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Birthday memories: an experimental think-aloud study on autobiographical remembering in the digital age

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ABSTRACT

In today's digital world, people are documenting their lives more extensively than ever before. To investigate how this pervasive (digital) documentation shapes the way individuals reconstruct and recall personally relevant events, we conducted a preregistered experimental think-aloud study in which participants ($N = 40$; German sample) were asked to remember their birthdays from 2019 and 2024 in as much detail as possible. Participants completed the study in their usual home environments and were allowed to consult any external resources that they wanted to consult. The results demonstrate that participants almost exclusively used digital external resources. Moreover, participants relied more heavily on external resources when recalling the more distant birthday. Importantly, the use of external resources was an overall adaptive strategy, insofar as it helped participants gain new insights that went beyond what they could recall from internal memory alone. This provides further evidence that integrating information stored in one's mind and information stored in the environment is a potentially beneficial and symbiotic process.

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Autobiographical memory; digital age; AMEDIA-model; think-aloud method

In today's digital world, people are documenting their lives more extensively than ever before. Consider the countless photos taken with smartphones, the stream of emails and *WhatsApp* messages that individuals send, the updates shared on platforms like *BeReal*, *Instagram*, or *Snapchat*, as well as the quantitative data automatically collected through fitness trackers and wearable devices (e.g., Cho et al., 2023). This ongoing stream of information from various digital sources has resulted in an *increased density of recorded life episodes* (Hutmacher et al., 2024a; see also Heersmink & Carter, 2020; Kalnikaitė & Whittaker, 2012). Although it seems reasonable to believe that this heightened level of documentation influences how we recall and piece together our personal histories, scholarly investigation into how digital technology is transforming autobiographical memory remains in its early stages (for some recent empirical evidence, see, e.g., Armstrong et al., 2023; Barnwell et al., 2023; Camia & Wang, 2025; Hutmacher et al., 2023; Joanroy et al., 2025; Johnson & Morley, 2021; Jungselius & Weilenmann, 2023; Martin et al., 2022; Vasquez et al., 2025).

To synthesise current findings and offer a comprehensive framework to guide future investigation, we recently introduced a model for Autobiographical Memory in the Digital Age (AMEDIA-Model; Hutmacher et al., 2024a, 2024b). Importantly, the model builds upon prior research into the extended mind and the influence of technology on memory (e.g., Clark & Chalmers, 1998; Eliseev & Marsh, 2021; Finley & Naaz, 2023; Finley et al., 2018; Heersmink, 2022; Marsh & Rajaram, 2019; Schönpflug & Esser, 1995; Sutton, 2010; Yamashiro & Roediger, 2019), as well as concepts such as transactive memory systems (Huebner, 2016; Peltokorpi, 2008; Wegner et al., 1985) and digital memory aids (Clowes, 2013; Bell & Gemmell, 2009). In short, the AMEDIA-Model conceptualises autobiographical remembering as an interactive process involving both information stored in one's mind (such as personal memories of a birthday celebration) and information stored in external resources (such as photographs, messages, videos, or diary entries related to the event). Central to the AMEDIA-Model is the view that the relationship between internal processes and external resources is not static or one-way. Instead, it unfolds dynamically and recursively. For example, someone might consult their phone to confirm whether a particular friend attended a party. Upon finding visual evidence of the friend's presence, they might also notice other details on the respective photos, which then triggers memories about the food, the guests' reactions, or subsequent conversations. In other words, the combination of information stored in one's mind and information stored in one's environment is considered to be an – at least potentially – symbiotic process.

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In addition, the AMEDIA-Model also assumes that *digital* external resources are especially significant for autobiographical remembering in our contemporary societies. This claim is not self-evident, as using external resources for remembering is not an invention of the digital age. To begin with, individuals engage with others as collaborative memory partners – asking friends, for instance, to help fill in gaps in memory about shared experiences (see, e.g., Grysman et al., 2024; Nelson & Fivush, 2004; Pasupathi & Wainryb, 2010; Welzer, 2010). In addition, humans have long employed memory supports ranging from cave paintings and oral traditions to books, monuments, and handwritten diaries (e.g., Donald, 1991, 2001; Heersmink, in press). Digital technologies differ significantly from these more traditional, non-digital resources, insofar as they integrate multiple forms of content (e.g., images, text, audio, and even biometric data; see, e.g., Konrad et al., 2016), offer expansive storage at almost no cost, and are accessible almost instantly and from virtually any location (Elsden et al., 2016; Heersmink, 2022). At the same time, the use of digital resources also comes with unique challenges such as the fact that both file formats and applications that individuals use undergo frequent changes (e.g., Blum & Beyer, 2019; see also Petrelli & Whittaker, 2010; van den Hoven et al., 2012; van House & Churchill, 2008).

