators. We have focused on the comparisons between spontaneous and suggestion-induced false memory to clarify the stage at which age acts on false memory formation (memory encoding vs. memory retrieval) and mechanisms of age effect, especially in older adults and MCI/AD. In addition, some variance in the age effect on false memory performance remains unexplained, suggesting that several other unmeasured factors such as concentration or attentional patterns (Dewhurst et al., 2007; Hellenthal et al., 2019), level of forewarning (McCabe & Smith, 2002), emotional vocabulary (Bookbinder & Brainerd, 2016; Zhang et al., 2021), depth of cognitive processing (Zhu et al., 2013), individual personality traits (Gündüz, 2007; Zhu et al., 2010), and underlying medical conditions (Mendez & Fras, 2011).

Although we tried to avoid the effects of publication bias as much as possible, such as using the trim-and-fill method and including unpublished databases to avoid systematic overestimation of effect sizes due to selective reporting, other types of publication bias may still influence the results. For example, given the sampling bias in psychology and neuroscience toward Western, Educated, Industrialized, Rich, and Democratic (WEIRD) populations (Falk et al., 2013; Henrich et al., 2010; Muthukrishna et al., 2020), limiting generalizability. Moreover, since we did not contact individual researchers for unpublished data through professional societies or newsletters, some unpublished work may have been overlooked. These limitations should be borne in mind when interpreting the findings, especially with regard to

publication bias.

Another limitation of the present meta-analysis is that several false memory paradigms were excluded from moderator analyses due to the small number of studies conducted with older adults. Paradigms such as social contagion, rumor mongering, forced confabulation, and visual scene paradigms, for example, were adopted by only a handful of studies in the aging literature. While excluding these paradigms maintained sufficient statistical power for the main analyses, it limits the generalizability of our conclusions to a broader range of false memory paradigms. Conceptually, we treat the paradigm as a theory-driven proxy for the continuum of lure-misinformation relatedness (ranging from strong semantic overlap in spontaneous tasks to more perceptual overlap in suggestion-induced tasks). However, as certain paradigms are sparsely sampled in older adults and relatedness indices are rarely reported, we could not model this continuum directly or make continuous comparisons of relatedness across paradigms. In line with this limitation, moderation emerged within spontaneous paradigms, but could not be robustly tested within suggestion-induced paradigms. Future research involving older adults in various paradigms is essential to determine if the observed age effects extend across false memory paradigms with the full spectrum of lure-target relatedness.

Moreover, given by the limited literature available, we combined the studies of MCI and AD together as cognitive impaired older adults. This may potentially mask the nuances of how neurodegenerative cognitive status affects false memory. Future research should address these gaps, especially by including more diverse populations

and differentiating cognitive statuses.

Conclusions

In conclusion, this meta-analysis incorporating 414 effect sizes, we found a robust aging effect of false memory, with older adults showing higher levels of false memory than younger adults in both spontaneous false memory and suggestion-induced false memory. In addition, older adults with MCI/AD showed significantly higher levels of spontaneous false memory but not suggestion-induced false memory than healthy older adults, suggesting the potential use of spontaneous false memory as a cognitive marker for MCI/AD. Moderation analyses revealed that enriching memory specificity during encoding significantly increased the aging effect on spontaneous false memory. Meanwhile, the aging effect on suggestion-based false memory was greatly impacted by factors related to monitoring process of memory. In sum, these data provide compelling evidence for age-related and neurocognitive differences in false memory and provide a comprehensive picture showing how factors related to memory encoding and retrieval can affect such differences. Our results also underscore the importance of developing integrated theories to account for the aging differences on false memory under various circumstances.

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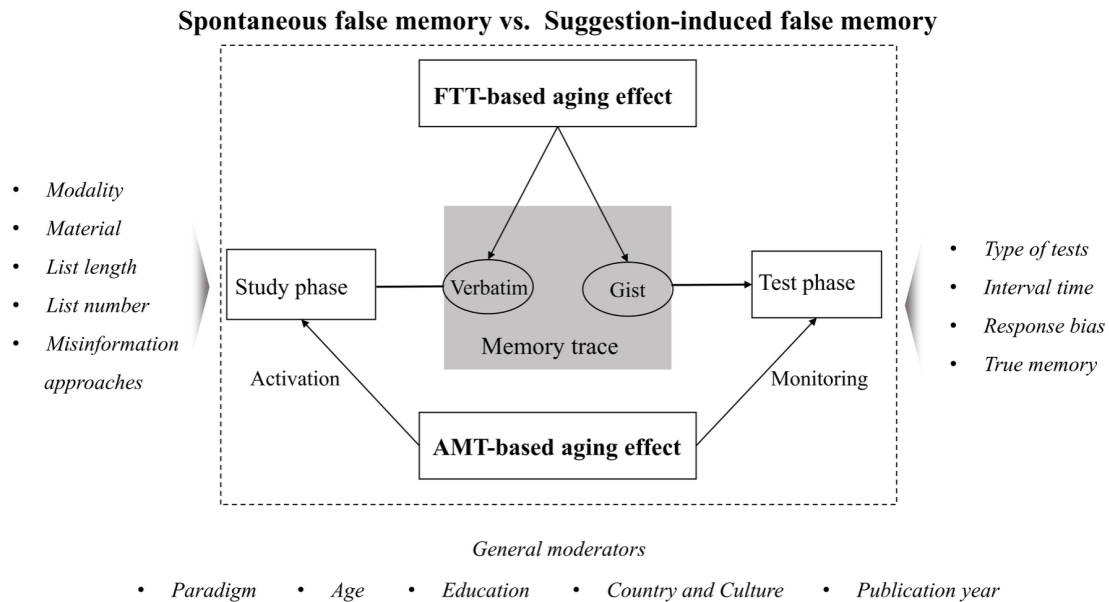
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Figure 1.

