Trends in Cognitive Sciences

CellPress

Review

Externalizing autobiographical memories in the digital age

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People externalize their autobiographical memories by creating representations that exist outside of their minds. Externalizations often serve personal and social functions, consistent with theorized functions of autobiographical memory. With new digital technologies, people are documenting more memories than ever and are sharing them with larger audiences. However, these technologies do not change the core cognitive processes involved in autobiographical memory, but instead present novel situations that affect how these processes are deployed. Smartphones allow events to be recorded as they unfold, thus directing attention and sometimes impairing memory. Social media increase the frequency of reviewing and sharing records which reactivate memories, potentially strengthening or updating them. Overall, externalization in the digital age changes what people attend to and remember about their own experiences.

Highlights

Humans have long preserved their personal memories externally (diaries, photographs), but such behaviors have skyrocketed with the advent of smartphones and social media.

The motivation to preserve most personal memories aligns with the functions of autobiographical memory such as social bonding instead than cognitive offloading.

Digital technology increases opportunities to record events as they unfold, use sophisticated editing tools, receive automated reminders of the past, and share experiences online.

Although the underlying cognitive processes (attention, rehearsal) remain constant, new tools affect how events are experienced and remembered. Simultaneous recording (e.g., via smartphone) can divide or direct attention, with consequences for memory.

Sharing on social media is now a goal, and huge online audiences have made personal memory records more public than ever, creating new social pressures.

Cognition and the externalization of memories

Humans have long externalized their personal memories by creating representations that exist outside of their minds and that allow sharing with others. Memory records appear on cave walls as well as in diaries and photographs, among other places. Such externalizations are examples of how tools in the environment can support cognition (**extended mind**; see Glossary) [1]. The frequency of externalizing **autobiographical memories** is exploding in the **digital age**: personal photo collections now number in the tens of thousands [2] and, worldwide, >350 million photos are uploaded to Facebook daily[i]. Digital tools are mobile, and the smartphone in one's pocket allows memory records to be created, edited, reviewed, and shared 'on-the-go' (Box 1). Digital records are dynamic, meaning they are easily edited, updated, and deleted. At the same time, social media have transformed the broader social context in which memories are externalized. With an average of 338 friends per Facebook user[ii], personal memories have never been so public.

What has not changed, however, are the core cognitive processes of the mind – the timescale is simply too short. The same attentional and memory processes apply when thinking about the social media user today as when thinking about the diarist a century ago. Instead, technology has changed the situations where cognitive processes are deployed. For example, attention is the same – but what people are attending to has changed. Memory rehearsal still increases memorability – but its frequency has increased. We discuss how these cognitive processes apply in the digital age, highlighting the role played by our increasing social connectedness while identifying new questions.

Recording directs attention, thus affecting memory

Recording one's life is enjoyable, and increases engagement in experiences [3]. However, people now have cameras in their pockets that allow synchronous recording of events, as opposed to retrospective externalization (as occurs with diaries). Nevertheless, photo-taking can be

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Box 1. A framework for preserving personal memories

A series of common activities (i.e., recording, curation, review, and sharing) underlie the external preservation of personal memories, regardless of what forms they take (e.g., photos, videos, diaries, blogs, social media posts). The process begins when a record of an experience is created (e.g., a photo is taken, a video is recorded, a diary entry is written). The process can end there if the record is abandoned (e.g., when a photo strip from a photo booth is lost or a diary entry is ripped out and shredded). In many cases, however, the user continues to interact with the memory record post-recording, and engages in some or all of the following activities: curating, reviewing, and/or sharing with others. That is, much like a museum curator, individuals curate their own personal memory records by editing individual records (e.g., applying color filters, photoshopping details, cropping out unwanted objects) and organizing large collections of records (e.g., sorting through hundreds of vacation photos to decide which few to include in a photo album). Doing so often involves revisiting the records and reviewing them – although one can also review records that have never been curated (e.g., rereading past diary entries). Often, but not always, some records are selected to be shared with other people (e.g., posting holiday photos to a Facebook album). Curation, review, and sharing are not required to occur in any particular order, are not limited to a single occurrence (e.g., a photo may be repeatedly edited), and are not mutually exclusive.

distracting and affect what is later remembered. This photo-taking impairment effect was first demonstrated in a study in which participants on a museum tour were instructed to photograph or observe a series of artworks. The next day, people recognized fewer of the objects they had photographed compared to those they had simply observed, presumably because they attended to the camera (as opposed to fully focusing on the object) [4]. This photo-taking impairment effect occurs across a variety of memory measures including visual discrimination tests, conceptual tests, and free recall [5]. It should be noted that, despite the name, this effect is not limited to photography. For instance, writing about one's thoughts and feelings during an experience (e.g., watching a TED talk) also impairs memory [6].

More generally, the memorial consequences of recording depend upon the processing demands placed on the user. For example, a traditional camera requires the photographer to focus each shot and physically take photos – whereas wearable cameras automatically (and even continuously) record the daily experiences of users (a practice known as **lifelogging** [7–9]). The photo-taking impairment effect disappears when a wearable camera is used because the act of recording no longer distracts the user from the experience [10].

