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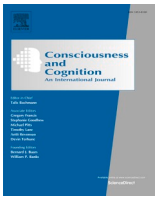

Full Length Article

Cueing autobiographical memory in young and older adults: an exploration of the effect of cue type on retrieval rates and memory characteristics

Ali Mair *

School of Psychology, University of Leeds, UK
Department of Psychology, University of York, UK

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ABSTRACT

Current theories of autobiographical memory (AM) emphasise the involvement of several non-memory auxiliary processes, such as executive function and mental imagery. However, the contribution of these processes to AM retrieval under different circumstances remains poorly understood, particularly in the context of ageing. The extent to which different AM tasks rely on auxiliary processing could explain variability in age-related AM deficits across different contexts. The current study explores the effect of cues varying in format (words, questions, sentences, photos, and videos) and content (e.g., event cues, evaluative cues, imagery cues) on AM retrieval rates in young and older adults. In Experiment 1, young and older adults (n = 101) retrieved AMs in response to a set of 208 cues; dependent variables were the proportion of cues that produced a memory, and ratings of the characteristics of the retrieved memories. Results showed that retrieval rates were influenced by both cue format and cue content, with cues that most closely mapped the task requirements producing the largest proportion of memories, regardless of other cue features (e.g., detail, imagery). Study 2 collected data from a separate group of 106 adults concerning their interpretation of the same cues, and analysed the responses in relation to the data from Experiment 1. Both retrieval rates and memory characteristics were related to features of the cues, such as specificity, theme, and emotional content. Data suggested that less easily accessed memories tended to be more autobiographically important. All materials and data – including 2500 brief descriptions of participants' autobiographical memories – are freely available for further exploration.

1. Introduction

Ageing is typically associated with a decline in autobiographical memory specificity (i.e., older adults recall fewer specific memories, or less detailed memories, than young adults; Addis et al., 2008; Levine et al., 2002; Piolino et al., 2006; Ford et al., 2014). However, recent research, including studies focusing on more naturalistic forms of retrieval, suggests that true age-related differences in AM may be overestimated by some laboratory tasks, which tend to constrain autobiographical retrieval in ways that are not yet fully understood (e.g., Berntsen et al., 2017; Gardner et al., 2015; Mair et al., 2017, 2021; Markostamou et al., 2023; Schryer & Ross, 2014; McVeigh et al., 2025). Methods employed across previous studies have varied considerably, and although performance on any given

* Address: School of Psychology, University of Leeds, Woodhouse Lane, Leeds LS2 9JT, UK.
E-mail address: a.mair@leeds.ac.uk.

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AM test is often taken to represent an individual's underlying AM ability, there are only weak correlations between scores on different tests (Mair, Poirier, & Conway, 2021) and between different approaches to scoring the same test (Kyung et al., 2015). Moreover, two recent studies have shown that (1) within a single sample of participants the magnitude of age effect in AM specificity depended on which test was used (Mair et al., 2021), and (2) older adults' retrieval goals can affect the number of episodic details they report (Mair, Poirier, & Conway, 2024). Together, these findings suggest that AM tests do not strictly measure AM ability, though precisely what they *do* measure remains unclear. This is an important question, because the development of interventions to improve AM in ageing depend on knowing the circumstances under which support is needed, as well as the most appropriate cognitive target for intervention.

Current theories of AM suggest that retrieval involves the complex interaction of multiple different cognitive systems (e.g., Conway & Pleydell-Pearce, 2000; Rubin, 2005, 2012), involving both memory processes and "working-with-memory" processes such as executive function (Moscovitch, 1992). For example, according to Rubin's (2012) model, AM is supported by a set of basic systems, including event memory, narrative reasoning, sensory processing, emotion, pain, vestibular function, and others. These systems operate independently, but their processing is coordinated by three different coordinating systems: a hippocampal system that binds together co-occurring activity, an emotion system that codes violations of expectation, and a frontal search and retrieval system that deals with cues and responses, including inhibition of irrelevant responses. According to this model, the relative contribution of each of the basic and coordinating systems is context-dependent. However, when AM tests are administered to young and older adults, there is typically little consideration of how these different systems might be recruited. Understanding the influence of auxiliary processes on memory is especially relevant in the context of ageing, since several candidate processes such as executive function (e.g., Clarys et al., 2009; Ferguson et al., 2021; Fjell et al., 2017), visual imagery (Dror & Kosslyn, 1994; Gulyás et al., 2022), and self-initiated processing (Morcom, 2016) are also generally impaired or reduced in older age. Importantly, these auxiliary processes are separate from memory per se, and each particular process may be required to a greater or lesser degree depending on the demands of a particular task or retrieval attempt. However, because their influence on task performance remains poorly understood, it is possible that difficulties with some of these processes may cause typical AM tests to inflate estimates of AM impairment in older adults. This is one possible reason why age-related memory deficits tend to be harder to detect in more naturalistic settings, when the remember is subject to fewer external constraints (e.g., rules of retrieval that must be followed; Berntsen et al., 2017; Markostamou et al., 2023; Schnitzspahn et al., 2020). An important question is therefore whether age-related AM deficits are not deficits of memory per se, but rather reflect deficits, or differences, in one or more of the auxiliary processes or systems supporting memory retrieval.

One way to manipulate the retrieval demands of an AM task is through the use of different retrieval cues. In the lab, these cues are most commonly generic single words (e.g., *happy*) or time periods/contexts (e.g., *high school*), both of which have the advantage that they are applicable to a wide range of people. In everyday life, however, a cue could be almost anything in the environment (external or internal), and a substantial proportion of the cues that trigger a conscious effort to retrieve a specific AM are likely to be specific rather than generic (e.g., a friend asks: "Do you remember the restaurant we went to on the last night of our holiday?"). In addition, AMs that are retrieved in everyday life are often retrieved involuntarily – that is, without deliberate intention – and these involuntary memories are most often cued by specific features of the external environment (Berntsen, 1998). Involuntary memories have been shown to come to mind faster, and to be more specific than intentionally retrieved memories (Schlagman & Kvavilashvili, 2008) and are also less sensitive to ageing (Berntsen et al., 2017). Most laboratory measures of AM therefore do not represent the ways in which AMs are most often retrieved in everyday life.

Several previous studies have investigated the effect of cue type manipulations on AM retrieval latencies and the number of memories retrieved. These studies have shown that factors such as cue concreteness, emotionality, and familiarity can influence how easily AMs come to mind. For example, concrete or high-imageability words lead to faster retrieval than abstract or low-imageability words (Rasmussen & Berntsen, 2014; Rubin & Schulkind, 1997; Uzer, 2016; c.f. Guler & Mackovichova, 2019), and presentation of physical objects leads to retrieval of more AMs compared with presentation of their verbal signifiers (Kirk & Berntsen, 2018). On the other hand, one study found that although spatial location cues (e.g., *park*, *classroom*) accessed AMs more quickly than event theme cues (e.g., *travelling*, *memorable meals*), the latter produced a greater number of memories (Sheldon & Chu, 2017). In terms of emotionality, positively valenced cues have been shown to produce more AMs with faster response latencies than negatively valenced cues, while emotionally arousing cues, whether positive or negative, are also associated with faster response latencies (Jakubowski & Francini, 2023; Schulkind & Woldorf, 2005; Sheldon et al., 2020). Cues that are more personal (e.g., friends'names) or more familiar also lead to faster retrieval than more generic or less familiar cues (Gurguryan et al., 2024; Harris & Berntsen, 2019; Jakubowski & Francini, 2023; Uzer & Brown, 2017). Recent work using a retrieve-aloud procedure has demonstrated that the specificity of a cue influences participants' retrieval strategy (Mace, Staley, & Sopoci, 2021).

The type of cue can also affect the kind of memories that are retrieved. Most previous investigations have focused on the concreteness or sensory properties of the cue, which might also be described as *nearness to experience*. For example, experience-near cues appear to access memories from an earlier age: age at encoding is younger for word-cued memories than memories cued by the concept of personal importance (Koppel & Berntsen, 2015), younger for high-imagery vs. low imagery words (Rubin & Schulkind, 1997), and younger for odour-cued vs. word-cued memories (Chu & Downes, 2000). Age at encoding is also younger for words with which participants report less overall lifetime experience (Gurguryan et al., 2024). Highly imageable words have also been shown to cue more episodically detailed memories than less imageable words (Rasmussen & Berntsen, 2014), and pictures cue more detailed AMs than words (Belcher & Kangas, 2013; Ridout et al., 2016). There are also differences in the phenomenology of memories retrieved in response to different cues. Personal and emotion words produce memories rated as clearer, more emotional, more significant, and more well-rehearsed than memories cued by generic concrete words (Harris & Berntsen, 2019), and memories evoked by odours are rated higher in emotion and reliving than memories cued by words and pictures (Herz & Schooler, 2002; Willander & Larsson, 2007), though odour-cued memories are also less specific (Miles & Berntsen, 2011). In addition, memories cued by popular music are rated as

more vivid and containing more episodic detail than memories cued by famous faces (Belfi et al., 2016).