In a recent study (Hutmacher et al., 2025), we empirically tested and confirmed the two key assumptions underlying the AMEDIA-Model described above, that is, the assumption that autobiographical remembering (in the digital age) involves the iterative combination of information stored in one's mind and information stored in external resources as well as the assumption that digital external resources would play a particularly prominent role in this context. More specifically, we created an experimental setting using the think-aloud method in which participants had to remember and reconstruct an important day and a random day from approximately one year ago. This method enabled the collection of detailed verbal data that closely reflected participants' real-time thought processes – offering richer insights than self-report measures alone (see Baumeister et al., 2007). Participants completed the task in their everyday home environments, ensuring they had access to the same external resources they would typically use. As the results demonstrated, participants indeed repeatedly switched between information stored in their minds and information stored in external resources, with digital resources standing out as especially influential. Moreover, the study highlighted the adaptive nature of using external resources in the sense that increased use of (digital) external resources was associated with greater information retrieval from these resources. Overall, the results suggest that the integration of information stored in one's mind and information stored in the environment in autobiographical remembering functions as a potentially synergistic and complementary process.

Although the study provided important insights regarding the interplay between memory and technology in the digital age, many open questions remain. Using the same experimental setup as the previous study, the present study was designed to address two important limitations. First, the previous study compared remembering an important day to remembering a random day. Although including a random day can be considered to provide a baseline against which one can compare the memories for the important day, it is well known from the literature that individuals do usually not strive to create external records of everything that they experience (i.e., total capture) but rather prefer to have the important moments in their lives well-documented (i.e., situation-specific capture; Sellen & Whittaker, 2010). In the present study, we therefore focused on memories for important events only. More specifically, we focused on the participants' birthday memories. We chose the participants' birthday as an exemplary case for an important day as birthdays are usually an integral and positively valued part of an individual's self-concept (e.g., Kesebir & Oishi, 2010), as they represent an important day that all individuals share (e.g., in contrast to getting married or celebrating Christmas), and as an individual's birthday occurs at a clearly identifiable and predictable date, allowing good experimental control. In addition, one might expect that individuals possess at least some digital recordings of their birthday that they can access if they choose to.

Second, the previous study compared two events that happened about a year ago. Given that memories become less detailed over time, however, one might expect that external resources in general and digital tools in particular become even more important when remembering events from the more distant past. At the same time, finding information in external resources may become more challenging as the temporal distance increases. For instance, individuals change their smartphone about every two to four years (Knight, 2023) and do not necessarily migrate all their data from their old to their new phones. In a similar vein, the popularity of social media platforms shifts markedly over time, and individuals may lose access to accounts they once used. This creates a potential tension between a greater dependency on external resources and their reduced availability with increasing temporal distance. Against this background, we decided to compare the participants' memories for their birthdays in 2024 and in 2019, that is, a relatively recent birthday and a more distant one. The recent birthday was chosen to align with the previous study. The selection of the more distant birthday was guided by two considerations. First, we aimed to choose a year preceding the COVID-19 pandemic to avoid potential confounds. Second, since we planned to recruit a student sample, we wanted to avoid selecting a birthday too far back in participants' childhood, when they may not have had the same access to digital devices as they do today. Taken together, the present study was designed to provide additional insights into the interplay between information stored in one's mind and information stored in the environment in the context of autobiographical remembering in the digital age.

Method

Participants

As the present study followed in the footsteps of the previous study using the think-aloud method in the context of autobiographical remembering in the digital age (Hutmacher et al., 2025), we aimed for the same sample size and recruited a total of $N = 40$ participants (19–29 years, $M = 22.05$, $SD = 2.69$, 15 male, 25 female).[1] In terms of educational attainment, 36 participants had completed high-school, and four participants had a bachelor's degree.

Participants were recruited through the participant recruitment system used by the University of Würzburg (Germany) and through personal contact. Participants received course credit. The study was conducted between April 23 and May 10, 2025. The study was conducted in accordance with the Declaration of Helsinki and the ethical guidelines of the German Psychological Society (DGPs). Based on the regulations for conducting psychological research in Germany, no formal IRB approval was required. All participants provided written informed consent. The study was preregistered (see https://aspredicted.org/2ry5-s39b.pdf). For the reader's convenience, the preregistered research questions are listed in Table 1.

Design and procedure

Overall, the present study followed the protocol from the previous think-aloud study (Hutmacher et al., 2025), with the main difference being that the two days that participants had to reconstruct were tested in one combined session instead of two separate sessions. The study was conducted in the participants' usual home environment in which they have access to the external resources that they also have access to in their daily lives. In order not to intrude in the participants' home environment, the study was conducted using a videoconferencing tool. After giving informed consent and completing a brief demographic survey, participants carried out the main task using the think-aloud method. Following established guidelines (Ericsson & Simon, 1993; see also Eccles & Arsal, 2017; Noushad et al., 2024), they were asked to verbalise every thought from the moment they received the instructions until they finished the task – speaking as if alone, without worrying about how their words sounded or explaining them to the interviewer. The interviewer stayed silent except to prompt participants to continue thinking aloud if they paused. To practice, participants first solved a simple math problem using the think-aloud method ("What is 24×36?") and then a question that was related to autobiographical memory but unrelated to the later experimental task ("When and with whom did you last eat pizza?").