Recording may also direct attention to some aspects of an event over others. Eye-tracking data from participants touring an archaeological exhibit show that individuals who engaged in volitional photo-taking were more likely to look at key artifacts (and look at them longer) than individuals who were not taking photos. In other words, photo-taking changes what people pay attention to [3]. Similarly, when photo-takers zoom in on a specific detail, the photo-taking impairment effect is eliminated [4]. Attention may be selectively deployed, as observed in another study where participants listened to an audio tour while viewing (and sometimes photographing) museum exhibits. In this case, photo-taking improved visual recognition memory but impaired recognition of the information presented through the audio guide [11].

Recorded personal memories are not offloaded

An alternative explanation for the photo-taking impairment effect is that taking photos is a form of **cognitive offloading**. That is, people sometimes rely on external devices instead of their own cognitive processing. For example, offloading computations to calculators allows one to skip mental arithmetic, and offloading phone numbers to contact lists eliminates the need to memorize them [12]. Reducing one's cognitive load provides resources for other tasks: when participants knew that a word list was externalized (saved to a computer), they remembered more of a second word list, known as the saving-enhanced memory effect [13].

Glossary

Autobiographical memories: memories of events from one's life, often accompanied by feelings of reliving the experience.
Cognitive augmenting: the use of external sources (e.g., photographs, diaries) to extend rather than replace one's biological cognitive capacities (e.g., memory).
Cognitive offloading: reliance on external aids (e.g., calculators, post-it notes, smartphones) to reduce the demand on internal cognitive processes (e.g., memory).
Deepfake video: a highly realistic but fake video created through machine learning and artificial intelligence algorithms that replace the original video subject with another person's likeness.
Digital age: the period of time beginning with the widespread use of personal computers in the late 20th century through to the present day characterized by the rapid exchange of massive amounts of digital information via computers.
Extended mind: the idea that external sources (e.g., objects, other people) can be used to expand the internal mind beyond the body.
False memory implantation: occurs when people remember events that never happened; typically requires repeated suggestion.
Lifelogging: the practice of creating a personal digital archive by documenting everything that happens to oneself, often by using wearable cameras and recording equipment.
Observer perspective: refers to the third-person point of view in a personal memory, where one sees oneself in one's own memory.
Transactive memory system: the idea of collectively sharing memory tasks, including encoding, storing, and retrieving, with others, often team members, friends, or romantic partners.

There is some evidence that knowing information is safely stored elsewhere relieves people of the burden of remembering it ([14]; *cf* [15]). This situation likely occurs for a subset of personal memories (e.g., taking photos of one's parking location to avoid later memory demands). However, offloading is unlikely to drive the recording of most personal events. Instead, theoretical work on autobiographical memories highlights other motivations (Box 2). A wedding is photographed to facilitate future reminiscence and to share it with friends and family – not to outsource the effort needed to remember it. An offloading mechanism is also inconsistent with findings showing that it is the most important, positive, and emotional memories that tend to be externalized – the very memories that are also most likely to be remembered independently [16]. The external preservation of personal memories (e.g., photographs, videos, diaries) is better conceptualized as **cognitive augmenting** – where external sources are used to extend the capabilities of biological memory rather than supplant it.

The offloading explanation of the photo-taking impairment effect was directly tested in two studies using different methods to ensure that some subjects understood that their photos were gone and not safely offloaded elsewhere [17]. In one study, participants used Snapchat, an app where photos automatically disappear after a short period of time. Participants in another study manually deleted the images they had just taken. In both studies, performance was compared to a regular photo-taking condition and to a control condition where participants only viewed the to-be-remembered artwork. If cognitive offloading drives the photo-taking impairment effect, memory should be less impaired when individuals knew their photos were gone forever. However, memory was impaired relative to the observation condition regardless of whether participants expected to have later access to the photos (standard camera condition) or not (Snapchat or manual deletion conditions) [17]. Converging results were obtained in a study where participants believed that their written accounts of an event would be erased (vs saved), offering further evidence against a cognitive offloading account [6]. Instead, these studies highlight how media usage imposes a cognitive load on the user. Although the form of the media did not matter (i.e., regular photos vs Snapchat photos), across studies memory was consistently lower with media use than without it [6,17,18]. Media use may distract and promote multitasking, ultimately impairing memory, regardless of the future accessibility of records. For example, in one study, users saw a countdown timer showing when each Snapchat photo would expire, potentially distracting them from the photo itself [18]. Understanding the effects of media usage in general is likely a more fruitful direction for future research than offloading.

Digital records are easily manipulated

Memory records are not always accurate; users can edit them or even create new ones to simulate events that never happened. Photo tampering has been around since the 19th century[iii].