Framework of meta-analysis on the effect of aging on false memory



Notes. Both Activation-Monitoring Theory (AMT) and Fuzzy-Trace Theory (FTT) postulate an effect of aging on false memory. The AMT postulates a change in activation spreading during the study phase as well as in source monitoring during the test phase with age. In parallel, according to FTT, the emphasis placed on the verbatim and gist traces varies with age. Furthermore, the meta-analysis of moderators is proposed from three aspects as study phase, test phase, and general moderators (*italicized*). Moderators in study phase include modality, material, DRM word list length, number of word lists, and misinformation approaches. Moderators in test phase include type of tests, time of encoding-retrieval interval, response bias, and true memory. General moderators include factors such as paradigm, participant age, year of education, cultural background, and publication year.

Figure 2

PRISMA flow chart for the study selection process

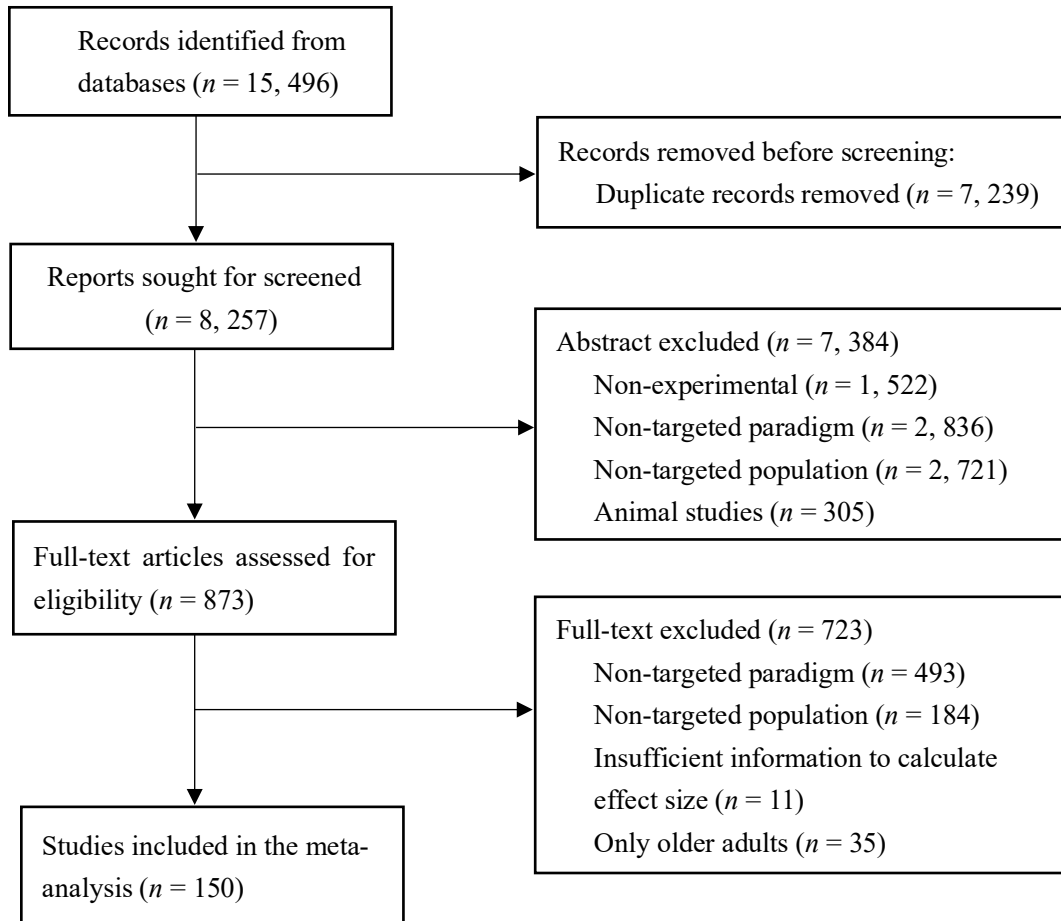
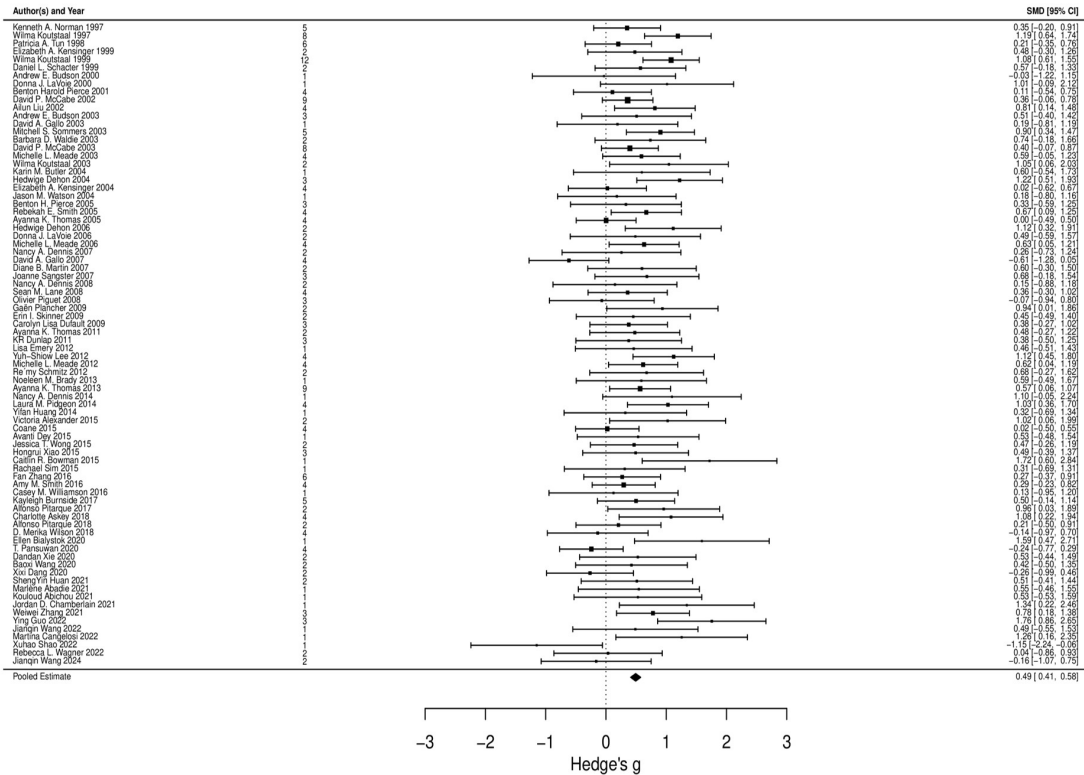


