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Jason R. Finley & Farah Naaz

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Strategic use of internal and external memory in everyday life: episodic, semantic, procedural, and prospective purposes

Jason R. Finley [a] and Farah Naaz [b]

[a]Department of Psychology, Southern Illinois University Edwardsville, Edwardsville, IL, USA; [b]Department of Psychiatry and Behavioral Sciences, Johns Hopkins University School of Medicine, Baltimore, MD, USA

ABSTRACT

Humans have access to both internal memory (information stored in the brain) and external memory (information stored in the environment). To what extent do we use each in everyday life? In two experiments, participants rated both internal and external memory for frequency of use, dependability, ease of use (Experiment 1), and likelihood of use (Experiment 2) across four purposes: episodic, semantic, procedural, and prospective. Experiment 1 showed that internal memory was favoured for episodic and procedural purposes, while external memory was favoured for semantic purposes. Experiment 2 further clarified that internal memory was favoured for episodic and common procedural purposes, while external memory was favoured for uncommon semantic, uncommon procedural, and far-term prospective purposes. This strategic division of labour plays to the strengths of both forms of memory. Participants also generally rated external memory as more dependable and easier to use. Results support the memory symbiosis framework.

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External memory; internal memory; offloading; technology; everyday memory

Memory is the transfer of information across time. Human beings, who have always been the species to extend itself into the environment, have access to both *internal memory* (information stored in the brain) and *external memory* (information stored in the environment). External memory may be as simple as a paper note or as complex as the internet (Finley et al., 2018).[1] Humans have a long history of using external memory (pp. 119–123), and we interact extensively with it in our everyday lives, increasingly so with the technology of the information age (Nestojko et al., 2013; Storm & Soares, in press). But the use of external memory traditionally received little attention in psychology research (e.g., Hertel, 1993; Schönpflug, 1986), though coordinated investigation has increased in recent years (e.g., Marsh & Rajaram, 2019; Risko et al., 2019; Risko & Gilbert, 2016). The question remains: in what ways are people using internal and external memory in everyday life? The current study addresses this question.

Four memory purposes

Theories about internal memory have often subdivided it into multiple types or systems (Roediger et al., 2002). Within long-term memory, one major distinction is *episodic* memory (specific events) versus *semantic* memory (general knowledge; Tulving, 1985). Taxonomies of human memory (e.g., Squire & Zola-Morgan, 1988) often place both episodic and semantic under the category of explicit memory (also known as declarative). This is in contrast to implicit memory (also known as non-declarative), which includes several subcategories, and the most important of those for everyday life is *procedural* memory (i.e., memory for how to perform a task). One more subcategory of memory is also important for everyday life, but not typically included alongside the others in a taxonomy: *prospective* memory (i.e., remembering to do something in the future). In contrast to prospective memory, the other three categories of interest can all be considered retrospective memory.

In our previous work, these four categories of memory —episodic, semantic, procedural, and prospective— emerged naturally from participants' responses to open-ended questions about purposes for which they used internal and external memory (Finley et al., 2018, pp. 49–55). This raises the question: can external memory be organised into the same four categories as internal memory? We argue yes. Although the categories may not represent easily identifiable systems in external memory, they do represent distinct *purposes*.[2] In fact, we argue that thinking of these four categories as purposes is helpful for understanding the role that both internal and external memory play in everyday life. Our thinking here is in the spirit of Willingham and Goedert (2001):

CONTACT Jason R. Finley jafinle@siue.edu Department of Psychology, Box 1121, Southern Illinois University Edwardsville, Edwardsville, IL 62026, USA

"Taxonomies of memory are organizational schemes for data—they are descriptive, not explanatory—and so can inspire theory, although they cannot serve as theories themselves."

Purposes were conflated in previous studies of everyday external memory

Several previous studies have gathered frequency ratings on a variety of internal[3] and external memory aids: Harris (1980), Intons-Peterson and Fournier (1986), Walker and Andrews (2001), and Schryer and Ross (2013). Each of these studies found more frequent self-reported everyday use of external memory aids than internal memory strategies. But they varied in the extent to which they specified purposes or contexts for the ratings.