Together these studies demonstrate that the properties of a cue can influence both the ease with which it produces an AM and the properties of the AM it cues. Moreover, the findings suggest that cues high in imagery, or nearness to sensory experience, may predict retrieval success. Whether imagery is the underlying *reason* for retrieval success remains unclear, however, because the relatively controlled cue sets used in previous studies do not necessarily permit other explanations to be ruled out. For example, high-imagery cues could lead to faster retrieval because they promote the use of mental imagery processing during retrieval, allowing fast mapping of visual features to stored autobiographical representations. On the other hand, high-imagery cues may be more specific: a photo of a park differs from the word "park" in that it both specifies a particular *kind* of park, and disambiguates the concept of a park as a recreational space from other meanings of the word, such as the verb *to park*. More specific cues may therefore lead to faster retrieval because they reduce the amount of executive processing required, whether mental imagery is invoked or not. That is, more specific (less generic) cues may be more likely to cue direct, as opposed to generative, retrieval (e.g., Uzer & Brown, 2017; cf. Harris & Berntsen, 2019). There are several theoretically relevant ways in which cues may differ from one another, such as imagery, specificity, detail, meaning, and so on, all of which may exert separate influences on AM retrieval. However, it is difficult to disentangle these factors when only a relatively narrow range of cues is tested, and this has been the case in previous studies in which the prioritisation of experimental control has necessarily constrained the cues that can be compared to one another. For example, studies comparing odour cues to verbal and visual cues have been restricted to presenting cues for which clearly identifiable odours exist, such as coffee and onion (e.g., Goddard et al., 2005). Moreover, because -historically- datasets have not been publicly available, it is difficult to explore previous findings in more depth.

The present study takes a step back, and aims to present a detailed description of the effect of a wide range of different retrieval cues on AM retrieval, in both young and older adults. This study is not intended to provide a definitive answer about which auxiliary processes are involved in AM retrieval and to what extent, but rather to lay some groundwork – openly and transparently – for later investigations to address these important questions. By presenting a wide range of cues that vary along several different theoretically relevant dimensions, the intention of this paper is to explore patterns that may help to untangle the effects of different factors. Cues used in this study include words, sentences, specific questions, generic photographs, and generic video clips. These cues vary in the format in which they are presented: some formats are verbal, others are visual; some formats are specific, others are generic. Within each format, cues also vary in terms of the kind of content or theme they present (e.g., event cues, social cues, evaluative (meaningful) cues) – this variable will hereafter be referred to as cue subtype. As is described below, the categories of cues are only partially controlled (e.g., cues are not matched for meaning across format or subtype) – the aim was to test the effect of a greater breadth of cues, with the intention of providing a foundation for some interesting exploration and new insight. Here I present completely open materials and data, which I hope will also be of use to other researchers interested in exploring AM retrieval.

2. Experiment 1

Experiment 1 tested for effects of cue format and cue subtype on (1) retrieval success, that is, the proportion of times the cue produced an AM, and (2) the characteristics of the AMs that were retrieved. Five different cue formats were used, including words, sentences, questions, photographs, and videos. These formats varied in multiple ways: modality (verbal vs. visual), specificity, and the amount of detail they contained. Within each format, cues were divided into different subtypes (event words, location words, social words, and evaluative words; imagery sentences and evaluative sentences; event questions and evaluative questions; event photos, location photos, and object photos; event/location videos and imagery/object videos). Subtypes varied in the extent to which they were "experience-near" (such as event cues and location cues) or reflective/autobiographically meaningful (evaluative cues). The cue subtypes were not matched across the five different formats for two reasons: first, matching would be difficult to achieve given the type of information conveyed by each format. For example, it is very hard to find photographs that could be described as "evaluative" but that do not contain any objects, locations, or people, but this is relatively easy to achieve with verbal cues. Similarly, although a sentence can convey imagery or not, photographs and videos by their nature always convey imagery. Given the difficulty of matching subtypes across formats, any attempt to do so would have resulted in a much-restricted set of stimuli that would not capture the wide range of possible cues that this study intended to explore. The second reason for not matching the cue subtypes across formats was that the differences between the categories allowed for greater exploration of some of the factors that might affect retrieval. For example, if imagery is an important dimension in cueing AM, then not only should photos be more effective cues than words, but imagery sentences should also be more effective than non-imagery sentences. As such, cue formats and types were intended to vary independently across a range of different dimensions that could be relevant to memory retrieval, such as the extent to which they promote mental imagery processing, the amount of information they contain, and how directly they map onto task requirements (i.e., to retrieve a specific event memory). Given the exploratory nature of this study, and the lack of existing empirical data on the memory-relevant dimensions and relative weightings of different types of cue, this process was necessarily speculative. However, a worked example is available in Supplementary File 1 for illustrative purposes (see OSF page; https://osf.io/rnvqy/).

The pattern of effects in young and older adults was explored, with particular reference to the concepts of imagery and specificity, as these features have previously been found to affect AM retrieval (when cues are words), and are also relevant to ageing, given evidence of age-related deficits in imagery and executive processing.

2.1. Method

Participants. All participants who completed the study were included in the analysis. Participants were 51 young adults (aged

18–30, M = 24.39, SD = 3.56; 34 females, 7 males) and 50 older adults (aged 60–88, M = 69.58, SD = 5.85; 33 females, 16 males, 1 other/preferred not to say) recruited online through Prolific (https://www.prolific.co) in 2021. All participants were fluent English speakers who were residing in the UK at the time of testing, and were paid £6 on completion of the study. Participants self-reported having normal or corrected-to-normal vision, and self-reported their highest level of education. All participants in the young group and 96 % of participants in the older group had completed formal schooling up to at least age 16. In addition, 33 % of the young group and 32 % of the older group had completed a Bachelor's degree or equivalent, and a further 27 % of the young group and 38 % of the older group were educated to postgraduate level. The average level of education in each group was not significantly different ($t(99) = 0.51$, $p = 0.61$, $d = 0.10$). All older adults were retired at the time of testing. In the young group, 49 % were in full-time employment, 20 % were in part-time employment, and 31 % were not employed.

Design. The study used a 2 (age group: young vs. older) × 5 (cue format: words vs. sentences vs. questions vs. photographs vs. videos) mixed design, with repeated measures on the second factor. Subtypes of each cue format were explored in follow-up analyses. The main outcome measure was the proportion of memories retrieved in response to each cue format, with additional analyses exploring response latencies (measured from cue onset) and some of the characteristics of the retrieved memories, namely age at encoding, memory specificity, vividness, personal importance, and rehearsal.

Materials. A set of 208 retrieval cues was prepared for this study, consisting of 16 cues belonging to each cue subtype within each cue format – that is, there were 16 event words, 16 object photos, 16 evaluative sentences, and so on. Since the number of subtypes within each format differed, the total number of cues within each overall format also differed. Each format and subtype is described in detail below, and the full set of cues is available on the Open Science Framework project page (https://osf.io/rnvqy/).

Photo cues. All photos were royalty-free user-uploaded files from Pixabay (https://pixabay.com/) that were free to use without attribution. *Object photos* depicted a single identifiable object or category of objects, either without a background or with a plain background that did not show a particular location (e.g., a close up of different types of sweets, a fox sitting in grass). *Event photos* depicted scenes in which a person or people were shown engaging in an identifiable activity (e.g., watching a football match, arguing over a toy, playing in a river). *Location photos* depicted scenes of generic (non-famous) places that one might visit (e.g., a lake, a forest, a motorway), but did not show any people in the foreground engaging in a particular activity. Thus, although event photos often depicted a particular location (e.g., football stadium, river), location photos did not depict a particular event.

Video ***cues.*** All videos were royalty-free user-uploaded files from Pixabay (https://pixabay.com/) that were free to use without attribution. Videos were a minimum of 7 s in length, and were stripped of any audio before use. Only the first 7 s of each video was shown in the experiment. *Event/location* videos depicted moving scenes in which (a) a person or multiple people were shown engaging in a particular activity (e.g., having a snowball fight, watching a band play on stage, riding a merry-go-round) (b) multiple people were depicted in a particular location (e.g., a busy street scene, a busy beach scene) or (c) first-person perspective videos showing an identifiable activity or scene (e.g., driving, ice-skating, looking out of a plane window). In contrast, *imagery/object* videos did not depict any people. These videos depicted animals (e.g., a bee collecting nectar, a dog playing in grass), everyday objects (e.g., a coffee machine pouring a coffee, a dripping tap, a record player) or other moving images (e.g., waves on the surface of water, flames of a fire).

Word cues. An initial list of 118 words was generated with the aim of creating four categories – event words, location words, evaluative words, and social words – with words high and low in imagery, and high and low in emotion, in each category. In a pilot test, four independent participants were asked to match each word to the category they thought was most appropriate, and to rate on a sliding scale how emotional the word was (from zero to high emotion, whether positive or negative) and the ease with which it generated mental imagery. The results of the pilot test informed the selection of the 64 words that were included in the final stimulus list. Where possible, words were only included if all four raters agreed on the most appropriate category, but 6 of the 64 words were categorised according to a majority (3/4) agreement. Each category contained a mixture of words that were high and low in emotion and high and low in imagery, though these were not perfectly distributed due to a lack of consensus among raters for some words. Further details of the pilot, including the full word list with all word ratings, are available on the OSF page.

Sentence cues. The set of sentence cues consisted of 16 imagery sentences and 16 evaluative sentences. *Imagery sentences* were descriptive passages intended to evoke mental imagery. They included detailed references to sensory experience and ranged in length from 14 to 32 words (M = 20.88, SD = 5.21). Imagery sentences were collected from classic fiction (5 sentences), travel writing (5 sentences), and reviews of restaurants, art exhibitions, and music events (6 sentences). *Evaluative sentences* were intended to provoke more profound autobiographical thoughts, without reference to sensory experience. Evaluative sentences were collected from classic fiction (8 sentences), self-help books and essays (4 sentences) and newspaper problem pages (4 sentences), and ranged in length from 7 to 20 words (M = 13.13, SD = 3.65).