Next, participants were informed that they would be asked to remember and reconstruct two specific days in as much detail as possible, without yet knowing which days. They were told they would have up to 15 minutes for each reconstruction. It was stressed that this time limit existed solely to keep each session to a reasonable length. In addition, it was emphasised that participants should not feel forced to fill the entire period and that they could stop as soon as they felt they had recalled everything relevant. Participants were also told that they didn't have to monitor the time themselves and that the interviewer would notify them once the 15 min were up, allowing them to concentrate on the task. Participants were told that they could use any digital or non-digital resources, move around, or even leave the room to retrieve information or consult someone else. They were encouraged to cover where they were, what happened, who they were with, how they felt, and any thoughts that arose when reconstructing the events. Participants were also informed that if something felt too personal, they could omit sensitive details or describe them more generally. If necessary, the interviewer answered questions about the procedure before revealing the target days.

Then, participants completed the actual think-aloud experiment. Participants were asked to remember and reconstruct their birthdays in 2019 and in 2024. Whether participants first remembered and reconstructed their birthday in 2019 or their birthday in 2024 was counterbalanced across participants. Finally, the interviewer asked follow-up questions as needed to clarify when participants had changed between different resources, which resources they had used, and from which resource they had retrieved which piece of information.

Table 1. List of research questions from the preregistration.

Number	Research question
1	Does the number of changes between internal processes and external resources differ between the two birthdays?
2	Does the time that it takes participants to consult an external resource for the first time differ between the two birthdays?
3	Does the number of changes from an internal process to an external resource change depending on the kind of event (birthday 2024 vs. birthday 2019) and the reason for the change (no internal memory vs. vague internal memory vs. detailed internal memory)?
4	Does the number of changes from an external resource to an internal resource vary as a function of the kind of event (birthday 2024 vs. birthday 2019) and the reason for the end of the consultation of the external resource (confirming previous knowledge vs. new insights vs. unsuccessful consultation)?
5	What kind of external resources do participants use when reconstructing the two birthdays?
6	Do the kind of event (birthday 2024 vs. birthday 2019) and the kind of retrieval (internal retrieval vs. external retrieval) influence the amount of retrieved information?
7	Is the number of different external resources that participants use associated with the amount of information that participants remember through external retrieval?
8	Does the time that participants spend on the task differ between the two birthdays?

Data analysis

The interviews were recorded and transcribed verbatim. Transcripts were processed and analysed with MAXQDA

2024 (VERBI software). We used the same codebook as in the previous think-aloud study on autobiographical memory in the digital age (Hutmacher et al., 2025). To ensure the objectivity of the coding process, a subset of the data was coded by two coders (CE and SK) independently from one another. After completing the independent coding, an interrater reliability was calculated (Brennan & Prediger, 1981). Two coded segments of the material were considered to match when the overlapping rate of the two codes was 90% or higher.

After a first round of independent coding (10% of the data, i.e., four participants), the interrater reliability was fair (for the interpretation of Cohen's kappa, see Landis & Koch, 1977), $\kappa = 0.31$. Against this background, the two coders and the first author discussed the discrepancies, agreed upon a final solution and added some clarifying remarks in the codebook. Another round of independent coding (another 5% of the data, i.e., two participants) showed an improved and moderate interrater reliability, $\kappa = 0.49$. Nevertheless, after an additional round of discussions and adjustments, a third round of independent coding was performed (another 5% of the data, i.e., two participants), resulting in a substantial agreement, $\kappa = 0.79$.

Given this substantial agreement, the remaining material was split between the two coders. However, any open questions or potentially ambiguous segments were reviewed and discussed by the two coders in collaboration with the first author. After the coding process was completed, the frequency of each code was calculated to allow for quantitative analysis. In the following, we provide a brief overview of the different variables that were coded and used for the subsequent statistical analyses (for more detailed descriptions, see the final codebook provided via the OSF).

Changes between internal processes and external resources

Number of changes. The coding scheme captured the frequency with which participants moved between internal processes – defined as the mental activities occurring within an individual's mind, such as thoughts, feelings, recollections, and reflections – and external resources. Three kinds of changes were distinguished: those in which an internal thought or memory prompted consultation of an external resource (*changes from internal processes to an external resource*); those in which material encountered in an external resource elicited an internal reflection or recollection (*changes from an external resource to internal processes*); and those in which one external resource was used immediately after another without any intervening internal processing (*changes from one external resource to another external resource*).

To elucidate the mechanisms underlying each kind of change, additional subcategories were used. Transitions from internal processes to external resources were subdivided into instances in which participants resorted to an external source because they lacked any relevant internal memory (*no internal memory*); those in which an imprecise memory existed and participants sought missing details externally (*vague internal memory*); and those in which participants possessed a detailed internal recollection but consulted an external source to verify its accuracy (*detailed internal memory*). Transitions from external resources back to internal processes were first classified according to whether the external consultation yielded useful information; *successful* consultations were further differentiated according to whether they merely *confirmed prior knowledge* or generated *new insights* and/or evoked new internal memories. *Unsuccessful* consultations were not subdivided further.

Time to first change. In addition to coding the different kinds of changes, we also determined how long it took participants until they consulted an external resource for the first time.

Kinds of external resources

External resources were categorised as *social resources* (e.g., family members), *non-digital resources* (e.g., paper diaries), or *digital resources* (e.g., smartphone photo gallery, social media). Based on this, we calculated the number of social, non-digital, and digital resources as well as the total number of different external resources that individuals used.