In the study by Harris (1980), participants rated how frequently they used 18 memory aids (nine each for internal and external), using a 7-point scale that has since been reused across several studies, including the current one. Importantly, participants were not given any overall context for the memory aids, although the descriptions of some of the aids included examples (e.g., "turning numbers into letters (e.g., for telephone numbers)") while others carried implied contexts (e.g., "shopping lists"). In a follow-up to Harris (1980), Walker and Andrews (2001, Experiment 1) presented an updated list of 18 memory aids for frequency ratings (nine each for internal and external). They instructed college participants to consider "the classroom setting, or in everyday situations outside of the classroom" and they furthermore provided an example of how each memory aid might be used (Walker & Andrews, 2001, Appendix A). Finally, Schryer and Ross (2013) used the Memory Compensation Questionnaire (de Frias & Dixon, 2005), which included frequency rating questions about ten internal and eight external memory aids, most of which included example contexts (e.g., "Do you write down appointments (for example, with the hairdresser or the dentist) in a notebook or calendar?"). For each these three prior studies, we looked closely at the rating prompts and classified each of them by purpose (episodic, semantic, procedural, and/or prospective), as shown in Table 1. The details of our classifications can be found in the Supplemental Materials.

Thus, across three prior studies on the use of internal and external memory aids in everyday life (Harris, 1980; Schryer & Ross, 2013; Walker & Andrews, 2001), the majority of the external aids were for prospective purposes[4] while the majority of the internal aids were not. The differing memory purposes, rather than the internal/external distinction, could explain why these studies found that external memory aids appeared to be used more frequently than internal memory aids.

But one study, by Intons-Peterson and Fournier (1986, Experiment 1), did directly address the issue of retrospective versus prospective purposes by treating this distinction as an independent variable. They adapted a series of specific situations from Herrmann and Neisser (1978) so that half were retrospective and half were prospective. For example, one retrospective situation was: "You are at the grocery store to pick up a few things you noticed you needed when looking in your cupboards earlier. Now you can't remember them all. How do you remember?" And one prospective situation was: "You have just looked through your cupboards and realize that it is time to go to the grocery store. How do you remember what you need to buy?" For each such situation, participants considered 19 memory aids (ten internal, seven external, and two involving both) and used 7-point scales to make four ratings: frequency, dependability, ease of use, and accuracy. Thus, unlike in the other studies, the internal and external memory aids were all rated for both retrospective and prospective purposes. Results again showed that participants self-reported using external memory aids more frequently than internal memory aids, across retrospective and prospective purposes.

However, in all of these prior studies, episodic and semantic purposes (both retrospective) were lumped together, and that distinction is where we found the most striking difference between internal and external memory use in our previous study (Finley et al., 2018). In that exploratory study, 476 U.S. participants from Mechanical Turk (an online recruitment platform) completed a large survey questionnaire covering all aspects of external memory use in everyday life. Four open-ended questions were of key interest. We asked participants to describe circumstances in which they used internal memory instead of external memory, and vice versa. And we asked participants to state "something that internal memory works better for", and "something that external memory works better for". Upon careful review of participants' variety of responses, we saw that the purposes episodic, semantic, procedural, and prospective could be applied, and we developed a coding scheme to do just that (pp. 196–199; see also Supplemental Materials). It is worth noting that

Table 1. Number of Items Addressing Each Memory Purpose in Three Prior Studies.

	External Memory				Internal Memory			
Study	Episodic	Semantic	Procedural	Prospective	Episodic	Semantic	Procedural	Prospective
Harris (1980)	1	1	0	7	3	8	0	3
Walker and Andrews (2001)	0	0	0	9	2	6	0	2
Schryer and Ross (2013)	0	2	0	6	4	3	0	2

Note. Some questions addressed more than one purpose, or none. See Supplemental Materials for more details.

the questionnaire never mentioned the terms or even the ideas of episodic, semantic, procedural, or prospective memory; these categories emerged naturally from the responses themselves. Our results showed a dramatic crossover interaction, reprinted here as Figure 1.