Question cues. The set of question cues consisted of 16 event questions and 16 evaluative questions. *Event questions* took the form of "Have you ever…?", with the text of the question probing for a specific, one-off event that was likely to have been experienced by many people (e.g., *Have you ever won a competition?* or *Have you ever rescued an animal?*). Evaluative questions, like evaluative sentences, were intended to provoke more profound autobiographical thoughts and therefore asked participants to consider the meanings behind their experiences, reflections on their relationships, life story, emotions, and so on (e.g., *What sort of person are you?* or *Have you ever had an experience that you later identified as a turning point in your life?*).

From the total set of 208 cues, 12 mixed experimental lists were generated each containing 52 cues – four of each subtype within each cue format (i.e., one quarter of the total set of cues). Each cue appeared in three different lists, co-occurring with three different cues from the same subset each time it appeared. The 12 cue lists are also available on the OSF project page.

Procedure. The study was carried out online using the Gorilla experimental platform (Gorilla, 2021). After providing informed consent and demographic data, participants were automatically assigned to one of the 12 experimental cue lists described above using the platform's inbuilt counterbalancing procedure. Participants were informed that they would see a series of cues and that, in

response, their task was to try to think of a personal memory that was unique (i.e., not a repeated event) and that lasted a day or less. The 52 cues were presented serially, in random order, and participants were required to press the spacebar whenever a memory came to mind. Participants were informed that they were not expected to think of a memory for every cue, but rather that the aim was to establish whether some cues led to memories more readily than others. This detail was included in order to avoid collecting a large number of non-memory responses in the case that participants felt forced to respond to every cue. Although it could have influenced participants to "give up" on cues that were perceived to be more difficult, such a pattern of responding would still be informative about the ease of retrieval. For the young adult participants, word cues, photo cues, and video cues were each presented for 5 s, and sentences and questions were presented for 7 s to allow sufficient time to read the text. For the older adults, word cues, photo cues and video cues were each presented for 7 s, and sentences and questions were presented for 10 s. The longer presentation times for older adults was intended to minimise between-group differences caused only by general slowing of reaction times in older adults (e.g., Salthouse, 1996), thereby allowing more direct comparison of the two groups on the rates of retrieval to each kind of cue.[1] Response latencies were measured from cue onset, and the length of the response window for each cue corresponded to its presentation time.

In cases where participants did retrieve a memory and pressed the spacebar, their reaction time was measured and they were then presented with an additional screen, which collected data about the retrieved memory. They were asked to (a) briefly describe the memory in one or two sentences, (b) indicate their age at the time the event happened, (c) indicate whether it was a one-off event or a repeated event, (d) indicate whether the event lasted less than a day or more than a day (e) rate how vivid the memory was, (f) rate how personally important the memory was, and (g) rate how much they had rehearsed the memory in the intervening period. Ratings were made on a sliding scale from 1 to 100, where 1 indicated that the memory was not at all vivid/important/rehearsed and 100 indicated that the memory was maximally vivid/important/rehearsed. No instructions were given about how to interpret these questions. The precise wording of these questions can be found on the OSF page. In cases where the spacebar was not pressed, the experiment automatically advanced to the next cue after the pre-determined presentation time had elapsed. A "continue" button was also provided on each page, which enabled participants to skip to the next cue if they felt they would not think of a memory for the current cue. Three attention checks were inserted into the experimental sequence, after 15 cues, after 30 cues, and after 45 cues. The attention checks consisted of simple tasks that had to be completed in a prescribed way in order to pass (e.g., pressing an on-screen button three times). A "continue" button was also provided on the attention check pages, in the same location as on each cue page, such that it was possible for a participant to miss the attention checks entirely if they completed the experiment by simply pressing "continue" repeatedly without engaging with the test. No participants failed more than one attention check, and all were retained in the sample for analysis.

3. Results

All experimental data are freely available on the OSF project page (https://osf.io/rnvqy/).

Data checking and processing. All participant responses were checked manually to ensure that spacebar presses were legitimate rather than accidental. This was achieved by collating all of the brief memory descriptions provided by the participants, and ensuring that they included a description of a memory. Three non-memory responses were identified, in which the participant indicated in the response box that the spacebar press was accidental; these responses, including the associated rating data, were excluded from the subsequent analysis, and the three trials were re-coded as non-responses.

Data belonging to one older adult was excluded from the analysis because their self-generated ID code, demographics, and the metadata associated with the response suggested the same person had completed the experiment twice; their first attempt was retained and their second attempt was removed.

The responses to the uniqueness (was the event one-off or repeated?) and duration (did it last less than a day or more than a day?) questions were initially used in combination to determine whether each response represented an episodic autobiographical memory (a unique event that lasted less than a day) or a non-episodic autobiographical memory (a repeated and/or temporally extended event, or an autobiographical fact such as *Jo is my sister*). A score of 1 was assigned for unique events, and a further score of 1 was assigned for those that lasted less than a day. A total score of 2 therefore indicated that the memory was episodic (both unique and less than a day), a score of 1 represented either a repeated or a temporally extended event, and a score of 0 represented either an event that was both repeated and temporally extended, or a memory that was not an event (e.g., an autobiographical fact). In total, 787 responses in the young adult group and 785 responses in the older adult group were classified as episodic. However, the brief descriptions were used, where possible, to confirm participants' answers to the uniqueness and duration questions. In cases where it was not possible to tell from the brief description, the classification based on responses to uniqueness and duration questions was retained. In a substantial minority of cases, the brief descriptions that were provided were clearly incompatible with the ratings, such that memories that the participant rated as unique and lasting less than a day in fact referred to repeated events (e.g., "This reminds me of my dad's wedding ring. When he played piano I would stare at his ring and think that his hands looked like mine"), temporally extended events (e.g., "going to Ibiza"), or autobiographical facts (e.g., "My mother was always accepting and supportive. She was proud of me"). Overall, there were 61 such responses in the young adult group (8 % of the memories self-rated as episodic) and 105 such responses in the older adult group (13 % of the memories self-rated as episodic). It is possible that in these cases the participants did retrieve episodic AMs, but that the brief descriptions did not accurately reflect the content of the retrieved memories, however excluding these responses from the episodic category gave a more conservative estimate of 726 episodic responses in the young adult group ($M = 14.24$, $SD = 8.40$)

[1] Supplementary File 7 contains additional analyses of the number of memories retrieved by both groups when the response windows were matched (i.e., excluding older adult responses submitted in the final seconds of their longer response windows).

and 680 episodic responses in the older adult group (M = 13.60, SD = 7.24). There were an additional 925 responses that participants self-rated as being non-episodic, all of which were checked and verified. The 166 reclassified responses were added to this group, giving a total of 1091 non-episodic memories (289 in the young adult group and 802 in the older adult group). One young adult did not retrieve any episodic AMs, and two young adults and one older adult did not retrieve any non-episodic AMs; these data were retained in the dataset as zeroes.

The brief descriptions of participants' memories, alongside the answers to the uniqueness and duration questions, are included in the available dataset on the OSF page.

Overall AM retrieval (episodic and non-episodic AMs). Overall response rates and the average memory ratings in young and older adults were compared first. The summary statistics are presented in Table 1. Older adults retrieved more memories than young adults overall ($t(99) = 5.38$, $p < 0.001$, $d = 1.07$), however when only episodic AMs were compared there was no difference between groups ($t(99) = 0.59$, $p = 0.55$, $d = 0.12$). Thus, the difference was caused by more retrieval of non-episodic AMs in older adults compared to young adults ($t(97) = 6.82$, $p < 0.001$, $d = 1.37$). Characteristics of the retrieved memories are presented separately for episodic and non-episodic responses in Table 2 and Table 3.

Across all responses, the mean response latency for older adults was significantly longer than for young adults ($t(99) = 10.78$, $p < 0.001$, $d = 2.15$). Ratings of memory importance ($t(99) = 1.31$, $p = 0.19$, $d = 0.26$) and vividness ($t(99) = 0.72$, $p = 0.48$, $d = 0.14$) did not differ between groups, but ratings of rehearsal were higher in young adults than older adults ($t(99) = 2.24$, $p = 0.03$, $d = 0.45$). Mean age at encoding was significantly later for older adults than for young adults ($t(99) = 16.86$, $p < 0.001$, $d = 3.36$).

For the 97 participants who retrieved both episodic and non-episodic AMs, the mean qualities of each were compared. Ratings were z-transformed (within participant) to account for potential bias in the use of the scales. Response latencies ($t(96) = 0.82$, $p = 0.41$, $d = 0.08$), age at encoding ($t(96) = 1.56$, $p = 0.12$, $d = 0.16$), and vividness ($t(96) = 0.49$, $p = 0.62$, $d = 0.05$) were similar for both types of response, but non-episodic AMs were more personally important ($t(96) = 5.69$, $p < 0.001$, $d = 0.58$) and more well-rehearsed ($t(96) = 4.88$, $p < 0.001$, $d = 0.50$) than episodic AMs.