Box 2. The functions of autobiographical memory

Why do we revisit our past experiences – often talking and thinking about them long after they occurred? Previous research suggests several answers to this question. The evolutionary answer is that such memories have survival value: past experiences with danger and reward are powerful directives for how one should behave, both now and in the future [68]. Memories can also fulfill other human needs, most notably by helping one to maintain a consistent self-identity over time (self function), by promoting learning from past mistakes (directive function), and by helping to build social connections (social function) [69–72]. Although these functions are often discussed separately, they are not mutually exclusive [73], and a personal memory may be externally preserved for one or more of these reasons. A social media user, for example, might post a video of their own experience with the ALS 'Ice Bucket Challenge' in response to another friend's video. Choosing to share that memory would portray a particular image to the world (i.e., of being a caring person), as well as signaling approval and shared values to their friends, thus fostering a sense of community. Depending on whether a person chooses to share a positive or negative memory, they can elicit liking or empathy [74] – consistent with other work suggesting that people may also use their autobiographical memories to improve or maintain their mood (e.g., emotion regulation) [75,76].

It is well known that exposure to altered or fake images and videos can distort beliefs [19,20] and can even lead to false memories of events that never took place (**false memory implantation**) [21–23]. For example, there are demonstrations that doctored photos changed people's memories of the crowd size at the 1989 Tiananmen Square protest in Beijing [24] and increased false memories of riding in a hot air balloon as a child [25].

Manipulated images are increasingly common in the digital age, but people are not very good at identifying manipulated images, even when explicitly tasked to do so [26]. Recent advances in artificial intelligence and machine learning allow for the creation of **deepfake videos**: extremely realistic, altered videos of people (especially public figures) appearing to say or do things they never did. Early evidence suggests that watching deepfake videos can lead to false memories of fake news events but, importantly, not at a consistently higher rate than exposure to misleading text or images [27].

A major change in the digital age is how easy it now is for individuals to edit their own records. Sophisticated tools such as Photoshop and Facetune allow users to easily make their photos more flattering, crop out unwanted objects, apply color filters, and use augmented reality filters to add whimsical elements like animal ears. In such cases, an individual is aware of the manipulation, in contrast to images doctored by others. In one of the only studies examining the cognitive consequences of such manipulations, participants used an iPad to take photos of projected scenes and later edited a subset, cropping out specific objects or applying a greyscale filter (control photos were reviewed unedited) [28]. Two days later, participants were asked to recognize which scenes had been shown in the first session as well as to identify objects from the scenes. Editing photos (i.e., removing objects, converting to greyscale) did not affect the ability of participants to recognize the original scenes. Participants had impoverished memory of the objects that were cropped out of the scenes – but, intriguingly, memory of the remaining, unaltered objects was enhanced [28]. One possibility is that the act of cropping out peripheral objects focused attention on the remaining objects, which then became more salient in the edited photo. Although these subtraction-centered edits (i.e., removing objects or colors) did not affect memory for the overall scene, no research has yet investigated the impact of adding new details (e.g., photoshopping in a missing friend) or more subtle edits (e.g., using filters to enhance one's appearance) on subsequent memory.

The ability to edit is not limited to individual records; people can also edit collections of records. Social media content, in particular, is curated to maintain a personal archive and craft a life narrative [29]. For instance, 'profile pruning' is increasingly common[iv], where people delete posts and untag themselves from photos [30]. Overall, collections of external memory records are positively biased: people retain more records of positive experiences than negative ones [30], likely increasing the review of positive memories in the future [31]. People also save photos that project their desired public image and personal aesthetic [2,32]. This tendency to curate positive collections of external records parallels the more general bias in autobiographical memory that favors positive memories [33].

Accessing externalized memories

Some memories are remembered at one point in time but not at another, illustrating the theoretical distinction between availability (what is stored in memory) and accessibility (what is retrieved in response to specific cues) [34,35]. The same problem occurs with externalized memories, such as when one fails to find a photograph that one knows to exist, because digital collections are often large and dispersed across multiple storage devices [36]. The problem is further complicated when the system automatically generates seemingly arbitrary file labels (e.g., 00060008.

jpg is one of the author's wedding photos). The default organization is temporal – another problem, given that people's memory for exact dates of events is poor and often reconstructed [37]. Despite these challenges, people are overconfident in their ability to locate specific records. For example, when asked to find a digital photo of an important event (i.e., a child's birthday), participants failed to find the requested image 39% of the time [36]. This organizational problem, however, will likely diminish as image recognition software and machine learning algorithms become increasingly accurate at automatically sorting and classifying photos.

Memory retrieval can be voluntary, driven by an individual's search through memory, or involuntary, in response to environmental cues [38]. Many apps and social media platforms provide such cues; for example, Facebook Memories periodically prompts users to review past memories (e.g., a photo from 3 years ago). Intriguingly, people underestimate how much they will enjoy rediscovering records of their past experiences [39]. For example, individuals asked to create time capsules for ordinary and special events (i.e., Valentine's Day) systematically underestimated how much they would later enjoy revisiting their memories. This was especially true for ordinary experiences, likely because individuals overestimated how much they would later remember [39].