Episodic purposes were mentioned more often for internal than external memory (64% vs. 10%), and semantic purposes were mentioned more often for external than internal memory (74% vs. 31%). Furthermore, procedural purposes were mentioned more often for internal than external memory (5% vs. 3%), and prospective purposes were mentioned more often for external than internal memory (26% vs. 2%; consistent with all four of the prior studies we reviewed above). Thus, external memory was *not* universally used more often than internal memory. The purpose of use matters.

Theories regarding external memory use

Under the term *cognitive offloading*, there has been theory development on the use of external resources for *working memory* in laboratory tasks. A "cognitive miser" view would predict that people offload time-consuming and/or effortful cognition onto external resources whenever possible (see Dunn & Risko, 2019). In contrast, Gray et al. (2006) proposed a soft constraints hypothesis in which people choose internal and/or external strategies based on tradeoffs between benefits and costs (speed of encoding and retrieval, and probability of retrieval). Risko and Dunn (2015) proposed that people are motivated to offload tasks onto external memory in order to maximise accuracy (not minimise effort), based on their metacognitive beliefs about the reliability of internal and external memory. Risko and Gilbert (2016) expanded on that view to propose a metacognitive model of cognitive offloading, which allowed for task-dependent biases toward internal or external resources, but did not specify those. That is, purpose of use was not explicitly addressed. That said, much of the work by Gilbert et al. (2020, 2022) has focused on intention offloading, which we can consider prospective memory, though typically using a short timeframe on the order of seconds or minutes (but see also Gilbert, 2015, which included a naturalistic component using a timeframe of several days).

In the current paper we are particularly concerned with *long-term memory* (i.e., anything beyond the present moment of approximately 15 s). In this domain, there has not been as much recent theoretical development. Although it is not much cited, an *extended memory system* framework was proposed by Schönpflug and Esser (1995) in which internal memory is served by several subsystems, some social and some technological. The framework was refined by Esser (1996), to further specify how people decide to encode to internal memory or one of several external memory stores. The decision is based on evaluation of three factors: the importance of remembering the information, the probability of successful future retrieval using that store, and the effort of encoding with that store. Esser argued that the importance factor generally outweighs the others, and that high importance leads to use of external stores. Furthermore, the choice among multiple external stores is guided by an automatic script for frequently encountered types of information (e.g., storing appointments in one's calendar), and selection of an appropriate existing store (based on the same three factors above) or creation of a new one when no script is available.

More recent empirical work has shown the phenomenon of impaired internal memory for information offloaded onto external memory stores. For example, in

