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RESEARCH ARTICLE

Photo age: Temporal preferences for external memory across the lifespan

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Abstract

Autobiographical memories show a temporal pattern with relatively many events recalled from the recent past (recency) and from adolescence to early adulthood (reminiscence bump), and very few events recalled from the first few years of life (childhood amnesia). The current study examined a temporal pattern for external memory – information stored outside of one's brain. Three survey studies asked participants to choose which age(s) in their life they would most want to keep photos from, supposing they had many photos from every year. Participants chose 1 year of photos in Study 1, which sampled undergraduates ($N = 499$, median age = 19), and in Study 2, which sampled online participants using stratified age brackets ($N = 252$, age range 18–82). Participants chose 3 years of photos in Study 3, which sampled online participants over 40 using stratified age brackets ($N = 240$, age range 40–93). Participants' choices largely showed preferences for time periods likely to be well remembered (recency and the reminiscence bump). Qualitative coding of participants' reasons for their choices showed common themes, such as positive emotions, connections to other people and pets, life milestones, personal growth, and school. Results suggest that in the case of photos, external memory served to mostly enhance or enrich internal memory and less often to compensate for internal memory.

Keywords: external memory; autobiographical memory; reminiscence bump; temporal patterns; digital technology

Photo age: temporal preferences for external memory across the lifespan

In the age of digital smartphone cameras and social media, an increasing proportion of our lives are shared with digital repositories. Smartphones with high-quality digital cameras have made photo-taking more accessible than ever before. In 2015, participants in an online survey reported taking an average of 2.7 photos per day (Finley *et al.* 2018). In 2019 surveys, university undergraduates reported taking an average of 3.4–3.9 photos per day (Soares and Storm 2022b) and in a similar survey in 2021 that average rose to 9.0 photos per day (Soares 2023). Though the number of photos taken by each person per day may vary widely, photo-taking seems to be an activity that many smartphone users engage in daily. Expansive digital photo albums could even act as a site of *external memory*, or information stored outside of the brain, for the autobiographical experiences documented therein.

A few theories characterize the relationship between internal and digital external memory. Much of the work examining the effects of using digital technology on memory uses the *transactive memory framework* (Sparrow *et al.* 2011; for review, see Eliseev and Marsh 2021; Finley *et al.* 2018; Marsh and Rajaram 2019; Storm & Soares in press). Transactive memory theory initially focused on the ways that memories can be shared across people, like romantic partners or work colleagues, to divide the labour of remembering by offloading the duty to remember some information onto other people (Wegner 1987; Wegner *et al.* 1985, 1991). The same dynamics have been proposed to occur with sites of external memory (Sparrow *et al.* 2011; for review, see Risko and Dunn, 2015). Digital devices and the internet can far outperform human limits on memory because they are highly indexed, almost constantly available, and can reliably hold more information than a single human might encounter in a lifetime. Digital stores may therefore be particularly temping external memory partners on which to offload memory (Ward 2013).

The existence of such a cognitive offloading relationship is consistent with findings showing memory impairments after saving information externally. Indeed, memory impairments for information saved on a computer (Sparrow *et al.* 2011), information obtained through an internet search (Fisher *et al.* 2021), and photographed information (Henkel 2014; Soares and Storm 2018, 2022a) have been observed relative to memory for information that is not digitally stored. Consistent with this cognitive offloading mechanism, one study showed that participants only experienced memory impairments associated with saving information when they were shown in a practice trial that the saving process was reliable (Schooler and Storm 2021). Another study found that saving information on a computer seems to free up cognitive resources by reducing the buildup of proactive interference, a finding also consistent with the idea that external memory in digital devices is used as a site for offloading memory (Storm and Stone 2015). Likewise, heavy use of the internet seems to be associated with an unwillingness to expend cognitive effort, perhaps resulting from an overreliance on externally stored information (Barr *et al.* 2015; Storm *et al.* 2017). Participants can also mistake information stored externally with information stored in their own memory, demonstrating overconfidence in their ability to explain information after searching online, even if the search is unsuccessful (Eliseev and Marsh 2023; Fisher *et al.* 2015).

The *blended memory framework* argues against the idea that external memory sources like photos supplant internal memory through cognitive offloading, instead characterizing the relationship as complementary (Fawns 2011, 2019). In this framework, photos belong to a *blended memory system* with internal memory, with remembering characterized as a collaboration between internal memory and ongoing behaviours such as photo-taking and photographic review. According to this framework, and the results of qualitative interviews, photo-takers recruit photos to deepen the experience of remembering, prioritizing feelings of authenticity over strict accuracy (Fawns 2011).

Finley *et al.* (2018) have also proposed a framework for understanding the dynamics between internal and external memory called the *memory symbiosis framework.* This framework proposes that people use internal or external memory differently based on the memory purpose of a task, with external memory preferred for semantic and prospective purposes, and internal memory preferred for episodic and procedural purposes. Participants confirmed these patterns of use in their open-ended self-reports regarding when they were likely to use internal and external memory (Finley *et al.* 2018, Figure 4.1), and these patterns were replicated and refined in a follow-up study using rating scales (Finley and Naaz 2023). In contrast to the cognitive offloading framework, which emphasizes how external memory can be used to supplant internal memory, the memory symbiosis and blended memory frameworks characterize external and internal memory as complementary and interdependent. According to an offloading framework, people

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seek out external memory sources like photographs to compensate for poor memory. The blended or memory symbiosis frameworks instead predict that people may seek out external memory to deepen the recollective experience of even well-remembered events.

Photos are often used to help cue recollection of autobiographical memories of personal experiences. Indeed, participants in surveys and interviews frequently report taking photos with the intention of remembering personal experiences (e.g., Finley *et al.* 2018; Soares 2023; Soares and Storm 2022b; Van House 2011). Some have even argued that people interact with photos as physically embodied representations of memories (van den Hoven *et al.* 2021). Because photos are highly related to memory, particularly autobiographical memory, patterns of autobiographical recollection might correspond with how people take, seek, and use their photos, and such behaviours could influence memory in turn.

Research in autobiographical memory has revealed that the likelihood of a person remembering an event depends, in part, on the time in their life that event occurred. *Childhood amnesia* describes a period of poor memory, such that most adults cannot recall the first 3–4 years of life (Dudycha and Dudycha 1941). Other periods are associated with highly available memories. For example, people report relatively high numbers of recent events when asked to recall events across their lifetime (Rubin and Wenzel 1996). Adults over 30 also report more autobiographical memories from adolescence and early adulthood than other times in their lives, resulting in a *reminiscence bump* in the frequency of reported memories occurring between ages 10 and 30 (Rubin *et al.* 1998). This pattern corresponds with inflated positivity ratings of cultural artefacts like films and songs, and the importance ascribed to public events that occurred during the years in which older participants were aged 10–30 (Holmes and Conway 1999; Koppel 2013; Rubin *et al.* 1998). The large life transitions that occur during the reminiscence bump could contribute to its prevalence. Indeed, Brown (2016) proposed that life periods are divided by these kinds of transitions like moving away from home and getting married which fundamentally change daily life.

The current study

The current study examined participants' understanding of the relationship between photographs and their internal autobiographical memory by comparing temporal patterns with which participants sought photographs to the temporal patterns typically observed for autobiographical memories. Participants were asked a hypothetical question about which year (Studies 1 and 2) or years (Study 3) of their lives they would most wish to save photos from. The temporal pattern of participants' responses was then compared to the typical temporal patterns observed in autobiographical recollection – childhood amnesia, the reminiscence bump, and recency.