External records facilitate memory reactivation

Once accessed, an external record is a detailed, rich cue [40] that reactivates memories. Unsurprisingly, given the literature on the power of retrieval practice [41], reviewing records often improves memory of the original events. This rehearsal benefit is observed when one flips through a photo album [42,43], looks at digital images on a screen [28,44–46], or samples photos that were automatically taken by a wearable camera (e.g., SenseCam) [9,47]. In the latter case, reviewing images from one's day boosts recall and recognition [9], aiding both younger and older adults [48], as well as memory-impaired populations [49,50]. Such review is beneficial if one's goal is improved memory, but one downside is that users may review events they would rather forget – as devices like SenseCam automatically capture images without discriminating between positive and negative events. Regardless of whether one wants to remember an event or not, reviewing it will help rememberers to fill in the gaps in their memories, and SenseCam images can trigger the recollection of highly specific details that had previously been forgotten [51]. However, the effects of review extend beyond reminding people of specific events; for example, both younger and older adults recalled more semantic (and episodic) details after reviewing their SenseCam photos than when events were cued by dates and titles without accompanying photos [48].

Although rehearsal is generally thought of as beneficial for memory, reactivated memories can also be updated – the memory can be reconsolidated in a way that reflects how the memory is rehearsed. Photographs are particularly rich cues (compared to narratives such as diary entries) [50,51], and can cue details beyond the single moment depicted in any one photograph [49]. As such, reviewing photos provides opportunities for reflection, elaboration, and meaning-making, which may strengthen or change a memory, depending on the similarity between the products of these processes and the original event. The power of a photo cue (especially when combined with reflection and elaboration) is evident when examining implanted memories. That is, even a real photograph (i.e., a childhood class photo) can increase the likelihood of a false memory being implanted [52] because it provides details that can be incorporated into a false memory or a larger childhood narrative.

Although memory rehearsal is not new to the digital age, three elements have changed, with potential to impact later memory: the sheer number of memory cues (i.e., records) stored externally,

the quality of those cues (e.g., digital, multimedia), and the accessibility of those cues, given the convenience of smartphones and the synchronization of records across devices (e.g., via cloud storage).

Sharing on social media affects memory

Even more than reviewing, sharing has increased in the digital age, raising the question of how the decision to share with others affects cognition beyond any effects of private review. That is, sharing is another form of rehearsal that can reactivate memories. However, sharing a memory online goes beyond privately reviewing a record because deciding to share often involves thinking about the reactions of others. Furthermore, compared to other forms of memory sharing (i.e., conversations), social media posts are longer-lasting – at the extreme, profile pages may remain active for months and years after the death of a user, serving as online memorials [53]. In general, the durability of online records allows people to return to the same post days, months, or years later, thereby encouraging repeated reactivation of the memory.

People believe that sharing one's experiences on social media will boost memory [40]. This perception may derive in part from the intrinsic memorability of the types of events that are shared on social media: they are often positive [54], personally important, and emotionally intense events [16]. Laboratory experiments can remove the natural confound between event-type and sharing, such as a study in which the participants were asked to watch a video while writing about their experiences for different audiences [6]. Some participants believed they were creating a personal record, whereas others believed that their writing would be shared with others; all participants later took a five-item multiple-choice quiz testing their memory of the video. In this case, creating personal versus to-be-shared notes had no impact on their ability to recognize the content of the video [6].

A different approach is to allow participants to select which events to share, but to statistically control for the properties of those events when examining later memory. For example, in one study undergraduates kept a diary of events and later indicated which events they had posted about on social media [16]. Memory was later better for the events that people shared online. Although the events chosen for sharing were more important and emotional than non-shared events, the memory benefit persisted even when statistically controlling for these event characteristics [16]. Several cognitive processes likely contributed to this benefit. First, posting involves decision-making when choosing between many records – only 6% of diary events were posted online in this study [16]. Second, sharing events on social media likely increases review because users receive notifications (e.g., likes, comments, shares) and return to the post when others respond. Third, posting on social media is a form of storytelling in which posted events are chosen to fit a desired narrative (i.e., schema) that later supports memory for those events. Crafting a social media post involves thinking about the original memory, elaborating on its key components, and reflecting on how it connects to one's broader life story.

Although sharing events on social media can benefit memory, there may be consequences for events that are not chosen for sharing. The larger literature makes clear that retrieving a subset of events is often at the expense of memory for related, non-reviewed events, an effect termed retrieval-induced forgetting [55,56]. A parallel effect holds when participants share some but not all photos from a category on social media. In one diary study, participants were instructed to record and photograph four types of emotional events (i.e., happy, funny, exciting, entertaining). Crucially, participants were instructed to post a subset of photos from two emotional categories (e.g., two happy events and two funny events) on their Instagram accounts to share with their followers. Later, they were cued with all four emotional categories and asked to recall all of their associated memories. Memories that were posted online were recalled best; however, memories that shared the same category but

were not posted online (e.g., the other two happy events) were less likely to be recalled than memories from the two emotional categories that were never posted online (e.g., the exciting and entertaining events) [55]. Although posting on social media can induce forgetting of one's own unshared memories, another intriguing possibility is that social media viewers may also experience retrieval-induced forgetting given that it occurs for listeners in conversations where speakers discuss parts but not all of a shared event [57,58].