Retrieved information

Retrieved information was classified according to whether it was based on an individual's mental representation (*internal retrieval*) or solely on data stored in an external resource (*external retrieval*). Because the think-aloud protocols did not always provide sufficient evidence to determine definitively whether remembering was solely based on an internal mental representation or was prompted by an external resource, we grouped all such cases under the overarching category of internal retrieval. That is, internal retrieval encompassed both unaided internal retrieval (i.e., instances in which participants spontaneously remembered details without consulting an external resource) and aided internal retrieval, wherein exposure to an external resource triggered internal memories (e.g., "Now that I see it in the photograph, I also recall spending that evening in a restaurant"). In other words, external retrieval only comprised those cases in which the retrieved piece of information was clearly attributable to the external resource (e.g., "I don't remember it, but the photograph clearly shows that I spent the evening in a restaurant").

Retrieved information was further classified as reflecting either *external characteristics* (i.e., location details, event specifics, presence of other individuals, conversational content) or *internal states* (thoughts and feelings). Because the four external-characteristic subcategories and the two internal-state subcategories differ both in number and phenomenological content and can therefore

not meaningfully be compared with one another, counts of external characteristics and internal states were summed up for the subsequent statistical analyses to provide overall estimates of information obtained via internal retrieval versus external retrieval. Nevertheless, the more fine-grained descriptive statistics are reported in Table 5. Each distinct piece of information was counted only once even if it was mentioned multiple times. Finally, we also determined the total duration of each participant's think-aloud procedure.

Results

All statistical analyses were performed using JASP (Version 0.19.3.0; JASP Team, 2024). When the sphericity assumption was violated in one of the ANOVAs, the Greenhouse-Geisser correction was applied.

Time spent on the think-aloud procedure

The time that participants spent on the task did not differ significantly between the two events, that is, between remembering the birthday 2019 ($M = 4.83$ min, $SD = 2.61$) and remembering the birthday 2024 ($M = 4.85$ min, $SD = 2.79$), $t(39) = 0.05$, $p = .960$, $d = 0.01$, 95% CI [−0.30, 0.32]. This ensures that the results reported below are attributable to a difference between the two conditions, rather than to a difference in time spent on the task.

Changes between internal processes and external resources

Number of changes and time to first change

Both when remembering their birthday in 2019 ($M = 2.93$, $SD = 1.98$) and when remembering their birthday in 2024 ($M = 1.85$, $SD = 2.23$), participants repeatedly changed between internal processes and external resources. Importantly, and as indicated by a t-test for dependent samples, changes were more frequent when remembering their birthday in 2019 compared to remembering their birthday in 2024, $t(39) = 2.77$, $p = .009$, $d = 0.44$, 95% CI [0.11, 0.76]. Next, we compared how long it took participants until they consulted an external resource for the first time. As about half of the participants did not use an external resource for at least one of the two events, the power for the resulting t-test would have been relatively low. Hence, we decided to impute the missing values.[2]

We used two estimates to do so: First, we replaced the missing values with the group mean. The respective t-test suggests that it took participants less time until they consulted an external resource for the first time when remembering their birthday in 2019 ($M = 0.73$ min, $SD = 0.78$) compared to remembering their birthday in 2024 ($M = 1.34$ min, $SD = 1.61$), $t(39) = 2.93$, $p = .006$, $d = 0.46$, 95% CI [0.13, 0.79]. Second, we replaced the missing values with the total time that each participant spent on remembering the respective events. Again, the results of the t-test suggest that it took participants less time until they consulted an external resource for the first time when remembering their birthday in 2019 ($M = 1.24$ min, $SD = 1.55$) compared to remembering their birthday in 2024 ($M = 2.61$ min, $SD = 2.60$), $t(39) = 3.48$, $p = .001$, $d = 0.55$, 95% CI [0.21, 0.88]. The results for both the number of changes and the time to the first change indicate that participants relied more on external resources when remembering their birthday in 2019 compared to remembering their birthday in 2024.

Changes from an internal process to an external resource

We ran a 2×3 repeated-measures ANOVA to determine whether the *number of changes from an internal process to an external resource* changed depending on the *kind of event* (birthday 2019 vs. birthday 2024) and the *reason for the change* (no internal memory vs. vague internal memory vs. detailed internal memory). An overview of the number and kind of changes between internal processes and external resources is provided in Table 2. There was a significant main effect for the kind of event, $F(1, 39) = 5.27$, $p = .027$, $\omega_p^2 = .039$, a significant main effect for the reason of the change, $F(2, 78) = 8.55$, $p < .001$, $\omega_p^2 = .103$, but no significant interaction between the two factors, $F(1.46, 57.02) = 2.18$, $p = .136$, $\omega_p^2 = .019$.