Based on the offloading framework, one would expect participants to use external memory sources like files, photos, and internet sources to compensate for failures of internal memory, focusing on times they struggle to remember. So, if participants consider photos purely a site of offloaded external memory, their answers should show an inversion of the typical patterns observed in autobiographical recollection – prioritizing events lost to childhood amnesia and de-prioritizing events remembered well due to recency and the reminiscence bump. The blended memory framework predicts the opposite pattern, that participants would seek out photos of events they already remember (i.e., recency and reminiscence bump memories) for the purpose of deepening their recollection, rather than trying to compensate for memory failures (i.e., childhood amnesia). So, the blended memory framework would predict participants to report photos from ages in a pattern resembling the temporal pattern of autobiographical recollection. The memory

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symbiosis framework claims that a photo serves as both an external memory itself, but also a cue that supplements internal autobiographical memory, and so predicts a mixture of these two patterns. Specifically, this framework predicts that participants would want to both choose ages for their photos to compensate for times they have little memory of, like early childhood *and* choose photos from times that they remember well due to recency or the reminiscence bump.

Study 1

Study 1 used an undergraduate convenience sample to initially investigate how people seek photographs throughout their lifetime. Most of these participants were young adults, with a large majority aged within the reminiscence bump range. As such, we could not distinguish between recency and the reminiscence bump for these participants. That being said, we could investigate the extent to which participants sought photos from well-remembered times (either due to recency or the reminiscence bump) and poorly-remembered times (early childhood). In addition, these data provided an opportunity to develop a coding scheme for participants' qualitative responses about why they chose the ages they did.

Method

Participants

A total of 499 participants, mostly college undergraduate students who participated for course credit, in addition to some volunteers recruited by students, were recruited for this study, from Spring 2020 to Fall 2021. All participants were based in the United States. The mean age was 21.53 (SD = 7.40, Mdn = 19.00, range: 18–67). Gender demographics were: 397 women, 97 men, 2 non-binary, 1 agender, 1 gender-fluid, and 1 not specified. Racial demographics were: 397 White, 70 Black, 28 Hispanic, 29 Asian, 2 Native American, 1 Native Hawaiian or Pacific Islander, 1 Arabic, and 6 Other or Unspecified. More information about when and where each group of participants was recruited is available in the Supplementary Materials posted on the Open Science Framework.

Data were collected from an additional 50 participants but excluded from analysis for the following reasons: not choosing a year (2), not giving an age (27), choosing a year in the future (1), and confusion about the instructions such that they wrote about photos that they actually took rather than a hypothetical set of photos (20). This study received ethical approval from the Institutional Review Boards (IRB) of Fontbonne University (FBUIRB012121-JF), and Southern Illinois University Edwardsville (Protocols 955, 1308, 1372).

Materials and procedure

Materials were two questions that participants answered as part of larger unrelated surveys. Surveys were completed online using Google Forms or Qualtrics. The first batch of data was collected as part of a larger study on memory and technology (Finley and Naaz 2023), and the remaining data were collected as part of unrelated larger surveys run for a research methods course. Participants saw the following question: '*Imagine that you have many photos from every year of your life. Now imagine that you could only keep the photos from one particular year. What age would you choose? (Type a whole number. Use 0 for the first year of your life, 1 for the year when you were 1 year old, 10 for the year when you were 10 years old, etc.)*' along with a response box that allowed entry of a whole number. The second question, '*Explain why you chose that particular age*', was open-ended. The exact

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wording of the two questions varied slightly across batches, and the full text of each version is available in the Supplemental Materials. Similar patterns of responses were observed across the slight question variations.

Results

Complete datasets from all three studies are available in the Supplemental Materials.

Quantitative

Figure 1A shows a histogram of the ages that participants chose. For simplicity, and to better align with Study 2, this histogram includes only participants aged 18–24 (n = 428), excluding 71 participants aged 25 and over. A histogram including all participants can be found in the supplement.

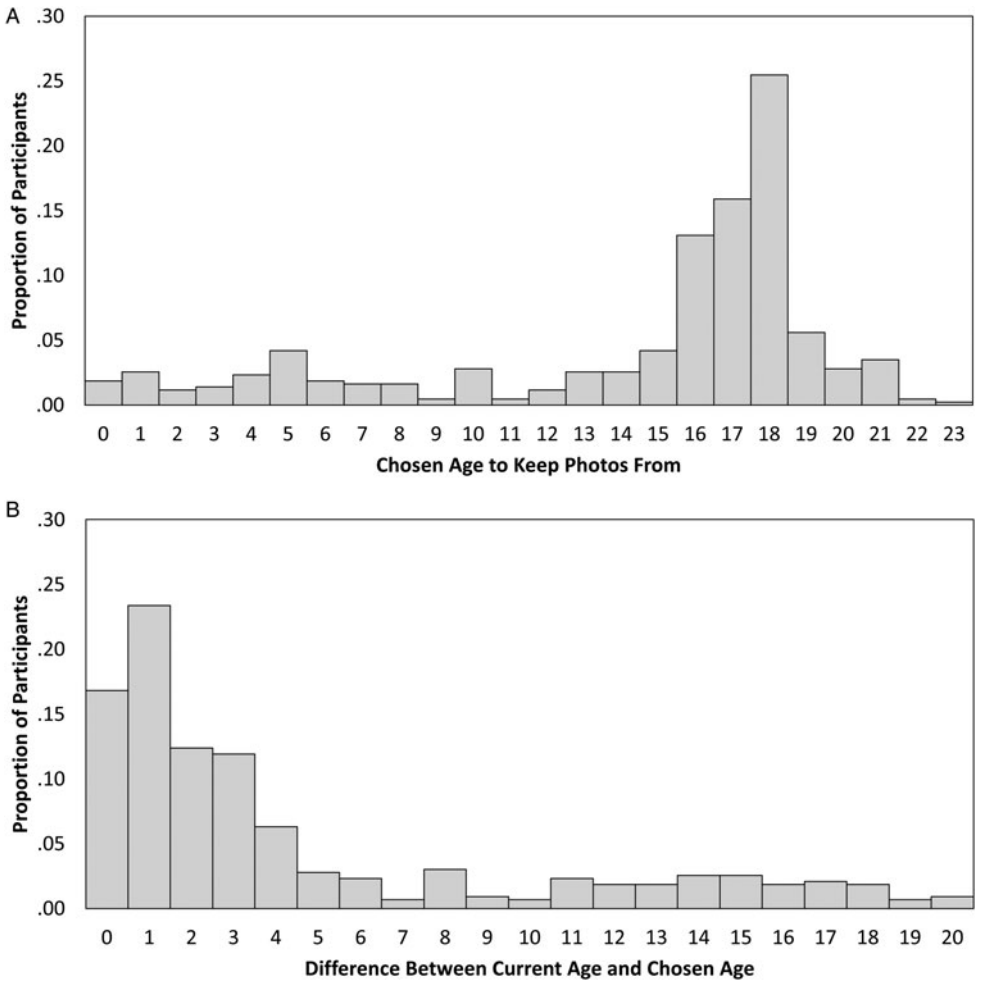

Figure 1. Distributions of chosen age, and difference between current age and chosen age in Study 1. Note: Figures show data limited to the sample of participants aged 18–24 (n = 428). Similar figures including all participants are available in the Supplemental Materials.