Potential consequences of increasingly public records

Although the idea of collectively storing memories outside an individual's mind is not new (**transactive memory system**), the internet and social media have led to exponentially larger social networks. These audiences in turn have contributed to the sharp increase in the recording and sharing of personal memories. We highlight here how the increasingly public nature of memory records has made sharing on social media its own goal, and we discuss the potential cognitive consequences of sharing with large online audiences.

First, sharing on social media has become a goal in and of itself where individuals take photos solely 'to post on social media' and 'to share the moment with someone else who is not there' [40]. Tellingly, the phrase 'do it for the gram' refers to people exclusively seeking out experiences (e.g., trendy restaurants, exotic destinations) to share with their followers on Instagram. Since the advent of front-facing camera phones, taking photos of oneself (selfies) has skyrocketed in popularity. Selfies can serve as memory 'trophies' that document one's accomplishments (e.g., finishing a marathon) or experiences (e.g., visiting the Eiffel Tower). The motivation behind taking selfies is often social: to gain attention, fit in with peers, and receive positive feedback on social media [59].

From a cognitive perspective, what is interesting is that the intention to share a memory (as is often the case with selfies) affects the phenomenology of the later memory. That is, photographing an event to share it with others increases the likelihood that the event will be remembered from a third-person, **observer perspective** (a hallmark of a reconstructed memory) compared to participants who did not intend to share their photos [60]. This likely occurs because anticipated sharing increases self-presentation concerns leading the photographer to imagine what others will see. This results in self-aware photos that are more likely to be posed and contain more smiling people [60].

A second change is that records shared online reach a much larger audience, whose members also have large audiences, snowballing into massive virtual audiences given the 4.2 billion active social media users around the world[v]. Family photos that were once viewed by dozens of individuals are now seen by hundreds or thousands of people online [61]. The size of an audience matters because it changes the content people share [62]. Sharing with a large audience (i.e., broadcasting) elicits self-presentation concerns and reduces the use of negative emotion words. By contrast, sharing with a single person (i.e., narrowcasting) is more intimate [62]. Large virtual audiences are also less visible than typical in-person audiences and, unsurprisingly, people underestimate the size of their audience when sharing on Facebook [63] – potentially leading them to divulge more personal information online than they would in person [64].

Many of the questions listed in the Outstanding questions are similar to the two just described – they are questions about cognition in unfamiliar social contexts. For example, parents have long recorded their children's milestones – but many parents today engage in 'sharenting' and document their children's childhoods in excruciating detail for large social media audiences. How will these children, once grown, remember their childhoods? Childhood memories are often less vivid and more vulnerable to distortion [65], allowing for the manipulation of specific memories or of one's overall impression of childhood. These questions and others are about

memory – but they arise because of a social context that could not have been envisaged two decades ago.

Concluding remarks

Over the past 20 years smartphones and social media have exploded in popularity, driving an unprecedented surge in the documentation and sharing of personal memories. Even beyond the sheer number and location of stored memories, the digital age brings changes that have implications for cognition: simultaneous recording and sharing are more prevalent, sophisticated editing tools are widely available, apps automatically cue memories, and the average audience size has multiplied exponentially.

Unlike the external storage of information, we suggest that people do not create external records of their personal memories to offload the effort needed to remember them, but rather to preserve these moments in ways that allow for later review and sharing with others. Although memory can suffer when recording interferes with one's experience [4], the reviewed data do not support a cognitive offloading explanation of the externalization of personal memories [6,17]. Instead, people's motivations for externalizing their personal memories are consistent with the theorized functions of autobiographical memory, with the exception that sharing on social media is now itself a goal. Social media also allow much more public memorials of loved ones [53,66] and offer the possibility of preserving one's own legacy – behaviors that may help users to regulate their emotions. With its large audiences and enduring nature, social media also help to maintain family records [61] and transmit generational knowledge that might otherwise be lost [67]. More generally, social media present a unique landscape for exploring the functions that autobiographical memories serve, given the relatively public nature (and large numbers) of shared records.

As technology advances, new tools and trends will inevitably emerge, transforming how external memory records are created, modified, reviewed, and shared. Although technology is changing quickly, these changes do not eclipse what we know about the workings of the human mind (e.g., simultaneous recording may divide attention but does not change basic attentional processes). Future investigations (see Outstanding questions) in this emerging literature will provide a deeper understanding of how the age-old behavior of externalizing personal memories has adapted to flourish in the current digital age.

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Declaration of interests

The authors declare no conflicts of interests.