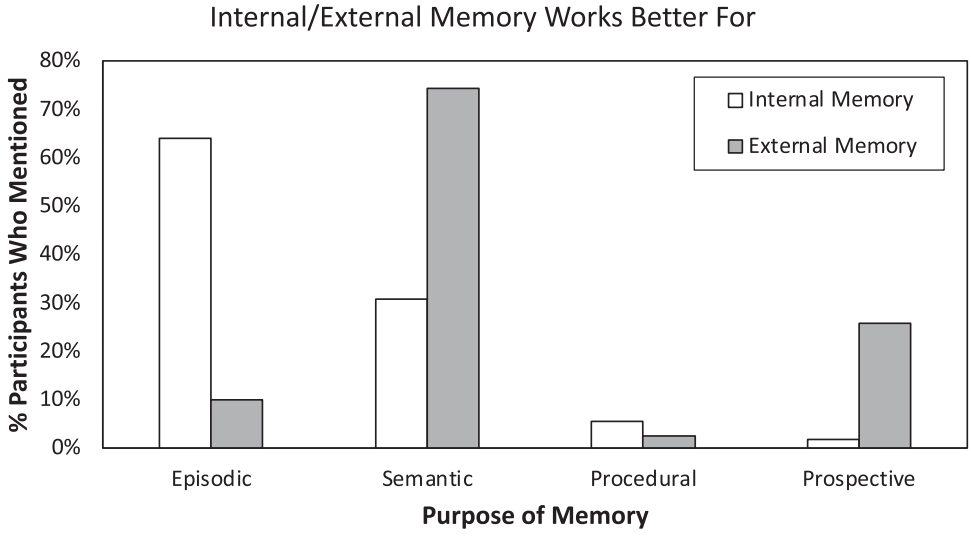

Figure 1. Percent of Participants Mentioning Different Memory Purposes for Internal and External Memory (Finley et al., 2018).

Note. Percent of participants who mentioned each of four different purposes in their responses to the following open-ended questions: "Something that human memory works better for" and "Something that external memory works better for". Reprinted with permission from Finley et al. (2018). Copyright Springer.

a study by Schooler and Storm (2021), participants' unaided recall was worse for facts they thought had been saved to the computer for reference on the test, as compared to facts they did not think were saved. Similarly, in a study by Eskritt and Ma (2014), participants' memory for the location of items was impaired when they were allowed to write notes about the locations but those notes were taken away before the memory test. In another study, Henkel (2014) had participants take photos of some museum artifacts but not others, and found a photo-taking-impairment effect such that memory was worse for the photographed artifacts. The *cognitive offloading hypothesis* (see Storm & Soares, in press) states that when information is saved to an external store, people completely relinquish any duty to store it in internal memory. This implies a mutually exclusive division of labour: information is either stored in internal memory, or it is stored in external memory.

Neither the extended memory framework nor the cognitive offloading hypothesis take into account memory purposes, as we have defined them in this paper. And neither highlight potential bi-directional relationships between internal and external memory. In contrast, in our book (Finley et al., 2018, Chapter 7), we developed what we will now call the *memory symbiosis framework*, Figure 5. Our framework summarises the interplay between internal and external memory, emphasising that they complement and depend on each other. The framework predicts, among other things, that humans tend to strategically distribute the work of memory across internal and external resources based on the contextual *purpose* of memory (episodic, semantic, procedural, and prospective) and the relative strengths and weaknesses of the resources, predicting the pattern of results in Figure 1. One goal of the current study was to further test that prediction (Experiment 1), while also exploring factors that could moderate the relationship between memory purpose and use of internal/external memory (Experiment 2).

We will discuss the memory symbiosis framework in greater detail in the General Discussion. For now, suffice it to say that external memory may in some cases supplant internal memory, and in other cases augment it, depending on the purpose of memory for a given context. Because the framework was developed in part based on our findings shown in Figure 1, it is important to replicate and expand on those findings, which was the goal of the current study.

The current study

The current study sought to further document how people are currently using internal versus external memory for different purposes in everyday life. This goal was motivated by (A) the limitations of prior research, reviewed above, which did not fully differentiate between different memory purposes, and (B) the need to replicate our own previous findings in order to test the memory symbiosis framework. Because our previous study (Finley et al., 2018) was exploratory, and the unexpected pattern we found there was based on qualitative analysis of responses to open-ended questions, a replication with more targeted questions and quantitative data is important. Toward that end, in Experiment 1 we explicitly explained to participants the four different memory purposes of interest (episodic, semantic, procedural, and prospective), and asked them to rate the frequency of use, dependability, and ease of use across those four purposes for both internal and external memory, which we also explicitly defined. Furthermore, we asked for ratings generally (Part 1), with respect to specific memory aids (Part 2), and in the context of more specific example situations (Part 3). In Experiment 2 we used simpler prompts (merely asking for ratings about likely use) while also distinguishing between common and uncommon goals for semantic and procedural purposes, and near- versus far-term goals for prospective purposes.

Experiment 1

Method

Design

The experiment used a 2×4 fully factorial within-subjects design. The independent variables were form of memory (internal vs. external), and purpose of memory (episodic, semantic, procedural, and prospective). The main dependent variables of interest were ratings of frequency of use, dependability, and ease of use. These ratings were made using 7-point scales.