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In analysing the distribution of chosen years across the lifespan, we focused on three critical time intervals: childhood amnesia (0–4), reminiscence bump (11–30), and recency (the most recent 5 years, including current age). However, for participants younger than 35 ($n = 469$, 94 per cent of our sample in Study 1), it is not possible to analyse the traditional reminiscence bump interval because recency encroaches on it. Therefore, for these participants, we partitioned the possible chosen ages into the following four intervals: childhood amnesia (0–4), middle childhood (5–10), pre-recency (11—[current age minus 5]), and recency (the most recent 5 years, including current age). We first determined the number of observed choices in each of the four intervals for each participant's age. We then calculated the number of choices that would be expected in each interval due to chance (i.e., a null hypothesis of no preference for any particular year), taking into account the number of participants of each age, and the length of each of the intervals for that age. A visualization of this process in Excel is available in the Supplemental Materials. There is a technical issue worth mentioning here: we did not collect participant birth dates, and therefore could not know precisely how long they have been their current age. This affected our calculations of the chance probability of choosing current age. Others have approached this issue by assuming that participants have lived, on average, 6 months into their current age (e.g., Berntsen and Rubin 2002). We instead opted to make our calculations of chance by using the assumption that each participant had lived fully through their current age, in order to be as conservative as possible in our tests of any recency effects. A chi-square test for goodness of fit showed that for participants aged 18–34, the distribution of their choices across intervals differed significantly from chance, χ^2 (3, $N = 469$) = 493.21, $p < .001$, Cramer's $V = .59$.

For each interval, we then conducted a follow-up exact binomial test (two-tailed, using the method of small *p*-values) to compare the proportion of choices observed to the proportion expected due to chance; we report effect size for these tests as Cohen's *h*. For the childhood amnesia interval, the observed proportion (.09) was less than chance (.24), $p < .001$, $h = -0.43$. For the middle childhood interval, the observed proportion (.13) was less than chance (.29), $p < .001$, $h = -0.42$. For the pre-recency interval, the observed proportion (.10) was less than chance (.22), $p < .001$, $h = -0.32$. For the recency interval (see Figure 1B), the observed proportion (.68) was greater than chance (.24), $p < .001$, $h = 0.91$. Thus, the choices of participants aged 18–34 were clearly dominated by recent years, with fewer choices in the childhood amnesia interval than would be expected from random choices.

Figure 1B shows a histogram of the difference between each participants' current age and their chosen age from which to save photos. There is a clear recency effect; most participants chose one of the last 3 years. A Kolmogorov–Smirnov test confirmed that the distribution of differences was not uniform, $D_{max} = .51$, $N = 428$, $p < .001$.

Qualitative

The short answer responses with participants' reasons for their choices revealed some common themes, which were coded using bottom-up qualitative coding. After reviewing a sample of responses, the authors constructed a codebook, but a few codes were added once the coding formally commenced. The first full pass was completed by the third author, and a second pass was completed by the first author. Both coders reached a consensus about the code(s) assigned to each participants' response for any disagreements, which made up only 45 of the codes assigned (of 6,487 total codes). Codes were not mutually exclusive. In fact, each response was assigned an average of 2.36 (SD = 1.24) qualitative codes. Table 1 shows the full codebook with examples and Table 2 shows the proportion of participants who chose each code and information about the current and chosen ages of each group.

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Table 1. Codebook for Studies 1, 2, and 3

Code	Description	Examples
Do remember	Events are described as well-remembered; time is described as one in which memories were made.	• *because that is when I made the biggest memories, I started my senior year of high school, graduated, started college, and got my first boyfriend* • *I had the most fun memories then*
Recency	Participant describes why current or recent age is preferred.	• *I don't have a reason to choose previous years. Nothing in my life stood out as much as becoming an adult in college, with a healthy relationship.* • *it's my current age and my family as they are now*
Plan to remember	Mention plans to remember, plans to keep photos for a later time, or enjoying remembering.	• *I did a lot of things I want to always remember and look back on.* • *Because life was simple back then and I like to be reminded of the happy times*
Don't remember	Describe seeking photos to compensate for a time that is not or not well remembered.	• *I can't remember it* • *I was old enough to have some memories but the pictures would ensure that the memories stay as fresh as possible.*
Childhood amnesia	Mention being too young to remember a time.	• *I was a baby and I don't remember much from then* • *This is around the age I don't have many memories*
Positive emotions	Mention of happier or better times, having fun, enjoyment.	• *I enjoyed that year.* • *This is the time of my life where I feel like I was the happiest.*
Negative emotions	Mention of choosing a time before a loss or sad/negative event. Mention sadness or other negative emotions.	• *One of the last years I had with my older sister who died.* • *had a bad car accident at 18*
Connections	Mention of others (e.g., friends, family, pets).	• *met most of my friends that year* • *All of my children were born and living at home at that time.*
Personal growth	Mention of personal progress/ transformation.	• *Started to grow up* • *Transformative year*
Body image	Mention wanting to see how they looked, looking different, better, healthier etc.	• *I had a lot of friends at the time, I was happy, stable and it was before my haircut* • *Young. Thin. Life ahead of me.*
Milestones	Mention milestones such as marriage, births, firsts (e.g., first job, first love), changing careers.	• *First romantic relationship* • *I chose that year, because I finally completed my GED.*

(*Continued*)

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Table 1. (*Continued.*)

Code	Description	Examples
School	Mention of school	• *I was in a club I really liked in high school* • *My memories of my senior year in high school.*
COVID	Mention or allude to the COVID-19 pandemic and shelter-in-place measures.	• *Corona wasn't around, and I had fun.* • *This is the year that I was both confined to my home due to covid. Also the year that we had a memorable freeze in Texas.*

Note. Codes assigned, descriptions, and illustrative examples. Two examples for each code are provided, the first from Study 1 and the second from Study 2.

The most common codes assigned were related to positive emotions, personal connections, school, and milestones. Table 2 shows the codes organized by themes. To compare specific proportions of interest we used Bonferroni-corrected exact binomial tests. Among codes specifically related to memory, a substantial proportion of responses mentioned memorable times or making memories (Do Remember,.20), over twice as often as responses that described using photos to compensate for memory failures either generally (Don't Remember,.08), $p < .001$, $h = 0.35$, or specifically due to Childhood Amnesia (.06), $p < .001$, $h = 0.43$. In terms of chronology, more responses described why a recent time was chosen (Recency,.16) than described a time they were too young to remember (Childhood Amnesia,.06), $p < .001$, $h = 0.33$. For emotional themes, Positive reasons (.61) were far more common than Negative reasons (.10), $p < .001$, $h = 1.15$. Among the reasons related to self or others, Connections to others (.42) were more common than Personal Growth (.13), $p < .001$, $h = 0.67$, and more common than Body Image (.05), $p < .001$, $h = 0.96$. In terms of events, the number of responses describing Milestones (.22) and School (.22) were nearly identical, $p = .829$, $h = 0.01$, which could be because most participants were young enough for the school to have played a major role in most of their life so far.

Discussion

Participants tended to respond to the hypothetical question about which year of photos they would choose to save throughout their life with ages they would have a high likelihood of remembering. Indeed, the majority (60 per cent) of all 499 participants chose one of the prior 3 years, with a large proportion choosing either their current age or their age from the prior year (38 per cent). The qualitative responses from participants align with this pattern. Participants mentioned having memories of the ages they chose in more than twice as many responses as those that mentioned using photos to aid in remembering times they could not.