Effect of cue format on retrieval rate. The next section concerns the number of memories that were retrieved in response to different cue formats: words, questions, sentences, photos, and videos. The dependent variable in these analyses is *retrieval rate*: the proportion of cues that produced a memory. Data are presented first for the total number of memories (episodic plus non-episodic), and afterwards for the number of (researcher-verified) episodic memories, as were required by the task instructions. Equivalent analyses of non-episodic memories are not included here, but are available in Supplementary File 4 on OSF. In addition, though response latency was also measured for all responses and may be another useful indicator of the ease with which memories are retrieved, differences in the available response window between age groups and cue formats make interpretation of these data difficult. Response latencies are therefore not explored further here, but analyses are available in Supplementary File 9.

All responses. As can be seen in Fig. 1, there were large main effects of both age ($F(1,99) = 28.68$, $p < 0.001$, $\eta_p^2 = 0.23$) and cue format ($F(4,396) = 96.86$, $p < 0.001$, $\eta_p^2 = 0.50$). Age and format interacted ($F(4,396) = 3.62$, $p = 0.007$, $\eta_p^2 = 0.04$), and follow up ANOVAs within each age group showed that though the format effect was present in both groups, it was larger in older adults (young adults: $F(4,200) = 40.7$, $p < 0.001$, $\eta_p^2 = 0.45$; older adults: $F(4,196) = 61.1$, $p < 0.001$, $\eta_p^2 = 0.55$). Post hoc pairwise comparisons with Holm correction showed that sentence cues produced fewer memories than any other cue type in both groups. However, aside from sentence cues, older adults retrieved relatively more memories in response to verbal cues as opposed to visual cues. In older adults, questions produced more memories than any other cue type, and word cues were not significantly different from photo or video cues. In contrast, in young adults, questions, photos, and videos produced a similar number of memories, and all three produced significantly more memories than word cues. Full statistical tests are reported in Supplementary File 3.

Episodic responses. When the analysis was restricted to only episodic memories, there was a similar effect of cue type on retrieval rate ($F(4,396) = 53.68$, $p < 0.001$, $\eta_p^2 = 0.35$), but this did not interact with age ($F(4,396) = 1.23$, $p = 0.30$, $\eta_p^2 = 0.01$), and there was no main effect of age ($F(1,99) = 0.16$, $p = 0.69$, $\eta_p^2 = 0.002$). Holm-corrected post hoc pairwise comparisons indicated that sentences and words produced fewer episodic memories than questions, photos, or videos (see Fig. 1). Full statistical tests are reported in Supplementary File 3 (see OSF page; https://osf.io/rnvqy/).

Effect of format within cue subtype. The next question was whether the significant effect of cue format described above was due to something inherent in the format itself (e.g., visual vs. verbal; specific vs. general) or whether the effect was driven by the subtype of cue within each format (e.g., event cues vs. evaluative cues). To explore this, subsets of the data were analysed in separate ANOVAs

Table 1
Overall response rates and characteristics of the responses in young and older adults.

	Mean (SD)	
	Young adults	Older adults
Total responses	19.90 (8.71)	29.64 (9.46)
Episodic AMs (verified)	14.24 (8.39)	13.60 (7.25)
Non-episodic AMs (verified)	5.67 (4.56)	16.04 (9.41)
Proportion episodic	0.70 (0.23)	0.48 (0.22)
RT (ms)	2746 (533)	3988 (623)
Age at encoding (years)	17.63 (3.69)	39.09 (8.29)
Personal importance (0–100)	54.12 (16.89)	49.85 (15.74)
Rehearsal (0–100)	43.82 (18.28)	35.77 (17.75)
Vividness (0–100)	69.23 (10.69)	71.05 (13.96)

Table 2
Mean characteristics of episodic vs. non-episodic AMs (SDs in brackets).

	Episodic AMs (n = 1406)	Non-episodic AMs (n = 1091)
Response latency (ms)	3363 (904)	3303 (1034)
Age at encoding (years)	28.34 (12.55)	27.57 (13.86)
Importance (0–100)	50.99 (16.31)	61.27 (20.58)
Rehearsal (0–100)	38.80 (17.84)	48.47 (21.30)
Vividness (0–100)	70.65 (12.84)	68.66 (18.50)

Table 3
Z-transformed memory ratings, by response type and age group.

	Episodic AMs		Non-episodic AMs	
	Young adults	Older adults	Young adults	Older adults
Age at encoding	0.01 (0.27)	0.004 (0.31)	−0.20 (0.72)	−0.02 (0.29)
Importance	−0.12 (0.25)	−0.22 (0.32)	0.17 (0.55)	0.19 (0.24)
Rehearsal	−0.10 (0.20)	−0.23 (0.37)	0.14 (0.63)	0.17 (0.28)
Vividness	−0.01 (0.24)	−0.08 (0.39)	−0.19 (0.71)	0.02 (0.28)

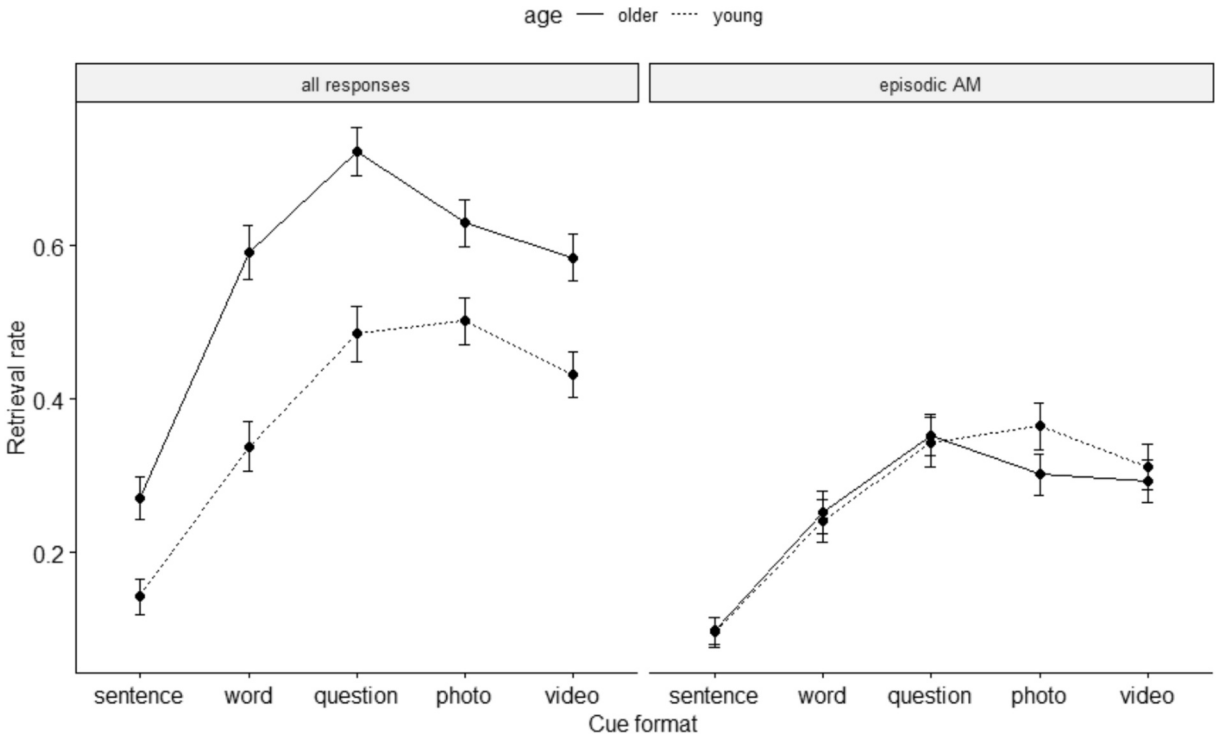

Fig. 1. Retrieval rates for young and older adults for each cue format. The left panel represents all responses (episodic and non-episodic memories combined) and the bottom panel represents episodic responses only. Note that retrieval rate is calculated as the proportion of times the cues produced a response, and is thus equated across formats despite each format containing a different number of cues. Error bars = +/- 1SE.

comparing the effect of cue format within the categories of event cues and evaluative cues; ANOVAs were performed for both the total retrieval rate and the retrieval rate restricted to episodic memories. The ANOVA for event cues compared the retrieval rate for words, photos, and questions, whereas the ANOVA for evaluative cues compared the retrieval rate for sentences, words, and questions. The pattern of results is presented in Fig. 2, and full statistical results are presented in Supplementary File 3. Both ANOVAs showed a main effect of format, and for event cues the format effect interacted with age. The pattern broadly replicated the overall effect of format described above, in that sentences produced fewer memories than other cue types, and questions produced more memories than other cue types. The latter was true especially in older adults, whereas young adults were cued equally well by photos and questions.