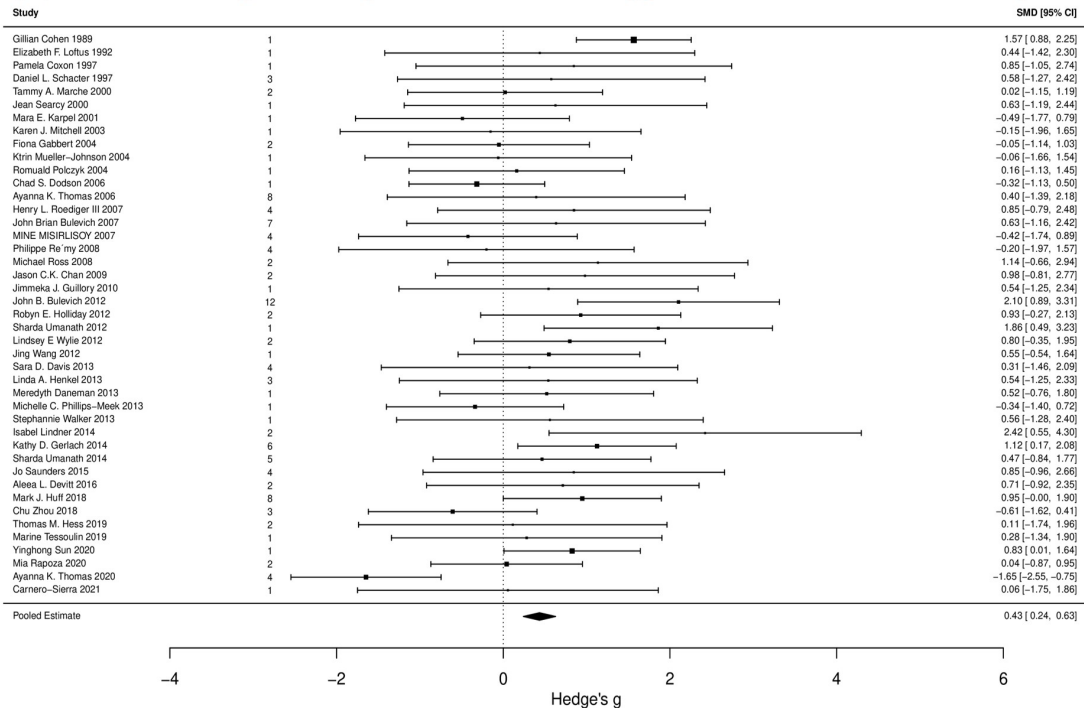
Figure 3

Forest plots of age differences in false memory

(A) Forest plots of age differences in spontaneous false memory



(B) Forest plots of age differences in suggestion-induced false memory

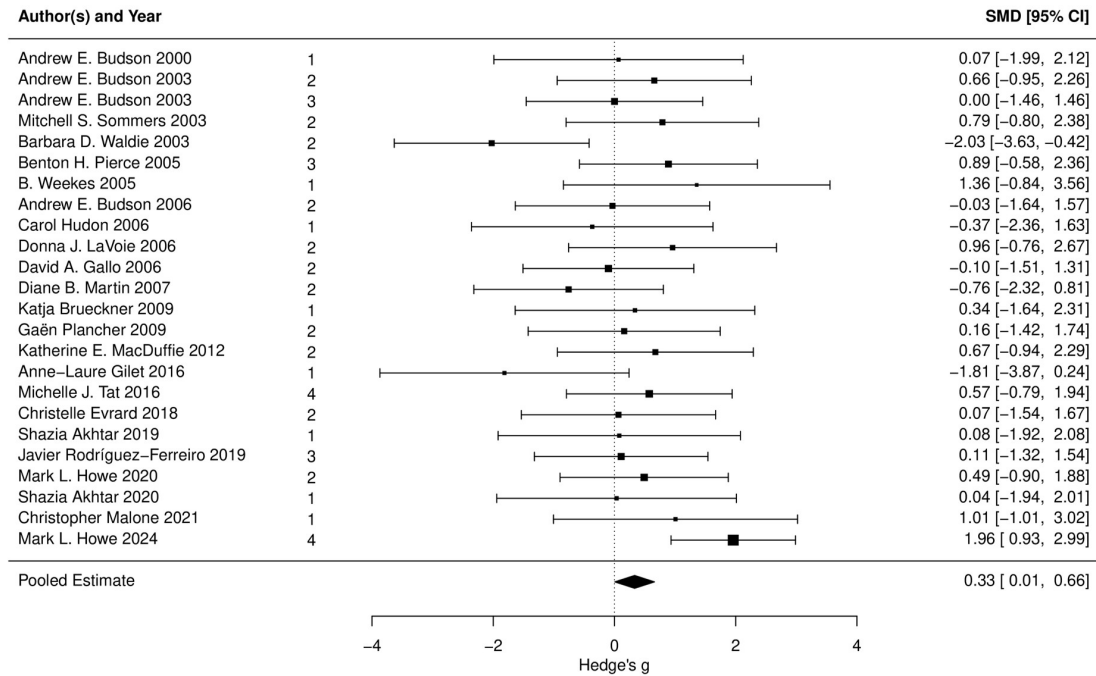


Note: The pooled effect sizes, along with 95% confidence intervals (CI).