Given that the bulk of the sample was under age 25, little can be said about how the overall temporal pattern of chosen ages aligns with the typical pattern of autobiographical recollection. Specifically, recency and a reminiscence bump are indistinguishable given the average age of participants sampled. However, participants' descriptions of why they chose the year they did were informative. School and milestones, like graduating high school, leaving home to go to college, getting a driver's license, and first romantic relationships, were frequently assigned codes. The milestones code contained

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Table 2. Mean proportions, ages, and chosen ages by qualitative code in Studies 1, 2, and *3*

	Study 1			Study 2			Study 3		
Theme and code	Prop.	Current age	Chosen age	Prop.	Current age	Chosen age	Prop.	Current age	Chosen age
Memory									
Do remember	.20	19.2 (2.4)	16.3 (4.1)	.12	35.4 (15.7)	17.6 (9.3)	.13	58.9 (10.9)	34.1 (20.6)
Recency	.16	20.1 (4.3)	20.0 (4.3)	.09	43.5 (16.6)	43.5 (16.6)	.07	59.3 (9.8)	57.4 (9.7)
Plan to remember	.08	19.0 (2.3)	15.0 (5.0)	.09	39.9 (15.8)	16.7 (13.2)	.09	55.6 (11.0)	25.4 (17.2)
Don't remember	.08	19.1 (2.5)	7.5 (6.5)	.04	35.1 (13.9)	7.5 (8.8)	.09	55.3 (10.7)	23.2 (16.1)
Childhood amnesia	.06	19.0 (1.6)	4.1 (3.8)	.03	30.4 (12.2)	3.4 (2.8)	.06	56.4 (10.7)	4.5 (5.2)
Emotion									
Positive emotions	.61	21.2 (7.2)	16.3 (6.1)	.53	43.6 (17.6)	21.8 (12.4)	.33	58.3 (12.5)	28.2 (16.8)
Negative emotions	.10	20.9 (5.3)	11.2 (6.4)	.17	44.6 (17.2)	23.6 (16.4)	.07	57.2 (11.8)	27.6 (20.8)
Self/Others									
Connections	.42	22.2 (8.2)	16.6 (7.7)	.58	46.1 (16.5)	27.2 (15.1)	.55	59.3 (11.4)	30.5 (16.2)
Personal growth	.13	20.6 (5.9)	17.5 (4.7)	.14	42.2 (18.5)	19.9 (9.7)	.23	60.3 (11.5)	30.1 (17.2)
Body image	.05	24.3 (13.0)	15.6 (7.8)	.06	44.0 (18.5)	15.4 (12.3)	.07	57.5 (12.7)	22.8 (16.7)
Events									
Milestones	.22	21.9 (7.8)	18.9 (5.6)	.27	48.7 (17.8)	25.8 (11.8)	.45	60.0 (11.5)	30.6 (14.4)
School	.22	19.4 (2.6)	16.6 (2.9)	.12	42.7 (17.1)	18.1 (7.2)	.12	59.8 (12.2)	20.3 (10.8)
COVID-19	.03	19.5 (4.0)	18.5 (4.0)	.02	52.3 (19.6)	51.5 (20.0)	.00	N/A	N/A

Note: Prop. is proportion of total responses assigned each code in Study 1 (499 participants, one response from each), Study 2 (252 participants, one response from each), and Study 3 (241 participants, three responses from each). More than one code could be assigned to each response, so proportions will not total to 1. Current age and chosen age are reported as means with standard deviations in parenthesis for participants whose response was assigned that code.

many events that would be commonly included in life story schemas or cultural life scripts, which seems to align well with theories that argue such structures are used to organize autobiographical memory (Berntsen and Rubin 2004; Glück and Bluck 2007). Interestingly, some participants also reported choosing the age they did to compensate for childhood amnesia, but this reasoning was less common.

Study 2

Study 2 was designed to replicate the findings of Study 1 with a more heterogeneous sample, and to collect data from a wider age range of participants. As such, participants were recruited from an online research platform and a variety of ages were intentionally sampled.

Method

Participants

Participants were 252 individuals recruited through the Prolific research recruitment platform (Palan and Schitter 2018) who participated for $1.66 in December 2021. The study took participants an average of 5 min 47 s (SD = 4 min 40 s) to complete, so the average pay rate for participation was $17.23 per hour. Data were collected from an additional seven participants but excluded from analysis for the following reasons: choosing a year in the future (1), confusion about the instructions such that they wrote about photos that they actually took rather than a hypothetical set of photos from every year (5), and refusal to imagine the hypothetical (1).

Participants were recruited using stratified sampling by age, with 42 participants recruited per age bracket. The lowest age bracket was 18–24, with four subsequent age brackets including 10 years' worth of ages and a final age bracket recruiting participants aged 65 and older. The mean age in the final sample was 44.62 (SD = 17.46, Mdn = 45, range: 18–82). There were 171 women, 72 men, 1 participant who wrote in transgender, and 1 participant who left the option blank. Demographics separated by age bracket are included in the supplement. There were two exclusion criteria for recruitment – only participants who listed their nationality as United States and who verified that they were fluent in English were recruited to participate. This study received ethical approval from the IRB at Mississippi State University (IRB-21-497).

Materials and procedure

A Qualtrics survey with the two questions used for most participants in Study 1 was constructed. Participants started the study by indicating their consent at the end of a digital consent form. Then, they were directed to screener questions and asked to report their age. If participants did not meet our criteria for inclusion, they were dismissed from the survey. The survey then directed participants to the critical questions, with a larger typing box for participants to explain their reasoning. Then, participants answered questions about their smartphone and social media use, demographic information, and their age during various common life events. For brevity, these extended demographics are included in the full dataset online. Finally, participants were debriefed and dismissed.

Results

Quantitative

Figure 2 shows the proportion of participants, broken down by age group, who chose each year, grouped into 5-year bins. With the age range of our sample in Study 2, we were able

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to analyse the distribution of chosen years across the lifespan, including all three of the time intervals of most interest: childhood amnesia, reminiscence bump, and recency. Analysing the frequency of choices in those intervals requires a different approach for different age ranges.

For participants aged 18–34 ($n = 82$), we partitioned the possible chosen ages into four intervals as in Study 1. A chi-square test for goodness of fit showed that for participants aged 18–34, the distribution of their choices across intervals differed significantly from chance, χ^2 (3, $N = 82$) = 30.81, $p < .001$, Cramer's $V = .35$. For the childhood amnesia interval, the observed proportion (.10) was less than chance (.20), $p = .018$, $h = -0.30$. For the middle childhood interval, the observed proportion (.15) was marginally less than chance (.24), $p = .052$, $h = -0.24$. For the pre-recency interval, the observed proportion (.32) did not differ from chance (.36), $p = .089$, $h = -0.08$. For the recency interval, the observed proportion (.44) was greater than chance (.20), $p < .001$, $h = 0.52$. Thus, 18–34-year-old participants' choices showed a preference against ages in the childhood amnesia interval and a strong preference for ages in the recency interval.