Resources

[i] https://www.businessinsider.com/facebook-350-million-photos-each-day-2013-9

[ii] https://www.pewresearch.org/fact-tank/2014/02/03/what-people-like-dislike-about-facebook/

[iii] https://www.scientificamerican.com/article/photo-tampering-throughout-history/

[iv] https://www.pewresearch.org/internet/2012/02/24/main-findings-12/

[v] https://www.statista.com/statistics/617136/digital-population-worldwide/

References

1. Clark, A. (2010) Memento's revenge: the extended mind, extended. In *The Extended Mind* (Menary, R., ed.), pp. 43–66, MIT Press
2. Broekhuijsen, M. *et al.* (2017) From PhotoWork to PhotoUse: exploring personal digital photo activities. *Behav. Inform. Technol.* 36, 754–767

Outstanding questions

How might digital externalizations of memories affect emotion regulation? Autobiographical memories help direct future action, form social bonds, and maintain a sense of self. Emerging research suggests that revisiting autobiographical memories also helps people to regulate emotions – but this is relatively unexplored in the digital realm.

How does sharing memories with an online audience differ from face-to-face interactions, and do these differences change how events are remembered? Audiences for social media posts are often much larger and less visible than in-person audiences.

Will childhood be remembered differently if it was documented online? Parents often use social media for 'sharenting', sharing photos and documenting the details of their children's lives as they grow up.

Does seeing other people's memory records on social media distort one's own memories? Although exposure to other people's memories can lead to retrieval-induced forgetting for shared events, it is unknown whether people borrow others' posts, treating those memories as their own.

How does social feedback and quantifiable validation (e.g., likes, comments) on social media affect memory? Although there are concerns about how social feedback negatively impacts mental health, much less is known about how this influences memory.

How might subtle photo edits (e.g., improving one's appearance) affect one's self-worth and how one remembers the affective tone of an event? How does including augmented reality features (e.g., face-tracking filters, special effects) in photos and videos affect memory? It is well demonstrated that exposure to doctored photos can lead to false memory implantation – but less is known about the effects of editing one's own photos.

How do visual externalizations of memory (e.g., photos, videos) differ from verbal ones (e.g., diaries, blogs),