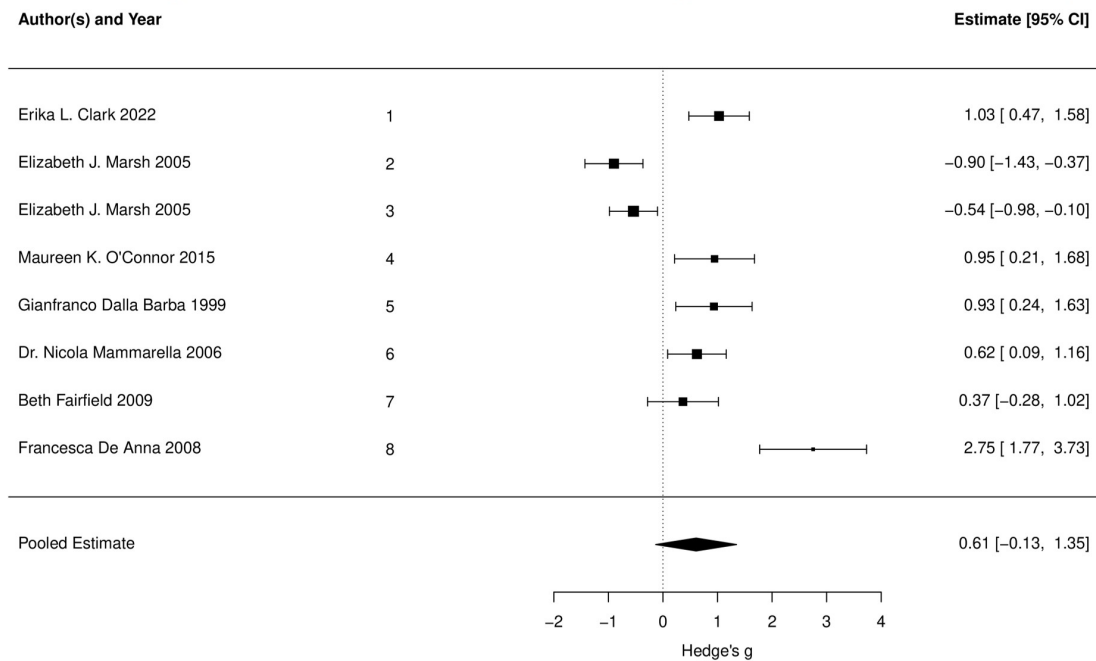
Figure 4

Forest plots for differences in false memory between older adults and MCI/AD.

(A) Forest plot of older adults vs. MCI/AD in spontaneous false memory



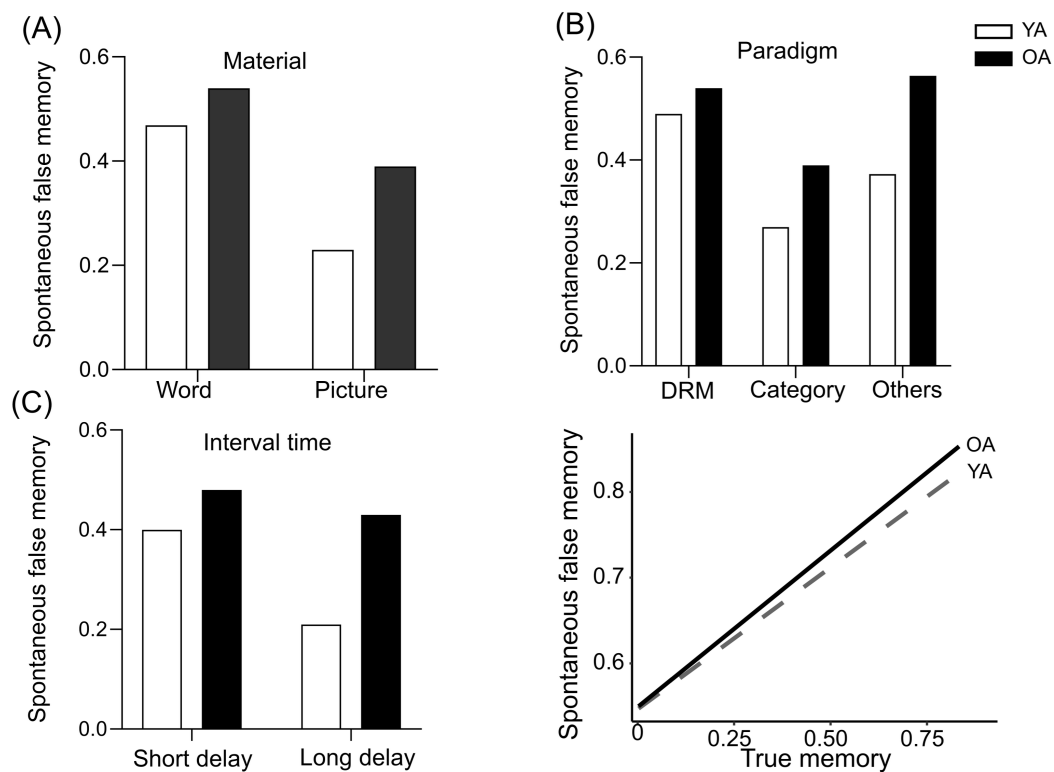
(B) Forest plot of older adults vs. MCI/AD in suggestion-induced false memory



Note: The pooled effect sizes, along with 95% confidence intervals (CI).