The significant main effect for the event indicates that there were more changes from an internal process to an external resource for the birthday in 2019 compared to the birthday in 2024. To better understand the main effect for the reason for the change, we additionally calculated post-hoc t-tests using a Bonferroni-Holm correction. Changes from an internal process to an external resource were more frequent when participants had no internal memory compared to when they had a detailed memory, $t(39) = 3.89$, $p = .001$, $d = 0.59$, 95% CI [0.18, 1.01], and more frequent when participants had a vague memory than when they had a detailed memory, $t(39) = 3.60$, $p = .002$, $d = 0.49$, 95% CI [0.12, 0.85]. There was no significant difference between the number of changes from an internal process to an external resource when participants had no internal memory and when they had a vague internal memory, $t(39) = 0.63$, $p = .536$, $d = 0.11$,

Table 2. Number and kind of changes between internal processes and external resources.

	Birthday 2019		Birthday 2024	
	M	*SD*	*M*	*SD*
Changes from Internal to External	1.35	0.89	0.90	1.11
No Internal Memory	0.68	0.62	0.35	0.58
Vague Internal Memory	0.55	0.75	0.35	0.74
Detailed Internal Memory	0.13	0.34	0.20	0.41
Changes from External to Internal	1.35	0.89	0.90	1.11
Successful: Confirming	0.03	0.16	0.05	0.22
Successful: New	0.98	0.83	0.60	0.90
Unsuccessful	0.35	0.48	0.25	0.54
Changes from External to External	0.23	0.48	0.05	0.22
Total Number of Changes	2.93	1.98	1.85	2.23

95% CI [−0.32, 0.53]. In sum, this suggests that participants usually turned to an external resource when they had either no internal memory or a vague internal memory, irrespective of the kind of event.

Changes from an external resource to an internal process

We ran a 2 × 3 repeated-measures ANOVA to determine whether the *number of changes from an external resource to an internal resource* varied as a function of the *kind of event* (birthday 2019 vs. birthday 2024) and the *reason for the end of the consultation of the external resource* (confirming previous knowledge vs. new insights vs. unsuccessful consultation; for descriptive statistics, see Table 2). We found a significant main effect for the kind of event, $F(1, 39) = 5.27$, $p = .027$, $\omega_p^2 = .039$ and a significant main effect for the reason of the change, $F(1.44, 56.27) = 25.23$, $p < .001$, $\omega_p^2 = .294$. The interaction between the two factors was marginally significant, $F(1.66, 64.87) = 3.27$, $p = .053$, $\omega_p^2 = .030$.

Given that the interaction was marginally significant, we decided to run additional post-hoc t-tests using a Bonferroni-Holm correction.[3] Regarding the birthday in 2019, the changes back to internal processes happened more frequently after gaining new insights than after confirming previous knowledge $t(39) = 6.86$, $p < .001$, $d = 1.60$, 95% CI [0.68, 2.53], or after an unsuccessful consultation of an external resource, $t(39) = 3.93$, $p < .001$, $d = 1.06$, 95% CI [0.14, 1.97]. In addition, the changes back to internal processes happened more frequently after an unsuccessful consultation of an external resource than after confirming previous knowledge, $t(39) = 3.91$, $p < .001$, $d = 0.55$, 95% CI [0.07, 1.03]. In sum, this suggests that consulting external resources was an overall successful strategy. In addition, when consulting an external resource was a successful strategy, then it also led to new insights; at the same time, there was also a significant number of cases in which consulting an external resource remained unsuccessful.

Regarding the birthday in 2024, the changes back to internal processes happened more frequently after gaining new insights than after confirming previous knowledge, $t(40) = 3.63$, $p = .002$, $d = 0.93$, 95% CI [0.06, 1.80]. Neither the difference between gaining new insights and unsuccessful consultations of external resources, $t(39) = 2.27$, $p = .058$, $d = 0.59$, 95% CI [−0.25, 1.43], nor the difference between confirming previous knowledge and unsuccessful consultation of external resources were significant, $t(39) = 2.08$, $p = .058$, $d = 0.34$, 95% CI [−0.18, 0.86]. Again, this suggests that consulting external resources led to new insights but also that there was a significant number of cases in which it turned out to be unsuccessful.

When comparing the number of changes from an external resources to an internal process for the two events, there was no significant difference regarding the number of cases in which using an external resource confirmed previous knowledge, $t(39) = 0.57$, $p = .570$, $d = 0.04$, 95% CI [−0.19, 0.27], and the number of cases in which it remained unsuccessful, $t(39) = 1.00$, $p = .323$, $d = 0.17$, 95% CI [−0.36, 0.70]. However, there were more changes back to an internal process after gaining new insights for the birthday in 2019 compared to the birthday in 2024, $t(39) = 2.30$, $p = .027$, $d = 0.63$, 95% CI [−0.26, 1.52]. This suggests that consulting an external resource was a particularly successful strategy in the case of the more distant birthday.

Table 3. Number of participants using the different external resources.

	Birthday 2019	Birthday 2024
Digital Resources	31	20
Smartphone Photo Gallery	22	14
Digital Calendar	12	6
Instant Messaging	3	6
Snapchat	10	6
BeReal	0	1
E-Mails	0	1
Internet Search	1	0
Instagram	2	1
Local Hard Drive	0	1
Other	2	0
Non-Digital Resources	**1**	**0**
Printed Photo Album	1	0
Social Resources	**1**	**0**
Family	1	0

Note. The table displays the number of participants ($N = 40$) who used the different social, non-digital, and digital resources. The numbers next to the overarching categories (i.e., digital, non-digital, and social resources) indicate the number of participants who used *at least one* resource from this category.