For participants aged 40 and older ($n = 141$), we partitioned the possible chosen ages into five intervals as follows: childhood amnesia (0–4), middle childhood (5–10), reminiscence bump (11–30), post-bump (31–[current age minus 5]), and recency (the most recent 5 years, including current age). Just as in Study 1, we determined observed frequencies and expected frequencies due to chance (accounting for participant ages and length of the five intervals). A chi-square test for goodness of fit showed that for participants 40 and older, the distribution of their choices across intervals differed significantly from chance, χ^2 (4, $N = 141$) = 18.35, $p = .001$, Cramer's $V = .18$. Results of the follow-up exact binomial tests were as follows. For the childhood amnesia interval, the observed proportion (.06) did not differ from chance (.09), $p = .373$, $h = -0.09$. For the middle childhood interval, the observed proportion (.10) did not differ from chance (.11), $p = .892$, $h = -0.02$. For the reminiscence bump interval, the observed proportion (.45) was greater than chance (.35), $p = .022$, $h = 0.19$. For the post-bump interval, the observed proportion (.23) was less than chance (.36), $p = .001$, $h = -0.29$. For the recency interval, the observed proportion (.16) was greater than chance (.09), $p = .011$, $h = 0.21$. Thus, 40

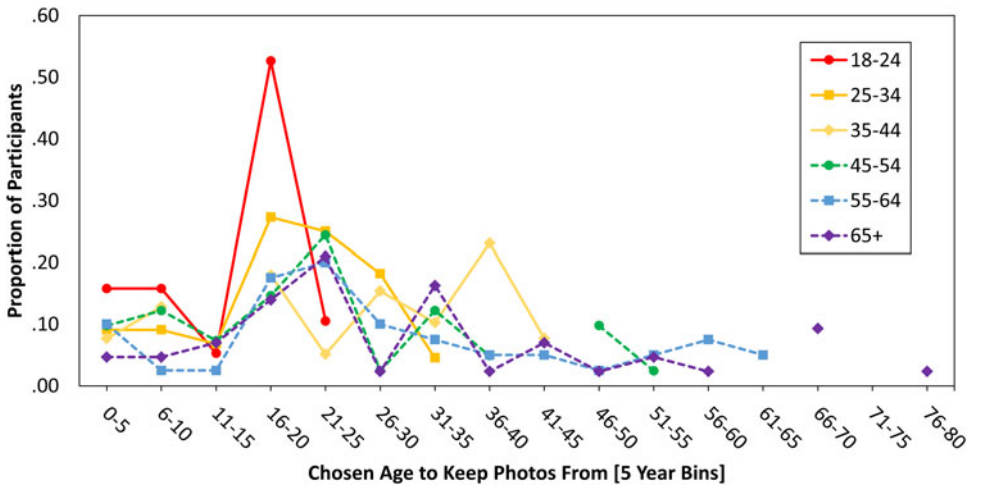

Figure 2. Distribution of chosen age across age groups in Study 2. Note. Chosen age in Study 2 grouped into 5-year bins, separated by age groups.

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+-year-old participants' choices showed a preference for ages in the reminiscence bump and recency intervals, and no consistent preference for or against ages in the childhood amnesia interval.

As in Study 1, a histogram was generated of the difference between participants' chosen age and their current age. Although less striking than in Study 1, a similar bias toward recency emerged (see Figure 3). A Kolmogorov–Smirnov test confirmed that the distribution was not uniform, $D_{max} = .28$, $N = 245$, $p < .001$. Separate histograms for each age group can be found in the supplement.

Given the range of ages collected in Study 2, we could also examine differences in chosen age based on current age. The mean chosen age increased with participant age, as confirmed by a simple linear regression, $F(1, 243) = 40.32$, $p < .001$, $R^2_{adj} = .138$, with slope $b = 0.32$, 95 per cent CI [0.22, 0.42], $t(243) = 6.35$, $p < .001$. It is worth noting that older people had more and higher ages to choose from, so this finding is not particularly surprising. However, for all age groups below 60, the mean age chosen by each group landed between the range 11 and 30 range that typically characterizes the reminiscence bump and the mean ages for participants over 60 were both below 35.

Qualitative

Qualitative codes were assigned using the same codebook as in Study 1. Again, the first and third authors reached a consensus about all codes assigned, with only 38 disagreements from a total of 3,185 codes. The proportion of participants whose response received each code, their average age, and the average chosen age for each code are included in Table 2. The patterns largely aligned with those observed in Study 1. Do Remember (.12) was more common than Don't Remember (.04), $p < .001$, $h = 0.27$, and more common than Childhood Amnesia (.03), $p < .001$, $h = 0.36$. Recency (.09) was more common than Childhood Amnesia (.03), $p < .001$, $h = 0.28$. Positive emotion (.53) was more common than Negative emotion (.17), $p < .001$, $h = 0.77$. Connection to others (.58) was more common than Personal Growth (.14), $p < .001$, $h = 0.96$, and more common than Body Image (.06), $p < .001$, $h = 1.21$. Unlike in Study 1, Milestones (.27) was more common than School (.12), $p < .001$, $h = 0.40$, likely owing to the increased number of participants older than traditional college age who have had more time for non-school-related

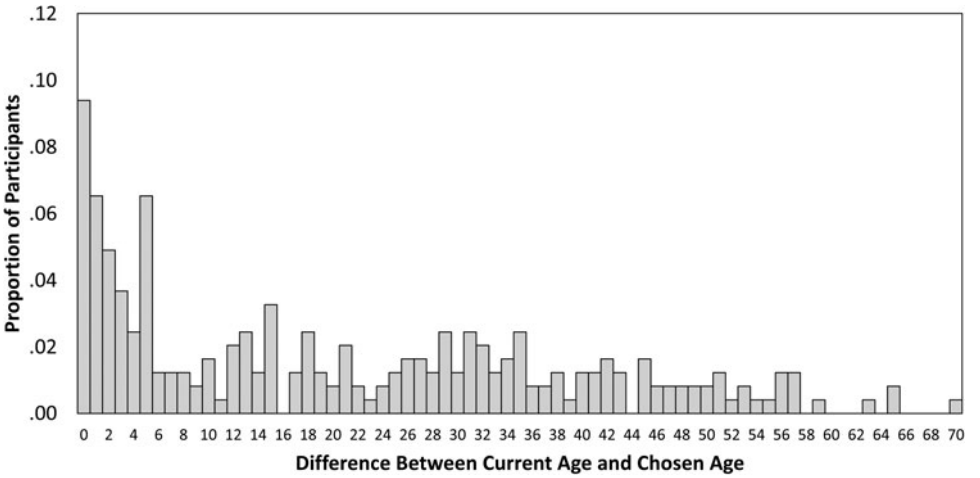

Figure 3. Distribution of difference between current age and chosen age in Study 2.

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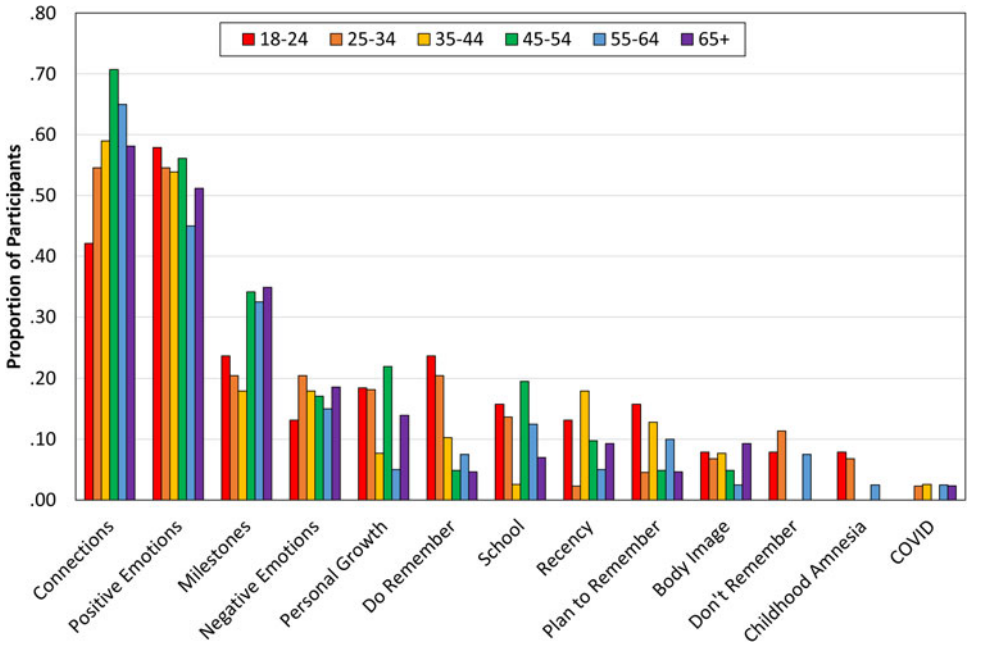

Figure 4. Frequency of choice reasons across age groups in Study 2.

milestones such as marriage and children, and as evidenced by higher mean chosen age for Milestones (25.8) versus School (18.1), $t(94) = 3.86$, $p < .001$, $h = 0.71$.