Participants

Participants were 51 undergraduate students at Fontbonne University, a small liberal arts college in St. Louis, Missouri, who participated for course credit and/or entry to win one of several $20 Amazon gift cards. There were 36 women, 15 men, and one agender person. The mean age was 20.82 ($SD = 4.64$, *range* = 18–40). The racial and ethnic demographics were as follows: 30 White/Caucasian, 17 Black/African, 3 Asian, 3 Hispanic/Latinx, 2 Native American, and 1 Arabic. Five participants were multiracial. In terms of employment status, 12 participants were employed, and five were out of work and looking for work. Demographics on annual household income are available in the Supplemental Materials. In terms of self-rated technological savvy, the mean was 0.71 ($SD = 0.85$) on a scale of −2 to 2, where −2 was very unsavvy, and 2 was very savvy. The mean hours per day using the internet was 6.32 ($SD = 3.56$, *range* = 2–18, $Mdn = 5$).

Materials and procedure

This study received ethical approval from the Institutional Review Board of Fontbonne University (FBUIRB012121-JF). The procedure consisted of an online questionnaire,

created using Google Forms, and run from February to June, 2020. The entire questionnaire is available in the Supplemental Materials. All participants received questions in the same fixed order. Participants completed the questionnaire at their own pace in a single session.

The initial instructions briefly defined the terms internal memory ("information stored in your own brain") and external memory ("information stored in the world outside of your brain, and it could be low-tech (e.g., paper) or high-tech (e.g., computer)"). The instructions also briefly defined the four categories of memory purpose: episodic ("memory of personally experienced past events"), semantic ("memory of factual information"), procedural ("memory of how to perform a task"), and prospective ("remembering to do something in the future"). Following initial instructions, there were four sections of questions, which we will refer to as Parts 1–4.

In Part 1, participants answered *generally phrased* questions about the frequency of use, dependability, and ease of use for internal and external memory, across the four memory purposes (episodic, semantic, procedural, and prospective), in that order. These questions all used 7-point ratings scales, shown in Table 2, adapted from Intons-Peterson Fournier (1986, Experiment 1).[5] Questions about each of the four memory purposes appeared on their own page, with both the internal memory and external memory questions on the same page in the same order for each purpose. On each page, there was a brief reminder of the definition of the given memory purpose. The group of internal memory questions was accompanied by a line drawing of a brain, and following that, the group of external memory questions was accompanied by line drawings of a computer and a book.

In Part 2, participants answered only frequency questions about six specific memory aids (three internal and three external) for each of the four memory purposes (episodic, semantic, procedural, and prospective, in that order). The frequency questions used the same 7-point scale as in Part 1. The specific aids listed varied across purposes, and are listed in Table 5. The list of aids was not exhaustive. We note that "internal memory aid" is synonymous with "internal memory strategy." We adapted the list from Intons-Peterson and Fournier (1986) and Walker and Andrews (2001), updated for common technology tools as of 2020. As in those previous studies, we only provided the brief labels of the aids (e.g., "mental imagery"), without detailed definitions. Participants could also write in any additional aids they used, separately for internal and external memory and for each of the four memory purposes.

Part 3 followed the same structure as Part 1, except instead of generally phrased questions, participants answered questions that gave specific examples of each memory purpose, shown in Table 3.

In Part 4, participants answered demographic questions, and a handful of general questions about memory, including a 5-point self-rating of their own internal memory ability relative to people of the same age: much worse, somewhat worse, the same as, somewhat better, and much better. Finally, participants also completed two brief objective measures of internal memory: the Corsi blocks test of short term memory span (Stoet, 2017; PsyToolkit, n.d.), and a verbal free recall test immediately following presentation of 20 concrete English nouns shown for 2 s each in a fixed random order. We included these two memory tests to explore possible associations between objectively measured internal memory ability and self-ratings of internal and external memory. Results from these measures were ambiguous and we do not focus on them in the current paper, but more details can be found in the Supplemental Materials.