Kinds of external resources

The descriptive results for the kinds of external resources that participants used are displayed in Tables 3 and 4. While Table 3 depicts the different kinds of external resources that participants used, Table 4 shows the average number of different digital, non-digital, and social resources that participants used. Importantly, participants almost exclusively used digital resources. More specifically, about three quarters of participants used at least one digital resource when remembering their birthday in 2019 and half of the participants used at least one digital resource when remembering their birthday in 2024. This difference is statistically significant: As indicated by a t-test for dependent samples, participants used more different digital resources when remembering their birthday in 2019 compared to remembering their birthday in 2024, $t(39) = 2.12$, $p = .041$, $d = 0.34$, 95% CI [0.01, 0.65].

Table 4. Average number of different external resources used by participants.

	Birthday 2019		Birthday 2024	
	M	*SD*	*M*	*SD*
Digital Resources	1.30	0.97	0.90	1.08
Non-Digital Resources	0.03	0.16	0.00	0.00
Social Resources	0.03	0.16	0.00	0.00

Note. The table displays the average number of different external resources that participants ($N = 40$) used when remembering the two events.

Also note that the digital resources that were used most frequently (i.e., smartphone photo gallery, digital calendar, instant messaging, and Snapchat) were the same for both events, suggesting that participants have preferred resources they access regardless of the specific event.

Retrieved information

We ran a 2 × 2 repeated-measures ANOVA to determine whether the *kind of event* (birthday 2019 vs. birthday 2024) and the *kind of retrieval* (internal retrieval vs. external retrieval) influenced the *amount of retrieved information*. As described above, the amount of retrieved information was operationalised as the sum of the different types of information (i.e., the different kinds of internal states and external characteristics) that participants remembered. A detailed overview of these different types of information across the two events and the two types of retrieval is reported in Table 5. There was a significant main effect for the kind of event, $F(1, 39) = 18.28$, $p < .001$, $\omega_p^2 = .077$, a significant main effect for the kind of retrieval, $F(1, 39) = 72.62$, $p < .001$, $\omega_p^2 = .497$, and a significant interaction between the two factors, $F(1, 39) = 16.38$, $p < .001$, $\omega_p^2 = .104$.

To understand the interaction better, we ran additional post-hoc t-tests using a Bonferroni-Holm correction. Participants retrieved more information through internal retrieval when remembering their birthday in 2024 compared to remembering their birthday in 2019, $t(39) = 4.46$, $p < .001$, $d = 0.88$, 95% CI [0.27, 1.50]. For external retrieval, there was no significant difference between the two events, $t(39) = 1.23$, $p = .226$, $d = 0.10$, 95% CI [−0.13, 0.34]. In addition, participants retrieved more information through internal retrieval than through external retrieval both when remembering their birthday in 2019, $t(39) = 6.80$, $p < .001$, $d = 1.26$, 95% CI [0.61, 1.91], and when remembering their birthday in 2024, $t(39) = 7.95$, $p < .001$, $d = 2.25$, 95% CI [1.19, 3.31].

Digital resources and retrieved information

As an additional test to determine whether consulting external resources is an effective strategy, we correlated the total number of different digital resources that participants used and the amount of information that they remembered through external retrieval. There was a significant positive correlation for both, the birthday in 2019, $r = .54$, $p < .001$, 95% CI [0.27, 0.73], and the birthday in 2024, $r = .69$, $p < .001$, 95% CI [0.48, 0.83]. The strength of the two correlations was not significantly different, $z = 1.05$, $p = .294$.

Discussion

Building on the AMEDIA-Model (Hutmacher et al., 2024a, 2024b) and the experimental setup of a previous study (Hutmacher et al., 2025), the present investigation was designed to provide additional insights regarding the interplay of memory and technology in the digital age, especially with respect to personally relevant events. More specifically, participants were asked to remember and reconstruct their memories of their birthdays in 2019 and in 2024, using all external resources that they may want to use.

To begin with, participants almost exclusively used *digital* external resources for reconstructing the two events. This demonstrates how easily available these tools have become in people's everyday lives. In contrast, non-digital resources and social resources were consulted hardly at all. Note, however, that the experimental setup may have influenced the participants' behaviour at least to some extent (see also Hutmacher et al., 2025): For instance, recording the study using a videoconferencing tool may have made digital tools cognitively more available for participants. In a similar vein, restricting the duration of the experimental procedure may have kept participants from trying to contact others (i.e., from using social resources) to a greater degree. Although we tried to minimise these effects by informing participants that they are free to stand up, leave the room, or interact with others, we therefore caution against overinterpreting the relative frequency with which participants used digital, non-digital, and social external resources, respectively.

Note also that there was a significant proportion of participants who did not use external resources when remembering their birthday. This indicates – relatively unsurprisingly – that individuals have good internal memories of events in their lives that are dear and important to

Table 5. Type of retrieval for different types of information across both types of events.