Effect of cue type on retrieval rate. The next analysis concerned whether, within each cue format, the type of cue (e.g., event cues, evaluative cues, location cues, social cues, etc.) affected the proportion of AMs that were retrieved. Retrieval rates for each cue type within each format are presented in Fig. 3, and full test results are presented in Supplementary File 3 (see OSF page; https://osf.io/

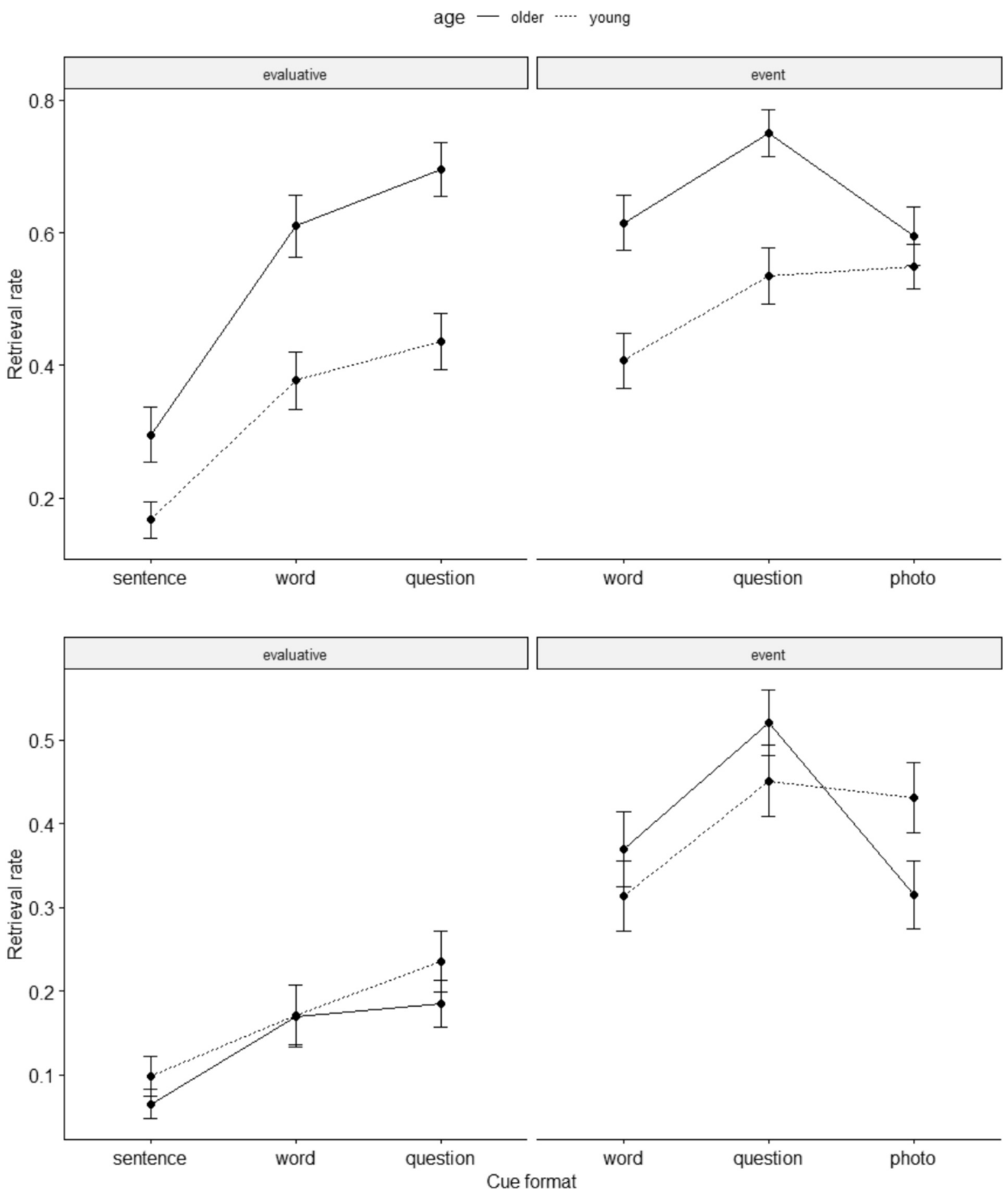

Fig. 2. Retrieval rates for young and older adults for each cue format within cue type. Left panels represent evaluative cues and right panels represent event cues. Top panels present all responses and bottom panels present episodic AMs only. Error bars = +/- 1SE.

rnvqy/). The results were similar for total responses and episodic responses, and showed that cue type did not affect retrieval rates for sentences, photos, or videos, but did affect retrieval rates for words and questions. More total memories ($F(1,99) = 6.21$, $p = 0.014$, $\eta_p^2 = 0.06$), and more episodic memories ($F(1,99) = 82.36$, $p < 0.001$, $\eta_p^2 = 0.45$), were produced in response to event questions than evaluative questions; neither of these effects interacted with age. For word cues, location words produced fewer total memories than all

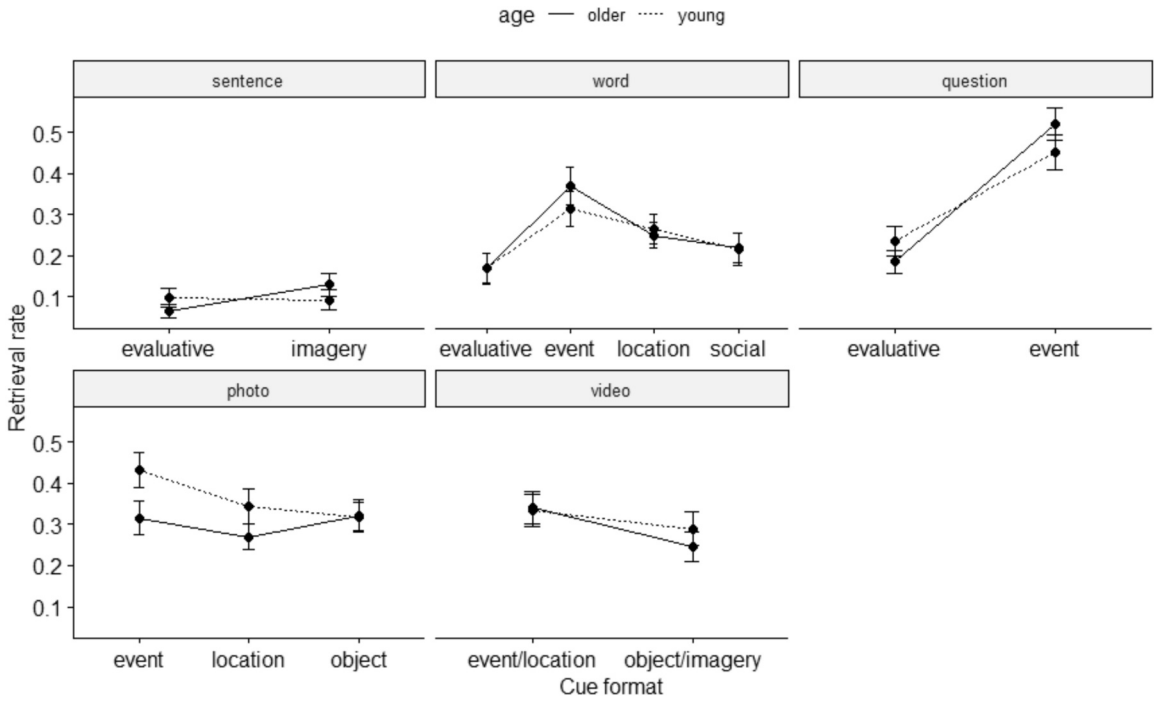

Fig. 3. Episodic retrieval rates for young and older adults for each cue type within each cue format (i.e., proportion of times the cue produced an episodic AM). Error bars = +/- 1 SE.

other types of word (all $p < 0.001$, $d = 0.36$–.45), and event words produced more episodic memories than all other types of word (vs. evaluative and social words, $p < 0.001$, $d = 0.46$; vs. location words $p = 0.03$, $d = 0.31$).

Characteristics of the retrieved memories. The following section explores the age at encoding of the memories that were retrieved, as well as ratings of personal importance, rehearsal, and vividness. In this section, results for all memories (episodic + non-

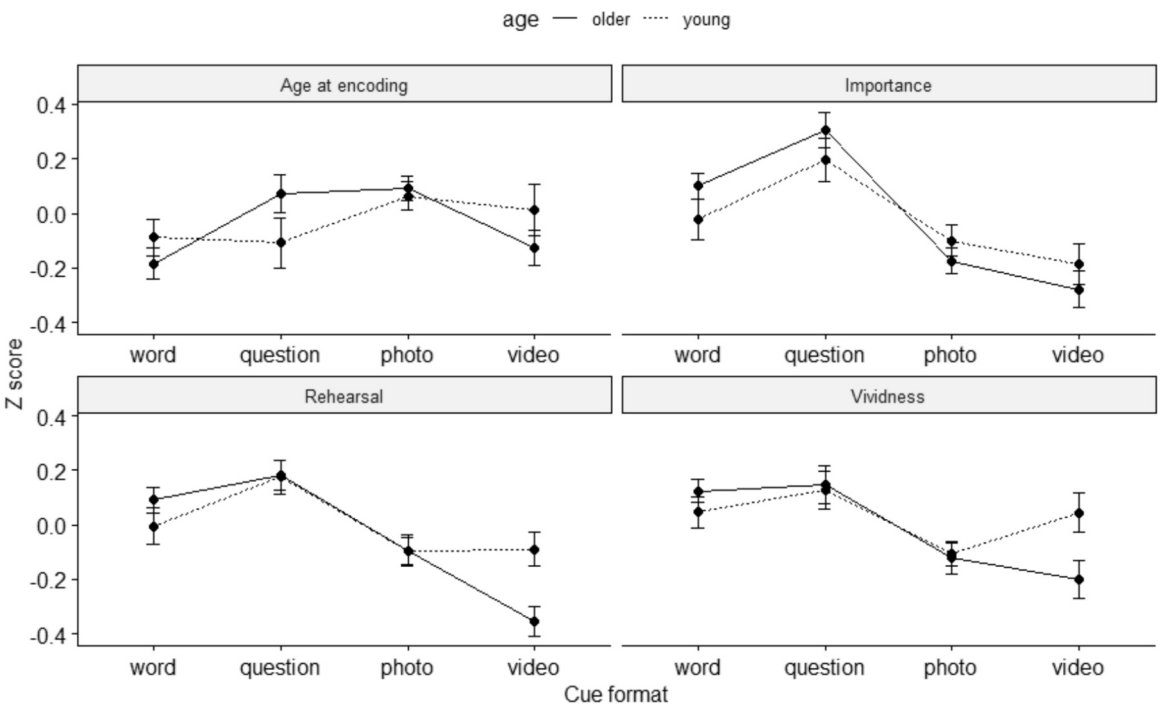

Fig. 4. Mean ratings (z scored) for retrieved memories in each cue format, in young and older adults. Error bars = +/- 1SE.