As shown in Figure 4, the frequency with which some codes were assigned to responses from participants of certain ages seemed to differ based on age group. For example, reasons concerning connections with others were used less by the youngest and oldest age groups as compared to the middle. We confirmed this with a logistic regression using age as a continuous predictor variable and the 'Connections' code as a binary outcome variable (yes/no). Parameter estimates from logistic regression are reported unstandardized and expressed in terms of effects on the odds. Effect sizes are reported as Nagelkerke's pseudo R^2. The analysis revealed a statistically significant linear trend ($\beta = 1.11$, $z = 2.39$, $p = .020$, $R^2_{\text{partial}} = .030$), and quadratic trend ($\beta = 1.00$, $z = 2.10$, $p = .036$, $R^2_{\text{partial}} = .024$). In addition, Milestone reasons increased with participant age, as confirmed by a logistic regression showing a linear trend ($\beta = 1.02$, $z = 2.25$, $p = .024$, $R^2_{\text{partial}} = .030$). Do Remember reasons were used more by younger participants ($\beta = 0.96$, $z = -2.91$, $p = .004$, $R^2_{\text{partial}} = .048$), as were Childhood Amnesia reasons ($\beta = 0.94$, $z = -1.99$, $p = .047$, $R^2_{\text{partial}} = .095$). Don't Remember responses also showed a marginally significant linear trend with younger participants more likely to be assigned this code ($\beta = 0.98$, $z = -1.79$, $p = .074$, $R^2_{\text{partial}} = .016$). All other codes did not show any significant or marginally significant linear trends.

Discussion

The results of Study 2 suggest that participants tended to report wanting to save photos from times in their lives likely to be remembered, relative to times in their lives not likely to be remembered, regardless of age. For older participants (40+), we could differentiate between a reminiscence bump and recency, and such participants showed a preference for ages between 11 and 30, consistent with a reminiscence bump. These findings are

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consistent with those of Study 1 and align more closely with the memory symbiosis or blended memory framework than the cognitive offloading framework.

Study 3

One possible explanation of participants' patterns of responses in Studies 1 and 2, which showed that most participants preferred to save photos from years they were likely to remember well, is that the nature of the question they were asked could have encouraged them to respond with well-remembered years. That is, because participants had to choose only 1 year from which to save photos, choosing to save photos from a time that was not well remembered could seem inherently risky, since such years might not contain any noteworthy or interesting events. In Study 3, we attempted to control for this motivation and to gather a more representative set of responses from participants by allowing them to choose 3 years from which to save photos instead of just one.

Study 2 also included a subset of older participants for whom we could investigate the presence of patterns of childhood amnesia, the reminiscence bump, and recency in their choices. Study 3 was designed to replicate Study 2 while focusing exclusively on participants aged 40 and older. With this sample, we could distinguish between recency and the reminiscence bump for all participants, with everyone in the sample having at least 10 years of recent memories outside of their reminiscence bump years.

Method

Participants

A total of 241 participants were recruited again through Prolific (Palan & Schitter 2018) and compensated with a $2.00 payment in April 2023. The study took participants an average of 6 min 31 s (SD = 4 min 25 s) to complete, so the average pay rate for participation was $18.39 per hour. Participants were again recruited using stratified sampling by age, but 10-year age brackets started at age 40, with four total brackets ranging from 40 to 49 up to 70+. For each bracket, 60 participants were recruited. One additional participant was recruited in the 40–49 age bracket because one participant in the bracket did not report qualitative reasons for their age choices.

The mean age in the final sample was 58.89 (SD = 11.61, Mdn = 60, range: 40–93). There were 141 women, 99 men, and one non-binary, genderqueer, or gender-fluid participant. Demographics separated by age bracket are included in the Supplemental Materials. The same recruitment requirements and ethical approval applied as in Study 2.

Materials and procedure

The procedure and survey were the same as in Study 2 except where noted. The most significant change was that participants were asked to report 3 years they would save photos from instead of one. Participants were asked to report all 3 years and their reasoning for choosing each year on the same page of the survey. Participants also saw some instructions explicitly directing them not to base their choices on the photos they actually did or did not have, but to base their judgements on the hypothetical scenario.

Results

Quantitative

Figure 5 shows the proportion of participants, broken down by age group, who chose each year, grouped into 5-year bins. Note that age groups in Study 3 were 10-year bins as in

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Study 2, but began on different years (e.g., 40–49 in Study 3 vs. 35–44 in Study 2). For these analyses, we excluded data from two participants who chose only two ages instead of three ($n = 239$). To analyse the distribution of participant choices in Study 3 in the same way as we did for Studies 1 and 2, we considered each choice separately, giving us 717 observations (3 per participant).

As in Study 2 for participants 40 and older, we partitioned the possible chosen ages into five intervals as follows: childhood amnesia (0–4), middle childhood (5–10), reminiscence bump (11–30), post-bump (31—[current age minus 5]), and recency (the most recent 5 years, including current age); we also calculated expected frequencies due to chance as in Studies 1 and 2. The frequencies and proportions expected due to chance for each interval were confirmed with a Monte Carlo simulation of 100,000 replications of simulated age-matched participants choosing 3 years at random without replacement. Thus, treating the choices as independent did not distort our estimates of chance, out to three decimal places. A chi-square test for goodness of fit showed that the distribution of choices across intervals differed significantly from chance, χ^2 (4, $N = 717$) = 44.87, $p < .001$, Cramer's $V = .13$. Results of the follow-up exact binomial tests were as follows. For the childhood amnesia interval, the observed proportion (.08) did not differ from chance (.09), $p = .550$, $h = -0.03$. For the middle childhood interval, the observed proportion (.11) did not differ from chance (.10), $p = .760$, $h = 0.01$. For the reminiscence bump interval, the observed proportion (.46) was greater than chance (.35), $p < .001$, $h = 0.23$. For the post-bump interval, the observed proportion (.28) was less than chance (.37), $p < .001$, $h = -0.20$. For the recency interval (see Figure 6), the observed proportion (.08) did not differ from chance (.09), $p = .289$, $h = -0.04$. Thus, 40+-year-old participants' choices for three ages to save photos from showed a preference for ages in the reminiscence bump, and no particular preference for or against ages in the childhood amnesia or recency intervals.

Figure 6 shows a histogram of the difference between participants' chosen ages and their current age. A Kolmogorov–Smirnov test confirmed that the distribution was not uniform, $D_{max} = .24$, $N = 717$, $p < .001$. Unlike in Studies 1 and 2, there was not a bias toward recency, perhaps because of participants being able to choose 3 ages.