Table 2. Rating Scales Used in Experiment 1.

Rating	Frequency	Dependability	Ease of Use
1	never	never works	extremely hard to use
2	up to two times in last six months	works about ¼ of the time	moderately hard to use
3	two or fewer times in the last four weeks	works about 1/3 of the time	somewhat hard to use
4	two or fewer times in the last two weeks	works about ¼ of the time	so-so
5	three to five times in the last two weeks	works about 2/3 of the time	somewhat easy to use
6	six to ten times in the last two weeks	works about ¾ of the time	moderately easy to use
7	11 or more times in the last two weeks	always works	extremely easy to use

Note. Scales reused from Intons-Peterson and Fournier (1986), frequency scale originated with Harris (1980).

Results

Data and Supplemental Materials are available at https://doi.org/10.17605/OSF.IO/4M8YA. Responses to the rating scale questions were coded numerically as indicated in Table 2. An alpha level of .05 was used for all tests of statistical significance. ANOVAs used the Greenhouse-Geisser adjustment to degrees of freedom when Mauchly's test

Table 3. Prompts Used in Part 3, Experiment 1.

Memory Purpose	Specific Prompt
Episodic	For remembering a past specific special event (e.g., weddings, birthdays, get-togethers, meetings, holidays, romantic dates, etc.) I use:
Semantic	For remembering important new facts (e.g., names, state capitals, email addresses, concepts in science or art, etc.) I use:
Procedural	For remembering a new skill (baking a cake, playing an instrument, driving a new route, using a new app or computer program, etc.) I use:
Prospective	For remembering an upcoming specific special event in the FUTURE (weddings, birthdays, get-togethers, meetings, holidays, romantic dates, etc.) I use:

indicated violation of sphericity. Complete ANOVA output tables are available in the Supplemental Materials. Comparisons of means, and of differences in means (interactions), were made using within-subjects *t*-tests, or one-way within-subjects ANOVAs. Effect sizes for *t*-tests are reported as Cohen's *d*, calculated using the pooled standard deviation of the conditions being compared. Confidence intervals for Cohen's *d* were constructed using the ci.stdmean.ps function in the statpsych package for R (version 1.0.0) based on Bonett (2008). Effect sizes for ANOVA are reported as omega squared for one-way ANOVA and partial omega squared for two-way ANOVA (Kroes & Finley, 2022).[6] Confidence intervals could not be constructed for omega squared as there is currently no consensus on how to do so for within-subjects designs (Kroes & Finley, 2022). Standard deviations (*SD*s) are reported raw (i.e., calculated using *N* as the denominator, not *N* – 1), on the grounds that the *SD* is a descriptive statistic, and the *N* – 1 Bessel adjustment should be reserved for use in inferential statistics. For all of the main analyses done with *t*-tests (which assume an interval or ratio scale of measurement), we also conducted Wilcoxon signed-rank tests (more appropriate for ordinal scales), and found the same pattern of results (see also de Winter & Dodou, 2010; Norman, 2010). Reports of the latter tests can be found in the Supplemental Materials. Associations between variables were measured using Spearman's correlation. Obtained power: with 51 participants, the study had 80% power to detect effect sizes of $r = .20$ ($d = .40$) or greater.

Part 1: generally phrased prompts

The mean (and standard deviation) of ratings in Part 1 are shown in Table 4. The pattern of ratings for internal versus external memory varied across the four memory purposes.

We pre-planned to conduct separate pairwise comparisons of internal versus external memory within each of the four memory purposes. Nevertheless, we first conducted two-way within-subjects ANOVAs that confirmed statistically significant interactions between purpose and form of memory (internal vs. external) for all three dependent variables.[7] For frequency: $F(2.05, 102.33) = 7.93$, $MSE = 1.44$, $p < .001$, $\hat{\omega}_p^2 = .030$. For dependability: $F(2.23, 109.26) = 8.35$, $MSE = 1.18$, $p < .001$, $\hat{\omega}_p^2 = .045$. For ease of use: $F(2.26, 112.82) = 7.10$, $MSE = 1.65$, $p < .001$, $\hat{\omega}_p^2 = .036$. We thus proceeded to the pairwise comparisons (*t*-tests), which we did not adjust for multiple comparison because they were limited in number and were pre-planned. Any concerns about inflated Type I error rate should be assuaged by the consistent patterns found across our previous work (Figure 1) and the two experiments in the current study.