Figure 5

Proportion of spontaneous false memory for younger and older adults by moderators.

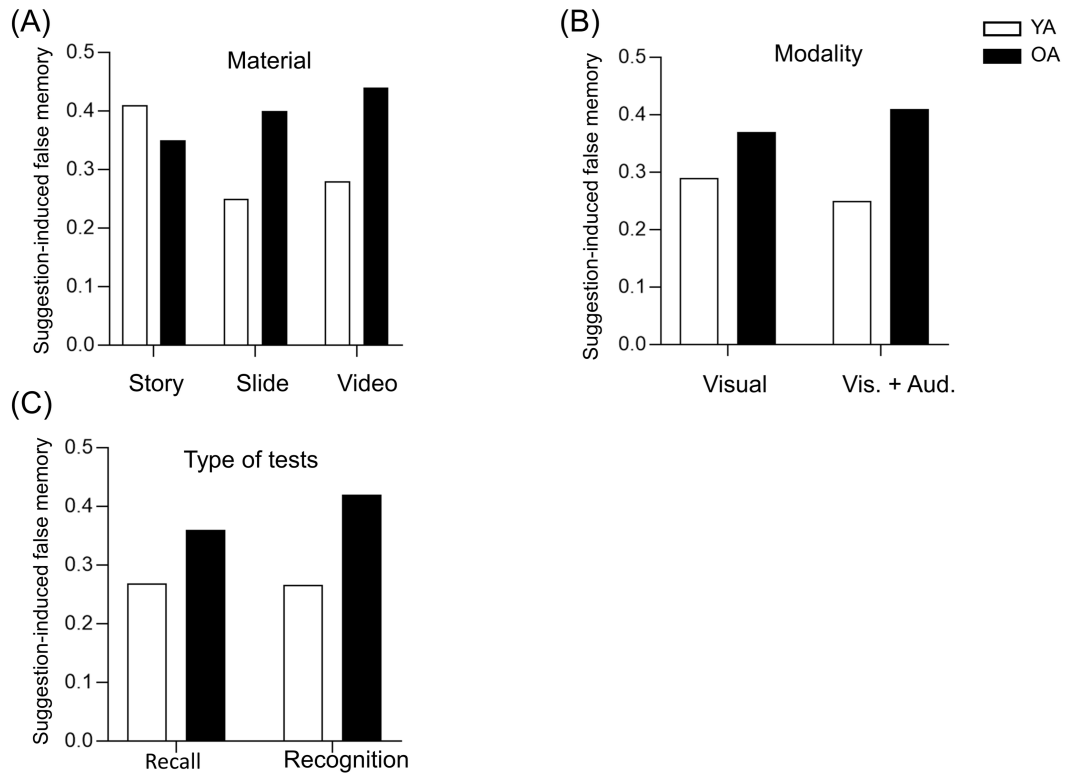


Notes: False alarm rates of critical lures for younger and older adults in spontaneous false memory moderated by (A) material, (B) paradigm, (C) interval time between encoding and retrieval and (D) true memory.

YA = younger adults, OA = older adults; DRM = the Deese/Roediger-McDermott paradigm.

Figure 6.

Proportion of suggestion-induced false memory for younger and older adults by moderators.



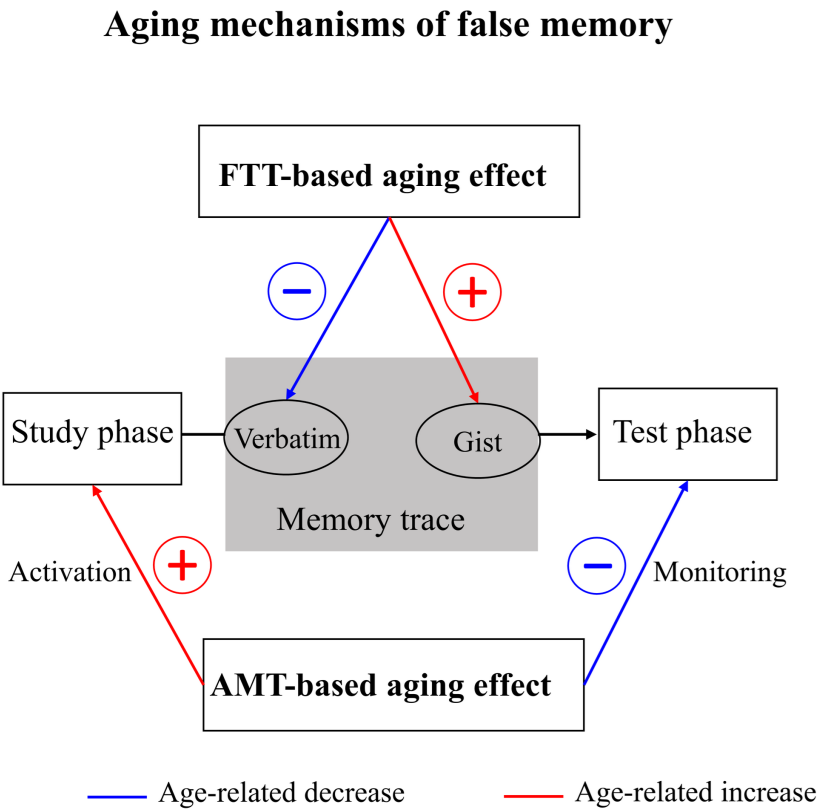
Notes: Proportions of suggestion-induced false memory for younger and older adults moderated by

(A) material, (B) modality, and (C) type of tests.