	Internal retrieval				External retrieval			
	Birthday 2019		Birthday 2024		Birthday 2019		Birthday 2024	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
External Characteristics								
Places	1.68	1.67	2.80	2.19	0.40	0.74	0.45	0.88
Events	5.23	3.96	7.78	4.45	1.30	1.57	0.93	1.80
Persons	2.80	1.73	3.58	2.32	0.60	0.81	0.23	0.66
Conversational Content	0.23	0.62	0.40	0.78	0.03	0.16	0.05	0.32
Internal States								
Thoughts	0.15	0.43	0.30	1.14	0.00	0.00	0.00	0.00
Feelings	0.45	0.75	1.40	1.61	0.00	0.00	0.00	0.00
Total	10.53	7.03	16.25	10.16	2.33	2.76	1.65	2.91

them. Importantly, this observation does not indicate that digital resources are irrelevant to these participants: They may well have consulted their digital records on earlier occasions, so they did not have to rely on them during the think-aloud procedure. All in all, the present study therefore provides another illustration that digital external resources play a central role in how individuals recall personal memories in our present-day societies.

As one might expect, participants relied more on (digital) external resources when remembering their birthday in 2019 compared to remembering their birthday in 2024. For instance, external resources were consulted more frequently and earlier during the experimental procedure when participants tried to remember their birthday in 2019. In addition, participants also used more different (digital) external resources when remembering their birthday in 2019. Taken together, and assuming that internal memories become less detailed and less available over time, this suggests that using external resources in the process of remembering autobiographical events is an adaptive strategy that helps participants to compensate for the weaknesses of their internal autobiographical memory (see, e.g., Bell & Gemmell, 2009; Burkell, 2016; Harvey et al., 2016).

This conclusion is further corroborated by the fact that participants mostly turned to external resources when they had either no internal memory or only a vague internal memory, irrespective of the event. Interestingly, there were hardly any changes directly from one external resource to another external resource, indicating that consulting an external resource usually goes – as predicted by the AMEDIA-Model – hand in hand with thinking about what one has found in these resources (i.e., internal processes). Importantly, consulting an external resource was an overall successful strategy in the sense that it often led to new insights that participants would not have had without the support of the external resource. Note, however, that there was also a number of cases in which consulting an external resource remained unsuccessful.

There are at least two potential reasons for an unsuccessful consultation of an external resource: On the one hand, it is possible that the information participants were looking for was just not there (e.g., there was no photo of them being in the restaurant with friends); on the other hand, participants may simply have been unable to find the respective piece of information (e.g., because the photo that they were looking for was hidden among the thousands of other photos on their phones). Although our data do not allow us to distinguish between these two cases, it has often been emphasised in the literature that individuals need to curate their data in order to create a meaningful data reservoir that they can draw from – and that this is something that individuals often tend to neglect (Hutmacher et al., 2024a; see also Banks, 2011; Sas & Whittaker, 2013; van den Hoven et al., 2012; Whittaker et al., 2012). Put differently, the present study provides at least some indirect evidence that maintaining well-organized and easily navigable digital records can enhance the utility of external resources for memory. In a similar vein, individuals may particularly benefit from using digital tools if these tools are designed in a way that supports efficient retrieval, contextual organisation, and reflection on personal information (see, e.g., Sellen & Whittaker, 2010).

As noted above, participants more frequently turned to (digital) external resources when remembering their birthday in 2019. Interestingly, there was no significant difference between the two events regarding the frequency of unsuccessful consultations of an external resource or regarding the frequency of consultations of an external resource that merely confirmed previous knowledge. In other words, the difference between the two events was driven by the fact that consulting an external resource more frequently led to new insights when remembering the birthday in 2019 compared to remembering the birthday in 2024. As we see it, the most plausible explanation for this finding is that there was simply more to be discovered in the external resources that participants were not able to retrieve based on their internal memory alone when remembering the more distant birthday.

It is interesting to consider this finding in combination with the findings regarding the amount of information that participants retrieved through internal and external retrieval, respectively. Overall, participants remembered more information through internal retrieval for the more recent birthday in 2024 compared to the more distant birthday in 2019. Note that internal retrieval comprises cases of unaided internal retrieval (i.e., remembering a piece of information without having to consult an external resource) and aided internal retrieval (i.e., remembering a piece of information after consulting an external resource). In short, while consulting external resources led to more new insights in the case of the more distant birthday, it did not completely erase the difference between the two events: It still remains easier to remember more recent than more distant events. Interestingly, however, the amount of information that participants retrieved through external retrieval, that is, the amount of information that they could not remember but still identified in external resources, did not differ between the two events, suggesting that external resources indeed provide a solid basis for reconstructing past events.

Overall, the findings suggest that integrating information stored in one's mind and information stored in the environment is beneficial in the sense that it enhances recall beyond what is possible through internal memory alone. More specifically, the present study shows that this pattern does not only apply to relatively recent events (such as one's birthday in 2024) but also to more distant events (such as one's birthday in 2019). This supports not only the core principles of the AMEDIA-Model (Hutmacher et al., 2024a, 2024b) but also aligns with similar theoretical approaches (Clark & Chalmers, 1998; Eliseev & Marsh, 2021; Finley & Naaz, 2023; Finley et al.,

2018; Heersmink, 2022) that all highlight that external resources serve not merely as tools for offloading information but play an important role in forming a broader, extended memory system.