3. Diehl, K. *et al.* (2016) How taking photos increases enjoyment of experiences. *J. Pers. Soc. Psychol.* 111, 119–140
4. Henkel, L.A. (2014) Point-and-shoot memories: the influence of taking photos on memory for a museum tour. *Psychol. Sci.* 25, 396–402
5. Lurie, R. and Westerman, D.L. (2021) Photo-taking impairs memory on perceptual and conceptual memory tests. *J. Appl. Res. Mem. Cognit.* 10, 289–297
6. Tamir, D.I. *et al.* (2018) Media usage diminishes memory for experiences. *J. Exp. Soc. Psychol.* 76, 161–168
7. Harvey, M. *et al.* (2016) Remembering through lifelogging: a survey of human memory augmentation. *Pervas. Mob. Comput.* 27, 14–26
8. Sellen, A.J. and Whittaker, S. (2010) Beyond total capture: a constructive critique of lifelogging. *Commun. ACM* 53, 70–77
9. Finley, J.R. *et al.* (2011) The effects of end-of-day picture review and a sensor-based picture capture procedure on autobiographical memory using SenseCam. *Memory* 19, 796–807
10. Niforatos, E. *et al.* (2017) Can less be more? Contrasting limited, unlimited, and automatic picture capture for augmenting memory recall. *Proc. ACM Interact. Mob., Wear. Ubiquit. Technol.* 1, 21
11. Barasch, A. *et al.* (2017) Photographic memory: the effects of volitional photo taking on memory for visual and auditory aspects of an Experience. *Psychol. Sci.* 28, 1056–1066
12. Risko, E.F. and Gilbert, S.J. (2016) Cognitive offloading. *Trends Cogn. Sci.* 20, 676–688
13. Storm, B.C. and Stone, S.M. (2015) Saving-enhanced memory: the benefits of saving on the learning and remembering of new information. *Psychol. Sci.* 26, 182–188
14. Sparrow, B. *et al.* (2011) Google effects on memory: cognitive consequences of having information at our fingertips. *Science* 333, 776–778
15. Marsh, E.J. and Rajaram, S. (2019) The digital expansion of the mind: implications of internet usage for memory and cognition. *J. Appl. Res. Mem. Cogn.* 8, 1–14
16. Wang, Q. *et al.* (2017) Externalising the autobiographical self: sharing personal memories online facilitated memory retention. *Memory* 25, 772–776
17. Soares, J.S. and Storm, B.C. (2018) Forget in a flash: a further investigation of the photo-taking-impairment effect. *J. Appl. Res. Mem. Cogn.* 7, 154–160
18. Kahn, A.S. and Martinez, T.M. (2020) Text and you might miss it? Snap and you might remember? Exploring 'Google effects on memory' and cognitive self-esteem in the context of Snapchat and text messaging. *Comput. Hum. Behav.* 104, 106166
19. Nash, R.A. (2018) Changing beliefs about past public events with believable and unbelievable doctored photographs. *Memory* 26, 439–450
20. Nash, R.A. *et al.* (2009) Digitally manipulating memory: effects of doctored videos and imagination in distorting beliefs and memories. *Mem. Cogn.* 37, 414–424
21. Scoboria, A. *et al.* (2017) A mega-analysis of memory reports from eight peer-reviewed false memory implantation studies. *Memory* 25, 146–163
22. Hessen-Kayfitz, J. *et al.* (2017) The labeling of photos when suggesting false childhood events can enhance or suppress false memory formation. *Psychol. Conscious. Theory Res. Pract.* 4, 288–297
23. Hessen-Kayfitz, J.K. and Scoboria, A. (2012) False memory is in the details: photographic details differentially predict memory formation. *Appl. Cogn. Psychol.* 26, 333–341
24. Sacchi, D.L.M. *et al.* (2007) Changing history: doctored photographs affect memory for past public events. *Appl. Cogn. Psychol.* 21, 1005–1022
25. Wade, K.A. *et al.* (2002) A picture is worth a thousand lies: using false photographs to create false childhood memories. *Psychon. Bull. Rev.* 9, 597–603
26. Nightingale, S.J. *et al.* (2017) Can people identify original and manipulated photos of real-world scenes? *Cogn. Res. Princ. Implications* 2, 30
27. Murphy, G. and Flynn, E. (2021) Deepfake false memories. *Memory* Published online April 28, 2021. https://doi.org/10.1080/09658211.2021.1919715
28. Henkel, L.A. and Milliken, A. (2020) The benefits and costs of editing and reviewing photos of one's experiences on subsequent memory. *J. Appl. Res. Mem. Cogn.* 9, 480–494
29. Zhao, X. *et al.* (2013) The many faces of facebook: experiencing social media as performance, exhibition, and personal archive. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, pp. 1–10, Association for Computing Machinery (ACM), New York, NY, USA
30. Frohlich, D.M. (2004) *Audiophotography: Bringing Photos To Life With Sounds*, Vol. 3. Springer Science and Business Media
31. Konrad, A. *et al.* (2016) Technology-mediated memory: is technology altering our memories and interfering with well-being? *ACM Trans. Compu. Hum. Interact.* 23, 1–29
32. Van House, N.A. (2011) Personal photography, digital technologies and the uses of the visual. *Vis. Stud.* 26, 125–134
33. Walker, W.R. *et al.* (2003) Life is pleasant – and memory helps to keep it that way! *Rev. Gen. Psychol.* 7, 203–210
34. Tulving, E. and Pearlstone, Z. (1966) Availability versus accessibility of information in memory for words. *J. Verbal Learn. Verbal Behav.* 5, 381–391
35. Stanley, M.L. *et al.* (2021) Cultural identity changes the accessibility of knowledge. *J. Appl. Res. Mem. Cogn.* 10, 44–54
36. Whittaker, S. *et al.* (2010) Easy on that trigger dad: a study of long term family photo retrieval. *Pers. Ubiquit. Comput.* 14, 31–43
37. Malek, H.B. *et al.* (2017) Reconstructing the times of past and future personal events. *Memory* 25, 1402–1411
38. Berntsen, D. (2021) Involuntary autobiographical memories and their relation to other forms of spontaneous thoughts. *Philos. Trans. R. Soc. B Biol. Sci.* 376, 20190693
39. Zhang, T. *et al.* (2014) A 'present' for the future: the unexpected value of rediscovery. *Psychol. Sci.* 25, 1851–1860
40. Finley, J. *et al.* (2018) *Memory and Technology: How We Use Information in the Brain and the World*, Springer International
41. Roediger, H.L. *et al.* (2021) Benefits of testing memory: Best practices and boundary conditions. In *Current Issues in Memory* (Rummel, J., ed.), pp. 360–395, Routledge
42. Koutstaal, W. *et al.* (1998) Post-event review in older and younger adults: improving memory accessibility of complex everyday events. *Psychol. Aging* 13, 277–296
43. Koutstaal, W. *et al.* (1999) Facilitation and impairment of event memory produced by photograph review. *Mem. Cogn.* 27, 478–493
44. St. Jacques, P.L. *et al.* (2013) Neural mechanisms of reactivation-induced updating that enhance and distort memory. *Proc. Natl. Acad. Sci. U. S. A.* 110, 19671–19678
45. St. Jacques, P.L. *et al.* (2015) Modifying memory for a museum tour in older adults: reactivation-related updating that enhances and distorts memory is reduced in ageing. *Memory* 23, 876–887
46. St. Jacques, P.L. and Schacter, D.L. (2013) Modifying memory: selectively enhancing and updating personal memories for a museum tour by reactivating them. *Psychol. Sci.* 24, 537–543
47. Chow, T.E. and Rissman, J. (2017) Neurocognitive mechanisms of real-world autobiographical memory retrieval: Insights from studies using wearable camera technology. *Ann. N. Y. Acad. Sci.* 1396, 202–221
48. Mair, A. *et al.* (2017) Supporting older and younger adults' memory for recent everyday events: a prospective sampling study using SenseCam. *Conscious. Cogn.* 49, 190–202
49. Foley, M.A. (2020) Effects of photographic reviews on recollections of the personal past: a new perspective on benefits and costs. *Rev. Gen. Psychol.* 24, 369–381
50. Silva, A.R. *et al.* (2018) A critical review of the effects of wearable cameras on memory. *Neuropsychol. Rehabil.* 28, 117–141
51. Loveday, C. and Conway, M.A. (2011) Using SenseCam with an amnesic patient: accessing inaccessible everyday memories. *Memory* 19, 697–704
52. Lindsay, D.S. *et al.* (2004) True photographs and false memories. *Psychol. Sci.* 15, 149–154
53. Bouc, A. *et al.* (2016) 'Why are they commenting on his page?': using Facebook profile pages to continue connections with the deceased. *Comput. Hum. Behav.* 62, 635–643
54. Nadkarni, A. and Hofmann, S.G. (2012) Why do people use Facebook? *Personal. Individ. Differ.* 52, 243–249