YA = younger adults, OA = older adults.

Figure 7.

Schematic illustration of aging mechanisms in false memory



Note. Based on the aging effect from the meta-analysis on 150 articles with 414 independent effect sizes, older adults are more susceptible to false memory than younger adults. According to the results of moderating analysis, we posit that the decline in verbatim memory trace (FTT-based) and monitoring functions (AMT-based), combined with semantic hyperactivation during study phase (AMT-based), may account for this aging effect in false memory. FTT = the Fuzzy-Trace Theory; AMT = the Activation-Monitoring Theory.

Table 1

Main effect and heterogeneity in random effect model and three-level model.

Comparisons	Random effect		Removed outliers		Three-level		Removed outliers	
	Main effect	Heterogeneity	Main effect	Heterogeneity Q	Main effect	Heterogeneity Q	Main effect	Heterogeneity Q
	g [95%CI]	Q (p)	g [95%CI]	(p)	g [95%CI]	(p)	g [95%CI]	(p)
YA vs. OA								
Spontaneous	0.561 [0.476,	1147.611 (p	0.515 [0.443,	905.538 (p	0.538 [0.432,	1147.611 (p	0.493 [0.410,	905.538 (p
	0.646] ***	< .001)	0.586] ***	< .001)	0.644] ***	< .001)	0.576] ***	< .001)
Suggestion-induced	0.533 [0.351,	1194.827 (p	0.499 [0.328,	1118.056 (p	0.460 [0.255,	1194.827 (p	0.435 [0.239,	1118.056 (p
	0.714] ***	< .001)	0.669] ***	< .001)	0.665] ***	< .001)	0.630] ***	< .001)
OA vs. MCI/AD								
Spontaneous	0.417 [0.073,	594.992 (p	0.314 [0.024,	489.113 (p	0.486 [0.053,	594.992 (p	0.333 [-0.003,	489.113 (p
	0.761] *	< .001)	0.605] *	< .001)	0.919] *	< .001)	0.668] .	< .001)
Suggestion-induced	0.608 [-0.133,	71.788 (p < .001)	—	—	0.608 [-0.286,	71.788 (p < .001)	—	—
	1.349]				1.502]			

Note. YA = younger adults, OA = older adults, MCI = mild cognitive impairment, AD = Alzheimer's' diseases; *** p < 0.001.

Table 2*Moderator Analysis for spontaneous false memory*

Moderators	Variable type	N of studies (K)	N of effect size (E)	Intercept/ Hedges' g (95%CI)	β (95%CI)	Test statistic	p	Var. Level 3	Var. Level 2
YA vs. OA									
Study									
<i>Modality</i>		145	237			$F(2, 234) = 2.736$	.067	0.144	0.072
Auditory	Categorical		50	0.470 (0.300, 0.640)					
Visually	Categorical		157	0.548 (0.447, 0.650)	0.079 (-0.149, 0.277)				
Vis. + Aud.	Categorical		30	0.265 (0.047, 0.483)	-0.205 (-0.477, 0.067)				
<i>Material</i>		142	232			$F(2, 231) = 18.847$	.001	0.121	0.069
Pictures	Categorical		46	0.866 (0.681, 1.051)					
Words	Categorical		186	0.426 (0.341, 0.511)	-0.442(-0.643, -0.241)				
<i>List number</i>	Continuous	144	236	0.448 (0.342, 0.554)	0.004 (-0.002, 0.010)	$F(1, 234) = 1.989$	.160	0.154	0.069
<i>List length</i>	Continuous	139	229	0.374 (0.150, 0.598)	0.012 (-0.006, 0.030)	$F(1, 227) = 1.603$	.207	0.164	0.063
Test									
<i>Type of test</i>		145	237			$F(2, 231) = 1.442$	.239	0.153	0.069
Recall	Categorical		59	0.537 (0.388, 0.686)					
Recognition	Categorical		161	0.457 (0.355, 0.558)	-0.080 (-0.258, 0.098)				

Moderators	Variable type	N of studies (K)	N of effect size (E)	Intercept/ Hedges' g (95%CI)	β (95%CI)	Test statistic	p	Var. Level 3	Var. Level 2
Recall+ Recognition	Categorical		17	0.672 (0.438, 0.906)	0.135 (-0.106, 0.376)				
Interval		141	228			$F(2, 223) = 15.268$	.001	0.139	0.060
Short delay	Categorical		207	0.451 (0.368, 0.534)					
Long delay	Categorical		21	1.124 (0.797, 1.450)	0.672 (0.333, 1.011)				
Response bias	Continuous	71	104	0.428 (0.294, 0.561)	0.103 (-0.029, 0.234)	$F(1, 102) = 2.397$	.125	0.165	0.096
True memory	Continuous	129	207	0.524 (0.433, 0.615)	0.078 (0.005, 0.151)	$F(1, 205) = 4.472$	.036	0.146	0.055
General									
Paradigm		145	237			$F(2,234) = 11.755$	.001	0.122	0.068
DRM	Categorical		144	0.362 (0.268, 0.457)					
Category	Categorical		78	0.732 (0.585, 0.880)	0.370 (0.196, 0.544)				
Others	Categorical		15	0.875 (0.554, 1.195)	0.513 (0.180, 0.845)				
Age									
YA	Continuous	134	219	-0.107 (-0.908, 0.693)	0.030 (-0.009, 0.069)	$F(1, 217) = 2.309$	.130	0.152	0.067
OA	Continuous	135	221	0.514 (0.018, 1.010)	0 (-0.007, 0.007)	$F(1, 219) = 0.001$	.972	0.153	0.071
Education									
YA	Continuous	73	123	0.560 (0.378, 0.742)	0 (-0.008, 0.009)	$F(1, 121) = 0.007$	.933	0.173	0.050
OA	Continuous	76	132	0.657 (0.166, 1.148)	-0.006 (-0.040, 0.028)	$F(1, 130) = 0.115$	.736	0.181	0.054