Nevertheless, we note four limitations that also provide avenues for future research. First, the present study relied on a sample of young adults who live in an affluent society of the Global North (Germany), that is, a sample of individuals who have grown up with digital technologies and who can afford to buy the latest products and software. Although individual researchers are not in a position to change the digital divide across and within societies, it would nevertheless be interesting and important to investigate how and to what extent digital technologies affect autobiographical remembering of individuals living in less privileged circumstances (see, e.g., van Dijk, 2020). The same applies to the investigation of different age groups. For instance, it has been demonstrated that older adults have their own ways of navigating the digital world (Hänninen & Tiihonen, 2025), suggesting that the way they use digital tools for documenting and remembering autobiographical experiences may differ from the strategies and the behaviour of younger generations.

Second, the present study focused on the participants' memories for their birthdays in 2019 and in 2024. As noted in the introduction, we chose to focus on birthday memories because birthdays are an example of a widely valued and meaningful personal event and because birthdays occur on a specific, predictable date, which makes them well-suited for controlled experimental research. It goes without saying, however, that there are many other events that could be investigated using the same paradigm in order to increase the generalizability of the findings. Moving beyond events that occur at a predefined date, for instance, one could focus on autobiographical key scenes that play a particularly prominent role in one's life story. One example in this regard are high points (e.g., one's wedding) and low points (e.g., the death of a loved one) that are different from other autobiographical memories because of their greater goal-relevance, personal importance, emotional intensity, and more frequent rehearsal (see, e.g., Camia et al., 2024; Cox & McAdams, 2014; McLean & Lilgendahl, 2008; Thomsen et al., 2012).

Third, participants in the present study were instructed to reconstruct and remember the two autobiographical events *in as much detail as possible*. Although this is something that individuals indeed may want to do in many situations of their lives (and especially with respect to events that are dear and important to them), autobiographical memories can be used for several other memory processes as well (see Hutmacher et al., 2024a; Sellen & Whittaker, 2010). For instance, individuals can use their memories as a starting point for reflecting upon past experiences and for adjusting their future behaviour based on what they are able to learn from them (see also Grysman et al., 2024; Pasupathi & Wainryb, 2010). Note also that revisiting information about one's life that is stored in (digital) external resources does not necessarily have to be a positive experience: To give but one example, one might be confronted with past behaviour that one finds cringe or embarrassing (e.g., an old *Instagram* post from ten years ago). Undoubtedly, all these phenomena warrant closer examination.

Fourth, an individual's use of (digital) external resources when reconstructing past events may crucially depend on the specific setting in which the process of remembering takes place. Instead of allowing participants to use all external resources that they want to use as in the present study, one could also manipulate which tools participants have access to in order to see how this affects remembering. Alternatively, one could also create a social setting in which participants have to remember certain events together with the people they have experienced them with (e.g., partner, family, friends). And while the present study already varied the temporal distance of the events that participants had to remember, considering both shorter time intervals (e.g., remembering events from one week or one month ago) and even longer time intervals (e.g., remembering events from a decade or more ago) seems like another line of research worth pursuing.

Overall, the present study highlights the dynamic interplay between information stored in one's mind and information stored in external resources when remembering autobiographical events. More specifically, the study demonstrates that relying on (digital) external resources in the process of reconstructing relatively recent as well as more distant personally relevant experiences – such as one's birthday – is an adaptive strategy. Further exploring how the rapid expansion of digital technologies has altered and continues to alter the way individuals document and remember their lives will be a key focus for future research.

Notes

1. The sample size calculation in the previous study was based on the premise that the primary focus was the comparison between two events (a random day and an important day). To have enough power (.80) to detect a medium-sized effect ($d = 0.50$) in a t-test with dependent samples ($\alpha = .05$, two-tailed), a minimum sample size of 34 participants was calculated using G*Power 3.1.9.7 (Faul et al., 2007). To account for potential exclusions, the sample size was set to 40 participants. Importantly, the empirically observed effect sizes met or exceeded those assumed in the power analysis. On this basis, we decided to collect a sample of equal size for the present study.
2. As we did not anticipate the missing values, the imputation was not preregistered. Note also that imputing missing values always risks introducing bias or distorting relationships in the data because the filled-in values are ultimately assumptions rather than observations. To limit this risk, we used two different estimates for the missing data (i.e., the group mean and the total time each participant spent remembering the respective event). As described in the main text, the results for both estimates point into the same direction, which ensures that our interpretation does not depend on a single

imputation method. Nevertheless, we caution against overinterpreting results based on imputed values and recommend viewing them as supportive rather than definitive.

3. Alternatively, one could have treated the interaction as nonsignificant and interpreted the main effects directly. Note that this would not change the main message of this part of the analysis, namely that consulting external resources was generally a successful strategy for both the 2019 and 2024 birthdays, although there were also a significant number of cases in which consulting an external resource remained unsuccessful.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Data availability statement

Quantitative data, study materials, and the codebook that was used for analysing the qualitative data are available at https://doi.org/10.17605/OSF.IO/KBTSQ.

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