and what are the consequences for memory? It is noteworthy that most of the literature reviewed here involves visual externalizations.

55. Stone, C.B. and Wang, Q. (2019) From conversations to digital communication: the mnemonic consequences of consuming and producing information via social media. *Top. Cogn. Sci.* 11, 774–793
56. Anderson, M.C. *et al.* (1994) Remembering can cause forgetting: retrieval dynamics in long-term memory. *J. Exp. Psychol. Learn. Mem. Cogn.* 20, 1063–1087
57. Stone, C.B. *et al.* (2013) Forgetting our personal past: socially shared retrieval-induced forgetting of autobiographical memories. *J. Exp. Psychol. Gen.* 142, 1084–1099
58. Mao, W. *et al.* (2021) Who will influence memories of listeners: evidence from socially shared retrieval-induced forgetting. *J. Appl. Res. Mem. Cognit.* Published online February 19, 2021. https://doi.org/10.1016/j.jarmac.2021.01.005
59. Balakrishnan, J. and Griffiths, M.D. (2018) An exploratory study of 'selfitis' and the development of the selfitis behavior scale. *Int. J. Ment. Heal. Addict.* 16, 722–736
60. Barasch, A. *et al.* (2018) How the intention to share can undermine enjoyment: photo-taking goals and evaluation of experiences. *J. Consum. Res.* 44, 1220–1237
61. Holloway, D. and Green, L. (2017) Mediated memory making: the virtual family photograph album. *Communications* 42, 351–368
62. Barasch, A. and Berger, J. (2014) Broadcasting and narrowcasting: how audience size affects what people share. *J. Mark. Res.* 51, 286–299
63. Bernstein, M.S. *et al.* (2013) Quantifying the invisible audience in social networks. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, pp. 21–30, ACM
64. Agger, B. (2015) *Oversharing: Presentations of Self in the Internet Age*, Routledge
65. Lindsay, D.S. *et al.* (2004) Adults' memories of childhood: affect, knowing, and remembering. *Memory* 12, 27–43
66. Mroz, E.L. and Bluck, S. (2019) In memory: predicting preferences for memorializing lost loved ones. *Death Stud.* 43, 154–163
67. Stone, C.B. *et al.* (2014) Personally relevant vs. nationally relevant memories: an intergenerational examination of World War II memories across and within Belgian French-speaking families. *J. Appl. Res. Mem. Cogn.* 3, 280–286
68. Nairne, J.S. and Pandeirada, J.N.S. (2008) Adaptive memory: remembering with a stone-age brain. *Curr. Dir. Psychol. Sci.* 17, 239–243
69. Bluck, S. (2003) Autobiographical memory: exploring its functions in everyday life. *Memory* 11, 113–123
70. Lind, M. *et al.* (2019) Identifying distinct sets of predictors of specific functions of autobiographical memory. *Memory* 27, 1313–1318
71. Bluck, S. and Liao, H. (2013) I was therefore I am: creating self-continuity through remembering our personal past. *Int. J. Reminiscence Life Rev.* 1, 7–12
72. Bluck, S. *et al.* (2005) A tale of three functions: the self-reported uses of autobiographical memory. *Soc. Cogn.* 23, 91–117
73. Bluck, S. and Alea, N. (2002) Exploring the functions of autobiographical memory: why do I remember the autumn?. In *Critical Advances in Reminiscence Work: From Theory to Application* (Webster, J.D. and Haight, B.K., eds), pp. 61–75, Springer Publishing
74. Alea, N. *et al.* (2019) The social function of autobiographical stories in the personal and virtual world: an initial investigation. *Top. Cogn. Sci.* 11, 794–810
75. Öner, S. and Gülgöz, S. (2018) Autobiographical remembering regulates emotions: a functional perspective. *Memory* 26, 15–28
76. Pasupathi, M. (2003) Emotion regulation during social remembering: differences between emotions elicited during an event and emotions elicited when talking about it. *Memory* 11, 151–163