episodic) are reported. To account for individual differences in the way the rating scales were used, raw values for each measure were z-scored separately for each participant, such that a score of 0 represents the participant's average score, negative values indicate below-average ratings and positive values indicate above-average ratings. Sentence cues have been excluded from these analyses due to their low retrieval rates. A summary of the findings is reported below, and full statistical test results are reported in Supplementary File 4 (see OSF; https://osf.io/rnvqy/). Following a reviewer's suggestion, additional analyses of the age of the reported memories were carried out (i.e., age at encoding subtracted from the participant's age at the time of testing). These analyses are summarised below and reported in detail in Supplementary File 10 (see OSF; https://osf.io/rnvqy/). Note that the *age of memory* measure differs from *age at encoding* in that it is not z-scored, which preserves the true variance between, as well as within, participants. Supplementary File 8 (see OSF page; https://osf.io/rnvqy/) also contains histograms of the age at encoding reported by older adults, which shows evidence of a reminiscence bump and a recency effect that vary somewhat by cue format and subtype.

Cue format. Cue format affected the age at encoding ($F(3,285) = 2.80$, $p = 0.04$, $\eta_p^2 = 0.03$), personal importance ($F(3,285) = 18.57$, $p < 0.001$, $\eta_p^2 = 0.16$), rehearsal ($F(3,285) = 15.76$, $p < 0.001$, $\eta_p^2 = 0.14$), and vividness ($F(3,285) = 6.38$, $p < 0.001$, $\eta_p^2 = 0.06$) of the retrieved memories (see Fig. 4). Holm-corrected pairwise comparisons (see Supplementary File 4; https://osf.io/rnvqy/) showed that verbal cues (words and questions) produced more important, more rehearsed, and more vivid memories than visual cues (photos and videos). The age at encoding effect was driven by words cueing memories from a younger age than photos ($t(95) = 3.47$, $p = 0.005$, $d = 0.43$). Regarding the age of the retrieved memories, there was a significant interaction between cue format and age group ($F(3,279) = 4.32$, $p = 0.005$, $\eta_p^2 = 0.04$) wherein, for older adults only, memories cued by words and videos were more remote than those cued by photos and questions (see Supplementary File 10; https://osf.io/rnvqy/). However, none of these effects held when comparing cue format within the category of event cues, or within location cues (the only cue types to be represented both visually and verbally). As such, the most likely explanation is that the overall effect of cue format was driven by differences in cue subtype within each format.

Cue type. Within word cues, photos, and videos, cue type did not affect age at encoding or any of the z-scored memory ratings. However, evaluative questions produced more important ($F(1,88) = 74.56$, $p < 0.001$, $\eta_p^2 = 0.46$) and more rehearsed ($F(1,88) = 13.29$, $p < 0.001$, $\eta_p^2 = 0.13$) memories than event questions in both young and older adults. For age at encoding, there was an interaction with age such that in young adults evaluative questions cued more recent memories than event questions ($t(87) = 3.31$, $p = 0.001$, $d = 0.76$), whereas in older adults the age at encoding was similar for both question types ($t(87) = 1.67$, $p = 0.099$, $d = 0.36$). Regarding the age of memory analysis (which was not z-scored), there were significant effects of word type ($F(3,150) = 5.04$, $p = 0.002$, $\eta_p^2 = 0.09$) and photo type ($F(2,158) = 3.78$, $p = 0.025$, $\eta_p^2 = 0.05$), neither of which interacted with age, and a significant age by question type interaction ($F(1,86) = 7.49$, $p = 0.008$, $\eta_p^2 = 0.08$). In each case, pairwise differences were only observed in the older adult group. Location words and social words cued more remote memories than event words and evaluative words. In contrast, location photos cued more *recent* memories than event photos or object photos. For question cues, evaluative questions cued more remote memories than event questions. See Supplementary File 10 (https://osf.io/rnvqy/) for full statistical results and plots of these effects.

Summary of Experiment 1. The analyses of retrieval rates above suggest that both the format and subtype of the cue influence its success in producing a memory. Cue formats prompting the highest retrieval rates – questions, photos, and videos – varied in terms of visual imagery and the amount of information in the cue, though all three formats presented relatively specific information, in the sense that there was little room for different interpretations. However, sentence cues were extremely specific, yet produced very few memories overall. Photo and video cues produced more memories than word cues, but only in young adults. This is broadly consistent with previous studies showing the superiority of cues higher in imagery (e.g., Rasmussen & Berntsen, 2014; Rubin & Schulkind, 1997; Uzer, 2016), though the high retrieval rates for question cues in this study suggest that the superiority of pictorial cues may be due to their increased specificity, rather than the visual imagery they contain. In terms of the characteristics of the retrieved memories there was no evidence for an effect of cue format on ratings of AM importance, rehearsal, vividness, or age at encoding. However, for question cues, the memories retrieved in response to evaluative questions were more important and more rehearsed than those retrieved in response to events questions. Despite the categorical overlap with subtypes of words cues (i.e., the distinction between evaluative and event cues), the same pattern was not observed for these less specific verbal cues.

4. Study 2

One issue with the analysis of Experiment 1 is that, because no attempt was made to match cues across formats and types, these classifications could be seen as somewhat arbitrary. That is, format and type represent just two of the many ways in which these cues varied, and as can be seen in Figs. 2-4, retrieval rates varied widely within each of the assigned categories (see also Supplementary File 5, for plots of retrieval rates for individual cues within each cue format, collapsed across participants). The large amount of variability in how participants responded to the cues even within each category indicates that further exploration of the cues is warranted. In order to explore the meanings of the cues in more depth, a follow-up study was conducted in which a separate group of participants were asked to rate each of the cues on a range of different dimensions. The aim was then to explore whether any patterns emerged when considering retrieval rates in Experiment 1, in relation to the ratings given by the new sample of participants.

4.1. Method

Participants. A total of 116 participants were recruited via Prolific and a University of York database consisting of Psychology students. Ten participants were subsequently excluded due to failed attention checks. The remaining sample of 106 participants was 80 % female (85 females, 20 males, 1 no response). Ages ranged from 18 to 59 ($M = 27.93$, $SD = 7.98$). Twenty four percent of the

sample were educated to postgraduate level, 28 % to undergraduate level, 39 % to age 18, and 8 % to high school or less.

Design. The study used a single-question design, in which each participant was asked to evaluate a set of stimuli. There were 208 stimuli presented, and 10 questions were posed about each stimulus, but each participant only answered one question per stimulus, selected at random.

Materials and procedure. The stimuli that were evaluated by participants were the 208 retrieval cues used in Experiment 1. A list of questions was constructed for the purpose of collecting ratings of each individual cue. First, a separate group of young adult participants ($n = 12$; aged 18–26, $M_{age} = 19.33$; 9 females, 3 males) was asked to perform a word association task on a random selection of one quarter (52) of the cues. In the word association task, participants were serially presented with the cues and asked to type the first thing(s) they thought of on seeing the cue. They were asked to type between one and ten words or short phrases per cue. Responses to the word association task were collated, and the words and phrases associated with the cues that produced the most and least memories in Experiment 1 were examined to identify reoccurring themes. Four such themes were identified: safety, fear, childhood, and travel. Of these, safety tended to be associated with poorer cues (i.e., those that produced fewer memories) and the other three themes tended to be associated with good cues (i.e., those that produced more memories). These four themes formed the basis of four questions for this study (items 4, 5, 9, and 10). Because the themes of fear and safety represent emotional concepts, but differ on both emotional valence and emotional arousal, two further questions (item 3: positive high arousal, and item 6: negative low arousal) were added for balance. A further four questions were derived from the autobiographical memory literature. These questions concerned whether the cue was socially relevant (item 1), whether it involved the beginnings of scene construction (item 2), the extent to which it constrained the memory search space (item 7), and the extent to which it would require generative retrieval to produce a specific memory (item 8). The full set of questions is presented in Table 4.

For the main part of the follow-up study, the 106 participants were asked to answer these 10 questions about each of the 208 cues. Because of the large number of cues, each participant was only required to answer a single question about each one. The question that was posed for each cue for each participant was selected at random. Question-cue pairs were presented serially, with three clickable response options below: yes, no, and don't know.