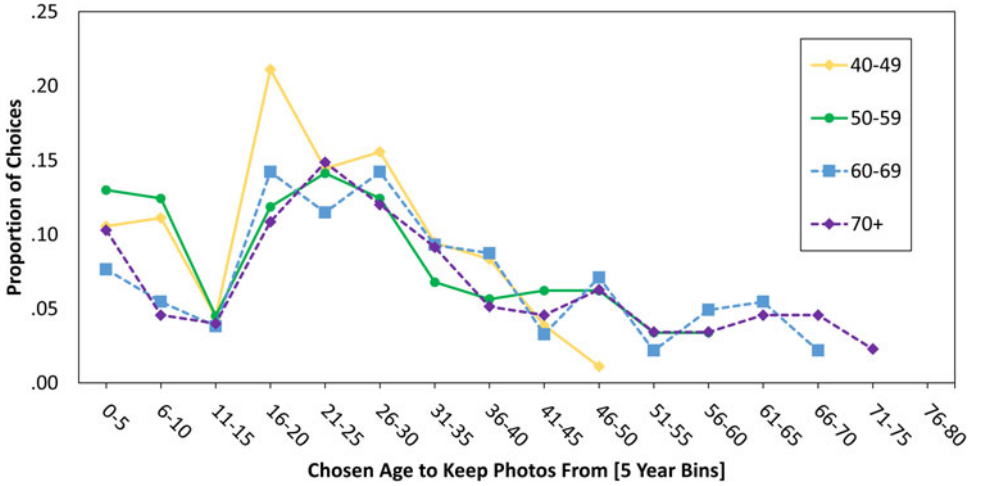

Figure 5. Distribution of chosen age across age groups in Study 3.

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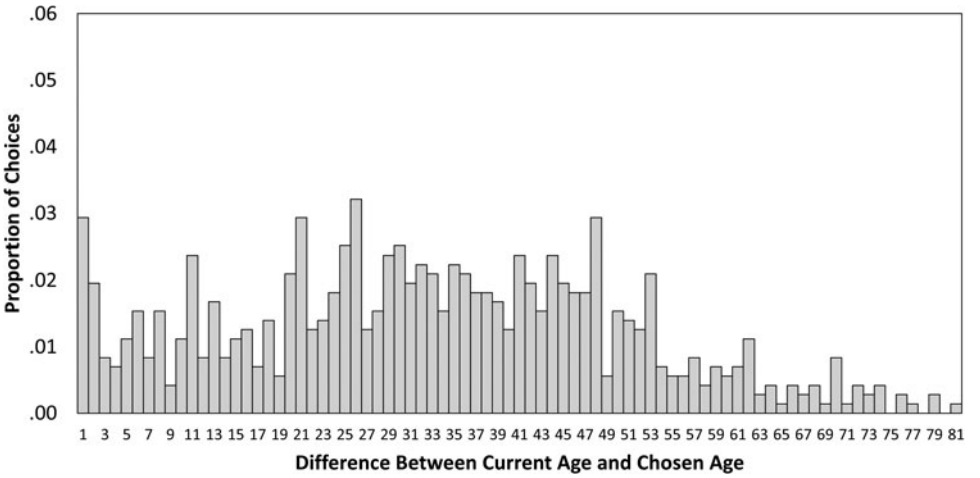

Figure 6. Distribution of difference between current age and chosen age in Study 3.

Qualitative

Qualitative codes were assigned using the same codebook as used in Studies 1 and 2. Three coders first assigned codes to the first 60 responses, with agreement between pairs of coders ranging from 83 to 88 per cent. The first author resolved any disagreements, giving the coders feedback for consistency. The remaining data were coded independently and divided evenly among each coder. Based on qualitative responses, five responses were removed because their response referred to actual photos participants had, and 1 response was removed because it was not comprehensible to the coders. The proportion of participants whose response received each code, their average age, and the average chosen age for each code are included in Table 2.

The patterns were largely similar to Studies 1 and 2. Do Remember (.13) was more common than Don't Remember (.09), $p < .001$, $h = 0.14$, and than Childhood Amnesia (.06), $p < .001$, $h = 0.27$. However, unlike in Studies 1 and 2, Recency (.07) was not different from Childhood Amnesia (.06), $p = .254$, $h = 0.04$, owing to relatively fewer Recency responses in this sample. Positive emotion (.33) was again more common than Negative emotion (.07), $p < .001$, $h = 0.69$. Connection to others (.55) was again more common than Personal Growth (.23), $p < .001$, $h = 0.68$, and more common than Body Image (.07), $p < .001$, $h = 1.14$. As in Study 2, but not Study 1, Milestones (.45) was more common than School (.12), $p < .001$, $h = 0.78$, with the mean chosen age again higher for Milestones (30.6) versus School (20.3), $t(405) = 7.20$, $p < .001$, $d = 0.75$.

Figure 7 shows the frequency with which codes were assigned to responses broken down into four age groups by decade. We again used logistic regression to test trends. Connections with others was used more by older participants ($\beta = 1.16$, $z = 2.05$, $p = .040$, $R^2_{\text{partial}} = .008$), as were Milestone reasons ($\beta = 1.03$, $z = 4.86$, $p < .001$, $R^2_{\text{partial}} = .045$). Plan to Remember reasons were used more by younger participants ($\beta = 0.97$, $z = -2.63$, $p = .008$, $R^2_{\text{partial}} = .022$), as were Don't Remember reasons ($\beta = 0.97$, $z = -2.83$, $p = .005$, $R^2_{\text{partial}} = .026$). No other reason codes showed significant linear trends.

General discussion

In three studies, participants were asked to report years of their lives they would want to save photos from, imagining they had many photos from each year but could only choose

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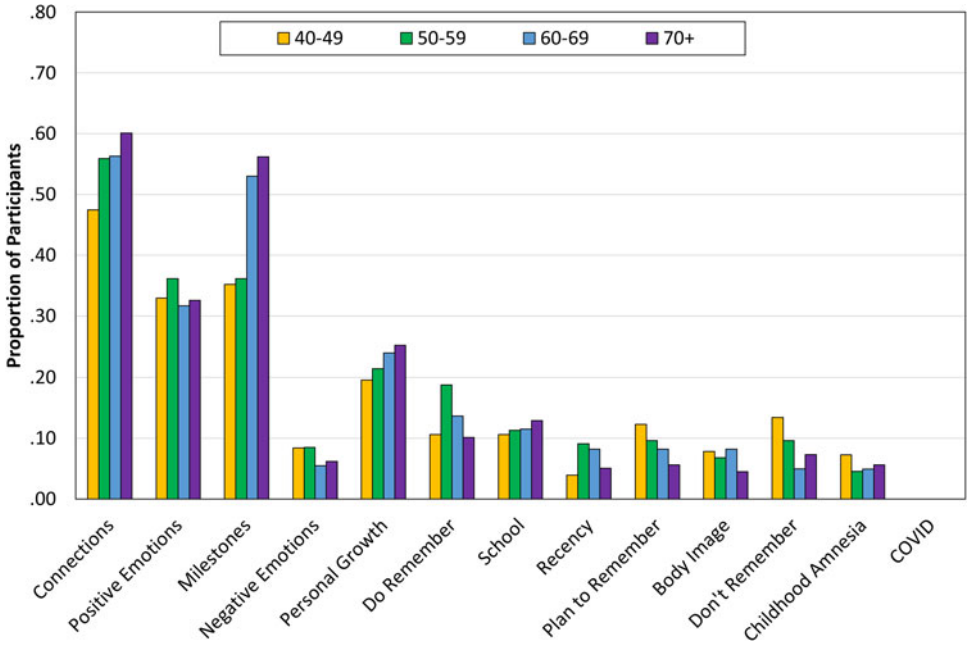