Moderators	Variable type	N of studies (K)	N of effect size (E)	Intercept/ Hedges' g (95%CI)	β (95%CI)	Test statistic	<i>p</i>	Var. Level 3	Var. Level 2
<i>Sex</i>									
YA	Continuous	47	84	0.476 (-0.067, 1.019)	0.167 (-1.129, 1.463)	$F(1, 82) = 0.066$	.798	0.135	0.128
OA	Continuous	47	84	0.559 (-0.165, 1.282)	-0.035 (-1.654, 1.585)	$F(1, 82) = 0.002$	.966	0.135	0.128
<i>Country</i>		124	207			$F(2, 204) = 0.015$	.986	0.172	0.069
GBR	Categorical		17	0.421 (0.085, 0.756)					
USA	Categorical		157	0.450 (0.344, 0.556)	0.030 (-0.323, 0.382)				
CHN	Categorical		33	0.453 (0.212, 0.694)	0.032 (-0.381, 0.446)				
<i>Culture</i>		145	237			$F(1, 235) = 0.121$	.729	0.157	0.068
Eastern	Categorical		33	0.455 (0.221, 0.688)					
Western	Categorical		204	0.499 (0.409, 0.588)	0.044 (-0.206, 0.294)				
<i>Publication year</i>	Continuous	145	237	14.997 (-7.005, 36.999)	-0.007 (-0.018, 0.004)	$F(1, 235) = 1.687$	.195	0.154	0.069
OA vs. MCI/AD									
Study									
<i>Modality</i>		29	47			$F(2, 44) = 0.503$	.608	0.309	0.617
Auditory	Categorical		10	0.035 (-0.667, 0.738)					
Visually	Categorical		22	0.442 (-0.067, 0.952)	0.407 (-0.461, 1.275)				
Vis. + Aud.	Categorical		15	0.434 (-0.269, 1.108)	0.399 (-0.574, 1.372)				

Moderators	Variable type	N of studies (K)	N of effect size (E)	Intercept/ Hedges' g (95%CI)	β (95%CI)	Test statistic	<i>p</i>	Var. Level 3	Var. Level 2
<i>Material</i>		29	47			$F(1, 45) = 7.149$	.010	0.273	0.559
Pictures	Categorical		8	1.217 (0.478, 1.956)					
Words	Categorical		39	0.131 (-0.221, 0.482)	-1.086 (-1.905, -0.268)				
<i>List number</i>	Continuous	29	47	0.109 (-0.552, 0.769)	0.033 (-0.051, 0.118)	$F(1, 45) = 0.621$	.435	0.278	0.675
<i>List length</i>	Continuous	28	46	1.224 (0.185, 2.263)	-0.078 (-0.164, 0.009).	$F(1, 44) = 3.298$	.076	0.210	0.696
Test									
<i>Type of test</i>		29	47			$F(2, 44) = 2.559$	.089	0.262	0.624
Recall	Categorical		11	-0.227 (-0.864, 0.410)					
Recognition	Categorical		30	0.587 (0.189, 0.985)	0.814 (0.063, 1.565)				
Recall+	Categorical		6	-0.070 (-0.884, 0.745)	0.157 (-0.743, 1.058)				
Recognition									
<i>Response bias</i>	Continuous	15	26	0.316 (0.016, 0.616)	0.046 (-0.085, 0.178)	$F(1, 24) = 0.528$	.474	0.220	0.045
<i>True memory</i>	Continuous	20	35	0.333 (-0.247, 0.912)	0.272 (-0.116, 0.660)	$F(1, 33) = 2.032$	.163	0.145	0.617
General									
<i>Paradigm</i>		29	47			$F(2, 44) = 0.466$	.631	0.325	0.657
DRM	Categorical		26	0.212 (-0.225, 0.650)					
Category	Categorical		16	0.580 (-0.052, 1.213)	0.368 (-0.401, 1.137)				
Others	Categorical		5	0.363 (-0.768, 1.493)	0.150 (-1.062, 1.362)				

Moderators	Variable type	N of studies (K)	N of effect size (E)	Intercept/ Hedges' g (95%CI)	β (95%CI)	Test statistic	<i>p</i>	Var. Level 3	Var. Level 2
<i>Age</i>									
OA	Continuous	27	45	6.998 (-1.012, 15.008)	-0.090 (-0.198, 0.018)	$F(1, 43) = 2.852$	.099	0.354	0.774
MCI/AD	Continuous	27	45	9.819 (3.900, 15.737)	-0.126 (-0.204, -0.048)	$F(1, 43) = 10.581$	.002	0.115	0.642
<i>Education</i>									
OA	Continuous	23	35	-0.345 (-1.716, 1.027)	0.054 (-0.047, 0.156)	$F(1, 33) = 1.917$	.282	0.000	0.872
MCI/AD	Continuous	23	35	-0.351 (-1.801, 1.098)	0.057 (-0.055, 0.169)	$F(1, 33) = 1.084$	.305	0.000	0.875
<i>Sex</i>									
OA	Continuous	11	18	0.243 (-0.728, 1.214)	0.193 (-2.105, 2.491)	$F(1,16) = 0.032$	.861	0.030	0.070
MCI/AD	Continuous	11	18	-0.106 (-0.648, 0.436)	0.813 (-0.150, 1.776)	$F(1,16) = 3.205$	.092	0.000	0.066
<i>MMSE</i>									
OA	Continuous	19	27	-18.268 (-35.502, -1.035)	0.647 (0.051, 1.243)	$F(1, 25) = 5.004$	.034	0.000	0.845
MCI/AD	Continuous	24	39	-4.310 (-8.485, -0.136)	0.199 (0.022, 0.376)	$F(1, 37) = 5.164$	.029	0.000	0.690
<i>Country</i>									
		26	41			$F(2, 38) = 4.631$	.016	0.000	0.642
GBR	Categorical		26	1.096 (0.506, 1.686)					
FRA	Categorical		6	-0.263 (-0.969, 0.443)	-1.359 (-2.279, -0.440)				
USA	Categorical		9	0.381 (0.037, 0.725)	-0.715 (-11.398, -0.033)				
<i>Publication year</i>									
	Continuous	29	47	-95.689 (-179.961, -9.418)	0.047 (0.005, 0.090)	$F(1,45) = 5.037$	.030	0.260	0.602