Three attention checks were included at roughly equal intervals, and any participant who failed at least one of the checks was excluded ($n = 7$). Participants who exhibited a pattern of unusually low response times – defined as < 800 ms across multiple questions and cues – were also excluded ($n = 3$). Finally, individual responses taking < 500 ms were also excluded, as it was judged that it would be impossible to perceive the cue, make a decision, and provide a response within such a short window. This final exclusion criterion affected 20 participants in total. For the majority of these participants ($n = 14$) there was only one such response, and in other cases the number of excluded responses was 2 ($n = 2$), 3 ($n = 3$), or 5 ($n = 1$). For all 20 of these participants the remainder of their responses were checked carefully to establish whether there was any clear pattern suggesting failure to engage with the task, but no further exclusions were applied.

To prepare the data for analysis, the proportion of "yes" responses for each question-cue pair was calculated.

5. Results

Differences in cue themes across cue formats. The mean proportion of "yes" responses for cues within each cue format (words, questions, sentences, photos, and videos) is presented in Table 5. ANOVAs carried out for each of the 10 questions, using an adjusted alpha ($\alpha = 0.005$) to correct for multiple comparisons, showed that cue formats varied most in terms of the vagueness of the cues ($F(4,203) = 22.60$, $p < 0.001$, $\eta_p^2 = 0.31$) and the number of possible meanings they had ($F(4,203) = 15.30$, $p < 0.001$, $\eta_p^2 = 0.23$). Cue formats also varied in the extent to which the cues tended to be associated with locations ($F(4,203) = 6.47$, $p < 0.001$, $\eta_p^2 = 0.11$) and people ($F(4,203) = 10.30$, $p < 0.001$, $\eta_p^2 = 0.17$), and the extent to which they were related to travel ($F(4,203) = 6.23$, $p < 0.001$, $\eta_p^2 =$

Table 4
Questions used in Study 2 to explore cues in more depth.

Question	Theme	Source/reference
Does this cue involve (or conjure the thought of) a person or people?	person	Social nature of AM (e.g., Alea & Bluck, 2007; Vranić et al., 2018)
Does this cue involve (or conjure the thought of) a particular location or place?	scene	Importance of scene construction for memory retrieval (e.g., Hassabis & Maguire, 2007; Robin, 2018; Rubin & Umanath, 2015). See also Sheldon & Chu (2017).
Is this cue related to any of the following concepts: excitement, happiness, or elation?	happiness	Included to balance valence & arousal of items 4 and 5 (see also Schulkind & Woldorf, 2005; Sheldon et al., 2020)
Is this cue related to any of the following concepts: safety, contentment, or calmness?	safety	Word association task (see also Schulkind & Woldorf, 2005; Sheldon et al., 2020)
Is this cue related to any of the following concepts: fear, anxiety, or anger?	fear	Word association task (see also Schulkind & Woldorf, 2005; Sheldon et al., 2020)
Is this cue related to any of the following concepts: sadness, boredom, or weariness?	sadness	Included to balance valence & arousal of items 4 and 5 (see also Schulkind & Woldorf, 2005; Sheldon et al., 2020)
Does this cue have many different meanings or interpretations?	meanings	Cues that point to many different memories require executive processing to resolve interference (e.g., Mazzoni et al., 2014)
Is this cue vague?	vagueness	Cues that do not point to anything specific require generative retrieval processing (e.g., Conway & Pleydell-Pearce, 2000).
Is this cue associated with childhood?	childhood	Word association task
Is this cue related to travel or holidays?	travel	Word association task

0.11) and childhood ($F(4,203) = 4.87$, $p < 0.001$, $\eta_p^2 = 0.09$). There was no effect of cue format on emotion ratings (fear: $F(4,203) = 3.15$, $p = 0.015$, $\eta_p^2 = 0.06$; safety: $F(4,203) = 3.04$, $p = 0.018$, $\eta_p^2 = 0.06$; happiness: $F(4,203) = 1.78$, $p = 0.13$, $\eta_p^2 = 0.03$; sadness: $F(4,203) = 2.38$, $p = 0.053$, $\eta_p^2 = 0.05$).

Post hoc tests with Holm correction (available in full in Supplementary File 6; https://osf.io/rnvqy/) showed that the verbal cue formats (words, questions and sentences) all had more possible meanings than visual cue formats (photos and videos), and words were rated as more vague than all other cue formats. Photo cues were more strongly related to locations than all other cue formats except videos, and video cues were more strongly related to travel than all other cue formats except photos. Question cues related more to people and childhood than all other cue formats.

Associations between cue themes and retrieved memories. The next step was to explore the relationship between cue theme ratings and the memories retrieved in Experiment 1, independent of cue format and type categories used in Experiment 1. Correlations were calculated between the proportion of "yes" responses to each question for each cue, and (1) the rate at which the cue produced a response in Experiment 1, (2) response latency, (3) age at encoding of the memory, (4) rated importance, (5) rehearsal, and (6) vividness. For 2–6, within-participant z-scores were used to minimise bias. Heatmaps of the correlation coefficients are presented in Supplementary File 6, and a summary of the associations is presented in Table 6. In general, cues that were vague and could be interpreted in different ways produced fewer memories ($r \sim -0.30$), but the memories that were retrieved were rated as more important and more well-rehearsed, especially in older adults ($r = 0.12 - 0.37$). In contrast, location cues had the highest retrieval rates ($r \sim 0.40$), but the relationship with memory importance, rehearsal, and vividness was very weak ($r < 0.01$). Similarly, cues relating to travel generally produced more memories ($r \sim 0.17$), but the memories were not particularly important, rehearsed, or vivid. Positive emotion cues, and those relating to people and childhood were associated with both high retrieval rates ($r \sim 0.20$) and high ratings of importance ($r = 0.22 - 0.33$), and were also positively associated with ratings of rehearsal and vividness, though to a lesser extent. Negative emotion cues were generally not associated with phenomenology ratings, though they were associated with higher retrieval rates in older adults.

6. General discussion

The present study sought to present a detailed exploration of autobiographical retrieval in response to different kinds of cues. The analysis in Experiment 1 focused on two main concepts: cue format (word, question, sentence, photo, video) and cue type (event cues, evaluative cues, etc.) Results showed that the cue format affected how likely the cue was to produce a memory (the retrieval rate), but did not affect the characteristics of the memories that were retrieved. Regarding retrieval rates, questions prompted memory retrieval most successfully, whereas sentences were poor cues that tended not to prompt memory retrieval. Words, photos, and videos were intermediately successful overall, and whereas young adults showed a slight advantage for visual cues over words, older adults did not show any such advantage. Within the word and question formats, event cues also produced more memories than other more abstract types of cues (e.g., evaluative questions and words). With the exception of the advantage of visual cues in young adults, the effects of cue format were broadly similar for young and older adults, and regardless of whether the analysis included all responses or only episodic memories.

This pattern of results suggests that the factor most predictive of retrieval success is the extent to which the cue maps onto the task demands without the need for additional processing, and this does not differ between young and older adults. That is, the reason that questions, and particularly event questions, produced more memories than other kinds of cues, is probably because questions specified more precisely what was to be recalled. In contrast, less specific cues likely required further processing, such as cue interpretation and generation of a search through memory contents (e.g., Conway & Pleydell-Pearce, 2000). In support of this explanation, the analysis in Study 2 showed that cues that were rated by a separate sample of participants as being vague or having many different possible meanings tended to produce the fewest memories overall, in both young and older adults. This "mapping" explanation draws on the hypothetical distinction between direct and generative retrieval (Conway & Pleydell-Pearce, 2000). According to this view, a cue that directly activates event-specific knowledge can lead to the construction of an autobiographical memory without much additional processing, as event-specific knowledge representations usually map to one general event, and consequently one main lifetime period.

Table 5
Mean agreement for each question (proportion of participants responding "yes"), by cue format.

	Words		Sentences		Questions		Photos		videos	
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
Meanings*	0.64	(0.20)	0.57	(0.21)	0.53	(0.25)	0.39	(0.18)	0.37	(0.21)
Location*	0.48	(0.31)	0.37	(0.28)	0.47	(0.24)	0.64	(0.26)	0.63	(0.27)
Person*	0.51	(0.29)	0.33	(0.25)	0.73	(0.20)	0.47	(0.24)	0.45	(0.30)
Childhood*	0.33	(0.29)	0.30	(0.24)	0.58	(0.27)	0.36	(0.33)	0.39	(0.31)
Happiness	0.45	(0.33)	0.42	(0.29)	0.52	(0.32)	0.57	(0.30)	0.56	(0.30)
Fear	0.26	(0.25)	0.28	(0.25)	0.38	(0.29)	0.18	(0.26)	0.23	(0.25)
Sadness	0.21	(0.21)	0.24	(0.21)	0.30	(0.21)	0.17	(0.23)	0.15	(0.23)
Safety	0.37	(0.33)	0.33	(0.28)	0.46	(0.26)	0.50	(0.28)	0.52	(0.33)
Travel*	0.32	(0.32)	0.31	(0.30)	0.25	(0.26)	0.47	(0.34)	0.57	(0.35)
Vagueness*	0.62	(0.21)	0.41	(0.19)	0.28	(0.19)	0.33	(0.16)	0.40	(0.22)

* Responses to these questions were significantly different across cue formats.

Table 6
Summary of associations between cue content (Study 2) and retrieved memories (Experiment 1).