Figure 7. Frequency of choice reasons across age groups in Study 3.

one (Studies 1 and 2) or three (Study 3). Overall, we found that participants reported wanting to save photos across time in a similar temporal pattern as is typically observed for autobiographical recollection. Patterns consistent with recency and the reminiscence bump were observed such that participants generally favoured recent years or years around late adolescence or early adulthood, lifetime periods that are likely to be well remembered. Some participants did choose ages that would typically not be recalled due to childhood amnesia. Indeed, some participants mentioned in their free responses that they chose these early ages specifically because they were too young to remember. However, this reasoning was not common, making up 3–6 per cent of responses coded. Instead, participants tended to choose times likely to be well remembered. Compared to years likely forgotten due to childhood amnesia, recent (within the last 5) years were more popular in Studies 1 and 2 (S1: 12 vs. 69 per cent, S2: 9 vs. 33 per cent) and about as popular in Study 3 (S3: 10 vs. 9 per cent of years chosen). Participants also frequently reported years likely to be well remembered due to the reminiscence bump. In Study 2, for participants aged 40 and above, 45 per cent chose years within the reminiscence bump range. In Study 3, which included only adults over 40, 48 per cent of years chosen landed in the 11–30 range and 86 per cent of participants chose at least 1 year in this window.

These findings are inconsistent with the idea that people rely on external memory sources like photos solely as a means of compensating for the failures of internal memory through cognitive offloading. On the contrary, participants more often chose ages that were likely to be well remembered than ages that were not. Indeed, participants' qualitative responses mentioning memory were consistently more likely to mention being able to remember the chosen age rather than not being able to remember the chosen age. These findings are more consistent with the idea that external memory is often used to enhance or enrich internal memory, rather than replace it. Such a complementary

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dynamic is emphasized in the memory symbiosis framework (Finley *et al.* 2018) and the blended memory framework (Fawns 2011). That being said, the present results do not contradict other research showing evidence of cognitive offloading, many of which have done so in the context of prospective memory (for review, see Gilbert *et al.* 2022). Instead, these findings suggest that cognitive offloading does not characterize all of the ways in which people use digital devices to support their memory.

Qualitative data (Tables 1 and 2) showed the kinds of life themes and events that were important for participants to have photos of, particularly for reasons associated with positive emotions, connections to others, life milestones, and personal growth. These findings align well with the idea that life stories are organized by the presence of large transitions (Brown 2016). Milestones like marriage and periods of personal growth (e.g., going off to college) stand out as representing such transitions, but participants also frequently alluded to other transitions, like choosing a year before the death of a loved one, in informing their decisions. Interestingly, older adults seemed to allude more frequently to major milestones than younger adults. It is possible that older adults simply have more milestones in their lives worth mentioning, but it is also possible that older adults use such milestones to mentally organize their longer lives to a greater extent than younger adults. Participants' preference for mentioning positive emotions over negative is also consistent with the positivity bias in autobiographical memory: the finding that most participants tend to report more positive than negative and neutral autobiographical memories (Walker *et al.* 2003). This observation is also consistent with recent work in which participants reported more positive recollections cued by saved photos in their smartphones' photo albums compared to recollection with deleted photos in their trash folders (Soares 2023).

Given the survey methodology used in the present study, replicating these findings across a wide variety of samples would further clarify how people prioritize external memories across time, and what factors may influence their choices. The sample collected, though diverse in other ways, was collected exclusively from people located in the United States. Future work should examine how people from other cultures, especially cultures with substantially different photo-taking practices or life story schemas, prioritize external memories across their lifetimes. It is also worth noting that most of these data were collected following the onset of the COVID-19 pandemic. It is possible that the pandemic changed how participants responded to the critical questions, but only a small proportion of participants (3% in Study 1 and 2% in Study 2) mentioned or alluded to COVID-19 or shelter-in-place measures. By 2023 when Study 3 was conducted, no participant mentioned the pandemic. The lack of mention is noteworthy in itself, in contrast to the impact the pandemic had on everyday life during its height.

The current study asked participants to choose years retrospectively, so their responses may not reflect how they curate or prospectively plan to remember photos throughout their lifetimes. Rather, the current study asked participants to speculate on their photo-seeking behaviour in a hypothetical situation. It seems likely that such a decision would be informed by factors like participants' metacognitive beliefs about their own memory and how memory works generally, and their own biased memories of their lives. Future work could examine how pre-existing or manipulated metacognitive beliefs or beliefs about the interface between the mind and digital technology could change participants' choices to save photos across the years.

Another important contributing factor to how participants chose their years of photos to save is their goals for remembering with photos. In a broad sense, it seems that older people might have inherently different relationships with their photos compared to younger people. For example, younger people might collect or curate photos with plans for their future selves to remember with those photos, while older adults might begin to think of photos as records for the next generation. The data preliminarily suggest

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changes in these reasons across age groups, but such differences could be driven by changing goals, differences in attitudes across older and younger adults who started using digital technology at different times in their lives, or both factors in combination. Future work should examine relationships and goals for external memory sources and how those goals might change throughout a lifespan, paying close attention to generational differences in digital technology use and attitudes.

The current study provides important clues about how people value, prioritize, and keep external memory sources in the digital age. Of course, people likely remember photos differently than they do with other external memory sources, digital or otherwise. A different temporal pattern could occur for people asked about diary entries, video recordings, social media posts, or other means of externalizing autobiographical memories. It seems likely that documents of autobiographical events would follow a similar pattern as was observed here, but that is an empirical question for future work. Furthermore, certain technologies are better suited for aiding different memory purposes, so documents more commonly used for semantic purposes like records or notes seem likely to show a different temporal pattern from photos, which typically serve more episodic purposes (Soares 2023; Soares and Storm 2022b). If people were told they would use photos for semantic or prospective purposes, the memory symbiosis framework predicts a pattern of results more consistent with using external memory to compensate for internal memory (Finley *et al.* 2018; Finley and Naaz 2023).

Overall, the current study's findings are consistent with the idea that people keep and seek out external memory sources for reasons beyond the kind of compensation for failures of internal memory that have been emphasized by the literature so far. Indeed, participants in all three studies tended to prefer photos from times in their lives likely to already be particularly well remembered (i.e., recency and reminiscence bump) rather than times likely to be forgotten. That said, some participants chose to save photos from their first few years of life during which memories are lost to childhood amnesia, showing some evidence of external memory playing a compensatory role as well. Since smartphone cameras have made photo-taking a daily behaviour, it seems likely that even more personal events, both important and mundane, will be remembered with the help of thousands of photos. The interplay between people's photos and their internal memory will continue to shape how they remember the lives they lead.

Data availability statement. Full data sets as well as all electronic materials are available freely online through the Open Science Framework: https://osf.io/avwes/. None of the studies reported were formally preregistered.

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Author contributions. **J.S.S.** conceptualized the whole article, conducted formal analysis, investigated the article, wrote the original draft, reviewed and edited the article, and administered the project; **J.R.F.** conceptualized the whole article, developed the methodology, conducted formal analysis, investigated the article, wrote the original draft, reviewed and edited the article, visualized the whole project; **P.M.R.** conducted formal analysis, wrote the review and edited the article.

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Competing interest. The authors have no conflicts of interest to declare.

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