Note. YA = younger adults, OA = older adults, MCI = mild cognitive impairment, AD = Alzheimer's' diseases, DRM = The Deese/Roediger-McDermott paradigm, GBR = United Kingdom of Great Britain and Northern Ireland, USA = United States of America, CHN = China, FRA = France.

Table 3

Moderator Analysis for the age effect (younger vs. older adults) on suggestion-induced false memory

Moderators	Variable type	N of studies (K)	N of effect size (E)	Intercept/ Hedges' g (95%CI)	β(95%CI)	Test statistic	<i>p</i>	Var. Level 3	Var. Level 2
Study									
<i>Modality</i>		81	115			$F(2, 113) = 6.532$	.012	0.451	0.297
Visually	Categorical		52	0.154 (-0.132, 0.441)					
Vis. + Aud.	Categorical		63	0.651 (0.394, 0.908)	0.497 (0.112, 0.881)				
<i>Material</i>		66	91			$F(2, 88) = 3.248$	.044	0.277	0.340
Slide	Categorical		26	0.751 (0.379, 1.122)					
Video	Categorical		54	0.569 (0.323, 0.815)	-0.182 (-0.627, 0.264)				
Story	Categorical		11	-0.094 (-0.648, 0.460)	-0.845 (-1.511, -0.178)				
<i>Misinformation</i>		67	89			$F(2, 86) = 0.317$	.729	0.592	0.399
Narrative	Categorical		48	0.388(0.051, 0.725)					

Moderators	Variable type	N of studies (K)	N of effect size (E)	Intercept/ Hedges' g (95%CI)	β (95%CI)	Test statistic	<i>p</i>	Var. Level 3	Var. Level 2
Photograph	Categorical		11	0.618 (-0.059, 1.296)	0.230 (-0.526, 0.987)				
Question	Categorical		30	0.301 (-0.108, 0.710)	-0.087 (-0.617, 0.444)				
Test									
Type of test		83	116			$F(2, 114) = 3.911$	.050	0.493	0.287
Recall	Categorical		49	0.212 (-0.082, 0.506)					
Recognition	Categorical		67	0.602 (0.345, 0.859)	0.390 (-0.001, 0.781)				
Interval		69	97			$F(1, 95) = 0.454$	.502	0.754	0.581
Short delay	Categorical		74	0.342 (0.079, 0.604)					
Long delay	Categorical		23	0.522 (0.060, 0.983)	0.180 (-0.351, 0.711)				
General									
Paradigm		83	117			$F(1, 72) = 0.015$	.902	0.525	0.284
Misinformation	Categorical		90	0.428 (0.207, 0.650)					
Others	Categorical		27	0.458 (0.027, 0.889)	0.030 (-0.454, 0.514)				

Moderators	Variable type	N of studies (K)	N of effect size (E)	Intercept/ Hedges' g (95%CI)	β (95%CI)	Test statistic	<i>p</i>	Var. Level 3	Var. Level 2
<i>Age</i>									
YA	Continuous	72	104	-1.012 (-2.289, 0.265)	0.074 (0.014, 0.133)	$F(1, 102) = 5.859$	.015	0.307	0.290
OA	Continuous	75	107	-3.601 (-7.287, 0.085)	0.057 (0.006, 0.108)	$F(1, 105) = 4.877$	.027	0.288	0.287
<i>Education</i>									
YA	Continuous	44	65	1.035 (-2.862, 4.932)	-0.030 (-0.314, 0.254)	$F(1, 63) = 0.042$	.837	0.399	0.411
OA	Continuous	47	69	6.315 (3.787, 8.842)	-0.374 (-0.540, -0.207)	$F(1, 67) = 19.348$	.001	0.115	0.418
<i>Sex</i>									
YA	Continuous	28	35	0.344 (-0.590, 1.277)	-0.280 (-2.667, 2.108)	$F(1, 33) = 0.057$	.813	0.394	0.000
OA	Continuous	28	35	0.054 (-0.789, 0.896)	0.530 (-1.754, 2.815)	$F(1, 33) = 0.223$	.640	0.383	0.000
<i>Country</i>									
		66	96			$F(1, 94) = 0.023$	.881	0.446	0.305
GBR	Categorical		10	0.324 (-0.284, 0.931)					
USA	Categorical		86	0.373 (0.151, 0.595)	0.050 (-0.606, 0.705)				
<i>Publication year</i>									
	Continuous	83	116	52.851 (-5.115, 110.817)	-0.026 (-0.055, 0.003)	$F(1, 114) = 3.208$	.076	0.486	0.286

Note. YA = younger adults, OA = older adults, GBR = United Kingdom of Great Britain and Northern Ireland, USA = United States of America.