Cue content	Retrieval rates and memories characteristics
Cues with many different possible meanings	• Fewer memories overall • No association with response latency • Memories more important and rehearsed, especially in older adults • Memories more vivid, in older adults only • Later age at encoding, in young adults only
Cues rated as vague	• Fewer memories overall • No association with response latency • Memories more important and rehearsed, in older adults only • No association with vividness • Later age at encoding, in young adults only
Cues related to a person or people	• More memories, with faster response latencies • More important and vivid memories in both groups • More rehearsed memories, especially in young adults • Earlier age at encoding, in older adults only
Cues related to childhood	• More memories, especially in young adults • No association with response latency • Memories more important in both groups, and more vivid in older adults • No association with rehearsal • Earlier age at encoding, especially in older adults
Cues related to a particular location	• More memories and faster response latencies, especially in young adults • Earlier age at encoding, in young adults only • No relationship with importance, rehearsal, and vividness
Cues related to travel or holidays	• More memories overall • No relationship with response latency, age at encoding, importance, rehearsal, or vividness
Cues related to happiness, excitement, or elation	• More memories, especially in young adults • Faster response latencies in both groups • Memories more important • Memories more rehearsed and vivid, especially in older adults
Cues related to safety, contentment, or calmness	• More memories, in young adults only • Faster response latencies in both groups • Memories more important • Memories more vivid, especially in older adults • Memories more rehearsed, in older adults only
Cues related to fear, anxiety, or anger	• More memories, in older adults only • No relationship with response latency, age at encoding, importance, rehearsal, or vividness
Cue related to sadness, boredom, or weariness	• More memories, in older adults only • Memories less important, in young adults only • No relationship with response latency, age at encoding, rehearsal, or vividness

Note. Correlations were calculated at the level of the individual cue (i.e., entire dataset collapsed across participants). Associations reported for all pairs of variables where $r > 0.10$.

On the other hand, a less specific cue that activates either higher-order knowledge (e.g., a general event or lifetime period) or non-specific event details (e.g., details shared by many different events) will cause diffuse spreading activation across many different autobiographical knowledge representations. In this latter case, additional processing is then required to form the stable pattern of activation required for memory construction.

Given the well-documented decline in executive function abilities that occurs with ageing (e.g., Clarys et al., 2009; Ferguson et al., 2021; Fjell et al., 2017) it is surprising that there were no observed age differences in retrieval in response to less specific cues (e.g., words), which theoretically should make successful retrieval more executively demanding. However, as the study was conducted online, and executive function was not directly measured, the absence of age effect may be a result of sampling bias. In any case, in Study 2 the association between cue vagueness/number of meanings and retrieval rates was slightly stronger in older adults, which is in line with this executive explanation of cue success.

While the suggestion that generative retrieval is more "difficult" than direct retrieval is not novel, the results of the present study suggest that this factor has more influence on AM retrieval success than other factors such as imagery, emotion, detail, and the semantic theme of the cue. However, there is a considerable degree of overlap between these factors, and others may still be important. The present study contributes to the existing literature on cueing effects in AM by beginning to untangle the influence of each factor. It is intended to lay the groundwork for future investigations that will examine retrieval processing in cue-driven AM more directly.

Regarding the amount of information in the cue, sentences were poorer cues than words, despite containing more semantic information that could be potentially overlap with autobiographical experience. Similarly, videos were (marginally) poorer than photos at prompting retrieval, despite containing objectively more information. In fact, this pattern of findings suggests that cues containing more information may be detrimental to retrieval if they constrain the search space too far – that is, if they are too specific, and consequently do not overlap sufficiently with the participant's prior experience (see also Mazzoni et al., 2014). Although this idea is consistent with the well-known principle of encoding-retrieval match (i.e., that a cue's success depends on the degree to which it matches, or overlaps with, the target; Tulving, 1979) and the more recent view that cues are effective to extent that they are able to

discriminate a target memory from among competitors (Nairne, 2002), its application to the context of more complex autobiographical memory warrants some discussion. In a cue that contains a large amount of information, such as a detailed sentence or video clip, the information could be interpreted either as a whole entity with a very precise meaning, or as a series of individual elements, each one of which could potentially overlap separately with the contents of autobiographical memory. The finding that such cues are relatively poor at triggering retrieval suggests either that (a) participants tend towards the former interpretation, thereby making it unlikely that the cue will produce a match in autobiographical memory (i.e., poor encoding-retrieval match), or (b) each of the individual elements does indeed activate parts of the autobiographical knowledge base, but the activated knowledge is disparate and causes interference between competing memories (i.e., poor discrimination). Either way, this hints at an apparent inflexibility in the way that the cues and/or memories are represented internally. The autobiographical knowledge base presumably includes so much information that even the most specific cues are likely to be relevant to *some* stored information, so the failure of such cues to reliably prompt retrieval suggests it is difficult to divorce component parts (of complex cues and/or memories) from their context.

Aside from the superiority of question cues, cues that provided visual imagery (photos and videos) produced more memories than those that did not (words), but only in young adults. This is consistent with previous studies showing that high-imagery words produce faster responses than low-imagery words (e.g., Rubin & Schulkind, 1997; Uzer, 2016), though direct comparison of word and photo cues on the retrieval of involuntary AMs shows the opposite effect (Mazzoni et al., 2014). It is also broadly consistent with studies showing the general superiority of verbal versus visual processing in older adults (e.g., Murre et al., 2013; Park et al., 2002). In Experiment 1 it was difficult to isolate effects of visual imagery both from cue subtype (e.g., event vs. evaluative) and from the amount of information in the cue. In the analysis in Study 2, visual cues were more strongly associated with the concepts of travel and childhood, both of which were related to higher rates of retrieval overall, and may have been more salient for younger vs. older adults (see, for example, correlations between childhood cues and retrieval rates in young adults, even for non-visual cues; Supplementary File 6; https://osf.io/rnvqy/). Thus, it is not clear whether photos and videos produced a relatively larger number of memories in young adults because of the visual imagery they contained, or because they prompted participants to think about more autobiographically relevant concepts.

An alternative explanation is that older adults' retrieval may have suffered disproportionately from the inclusion of additional details in the visual cues, relative to word cues, that might reduce the overlap between the cue and stored memory representations (see Mazzoni et al., 2014, for a discussion of this idea). To illustrate, consider a participant who lives in the UK who, when presented with the word beach, brings to mind concepts such as cold, grey, windswept, pebbles, fish and chips, based on many personally experienced trips to the seaside. This would be in stark contrast to the imagery present in a photograph of a tropical beach with white sand and palm trees, which shares very few features with the average beach in UK. Consequently, when presented with such a photograph, the hypothetical UK participant might arrive at a memory about a beach via the effortful *inhibition* of the tropical imagery that does not overlap with their personal experience. This example highlights the challenge of making inferences based on participants' behaviour, when it is not known how different cues are interpreted. One potential avenue for future study is to analyse the content of memories retrieved in response to different cues, which may shed more light on the nature of retrieval processing. For example, do cues containing visual imagery produce memories with more descriptions of imagery, or do they tend to produce memories with particular themes?

The discussion above relates primarily to retrieval rates, however the present study also collected data on some of the characteristics of retrieved memories. In general, the format in which cues were presented did not affect the rated importance, rehearsal, vividness, or age at encoding of the retrieved memories. However, these ratings were affected by cue subtype/theme. For example, in Experiment 1, cues that were specifically intended to promote autobiographical reflection (e.g., evaluative questions, words, and sentences) produced memories that were rated as relatively important and well-rehearsed, compared to memories prompted by other cues. Similarly, Study 2 showed that cues related to people, childhood, and positive (but not negative) emotions also tended to produce memories that were more important, well-rehearsed, and vivid. The same was also found for cues that were vague or had many different possible interpretations, despite these cues being relatively poorer at triggering retrieval. These findings raise an interesting contrast: the memories that come to mind most readily (e.g., in response to event cues in Experiment 1 and location cues in Study 2) appear to be somewhat more superficial than those that are comparatively harder to retrieve (e.g., evaluative cues in Experiment 1 and vague cues with many meanings in Study 2). An important consideration when measuring AM, therefore, is how to balance potential conflict between different goals in AM: on one hand fluency, or the ability/ease with which memories come to mind, and on the other hand the autobiographical importance of the memories.

7. Conclusion

Cues varied dramatically in their ability to trigger autobiographical memory recall. Data from the present study suggest that the factor most predictive of retrieval success (in terms of retrieval fluency) was the extent to which cues minimise the requirement for executive processing, though further research is needed to test this hypothesis directly. Cues that contained more information tended to be poor at prompting AM retrieval, perhaps due to excessive constraints placed on the autobiographical search space, or due to diffuse activation of a large number of candidate memories, requiring additional executive capacity to resolve interference. In general, young and older adults responded to cues in similar ways. Cue meaning or theme also influenced AM retrieval (in terms of the kinds of memories that were retrieved), with data indicating that the cues that mostly readily triggered retrieval were associated with memories that were more superficial and less autobiographically important. This could have important implications for explaining factors such as the amount of detail participants are able to recall about retrieved events (memory elaboration), which may also be affected, in turn, by the kinds of memories that are retrieved. This study is accompanied by open data, including details of all memories retrieved by

participants, and it is hoped that this descriptive resource will provide opportunities for other researchers to explore autobiographical memory retrieval in different ways.

CRediT authorship contribution statement

Ali Mair: Writing – review & editing, Writing – original draft, Visualization, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Data availability

Data are open, and linked to from the manuscript

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