For general *episodic* purposes: frequency was rated higher for internal than external, $t(50) = 2.02$, $p = .049$, $d = 0.20$, 95% CI [0.00, 0.41]; dependability was rated higher for external than internal, $t(50) = -3.17$, $p = .003$, $d = -0.53$, 95% CI [−0.88, −0.19]; and ease of use was not rated differently for external versus internal, $t(50) = -1.53$, $p = .132$, $d = -0.26$, 95% CI [−0.60, 0.08].

For general *semantic* purposes: frequency was rated higher for external than internal, $t(50) = -2.11$, $p = .040$, $d = -0.27$, 95% CI [−0.54, −0.01]; dependability was rated higher for external than internal, $t(50) = -5.52$, $p < .001$, $d = -0.83$, 95% CI [−1.16, −0.51]; and ease of use was rated higher for external than internal, $t(50) = -3.85$, $p < .001$, $d = -0.59$, 95% CI [−0.91, −0.28].

For general *procedural* purposes: frequency was rated higher for internal than external, $t(50) = 2.87$, $p = .006$, $d = 0.49$, 95% CI [0.15, 0.88]; dependability was not rated differently for internal and external, $t(49) = 0.08$, $p = .934$, $d = 0.01$, 95% CI [−0.32, 0.35]; and ease of use was not rated differently for internal and external, $t(50) = 0.88$, $p = .385$, $d = 0.14$, 95% CI [−0.18, 0.47].

For general *prospective* purposes: frequency was not rated significantly differently for external versus internal, $t(50) = -1.64$, $p = .107$, $d = -0.22$, 95% CI [−0.50, 0.05]; dependability was rated higher for external than internal, $t(50) = -5.42$, $p < .001$, $d = -0.93$, 95% CI [−1.31, −0.57]; and ease of use was rated higher for external than internal, $t(50) = -4.32$, $p < .001$, $d = -0.76$, 95% CI [−1.14, −0.40].

The frequency ratings are shown in Figure 2. For a frame of reference, a frequency value of 5.5 corresponds to roughly 3 times per week. Although we are not so interested in point estimates of absolute frequency, it is worth noting that even the lowest mean frequency rating corresponded to roughly once per week, indicating regular use of both internal and external memory across purposes. At most only 4% of participants responded "never" (1) for a particular form and purpose.

The relative frequencies of internal versus external memory are of particular interest, especially for episodic versus semantic purposes. For episodic purposes, internal memory was reported as more frequently used than external memory; for semantic purposes, the opposite was true. The difference in patterns between episodic and semantic purposes was a statistically significant crossover

Table 4. Mean (and SD) of Ratings in Part 1 (Generally Phrased Prompts), Experiment 1.

	Frequency		Dependability		Ease of Use	
Purpose	Internal	External	Internal	External	Internal	External
Episodic	5.55 (1.47)	5.22 (1.74)	4.88 (1.11)	5.51 (1.21)	4.92 (1.51)	5.33 (1.63)
Semantic	5.47 (1.38)	5.82 (1.15)	4.71 (1.19)	5.73 (1.22)	4.98 (1.26)	5.73 (1.24)
Procedural	5.65 (1.52)	4.86 (1.67)	5.43 (1.42)	5.42 (1.39)	5.51 (1.51)	5.29 (1.47)
Prospective	5.53 (1.45)	5.86 (1.47)	4.37 (1.25)	5.57 (1.27)	4.57 (1.49)	5.75 (1.56)

Note. Ratings were on 1–7 scales. See Table 2.

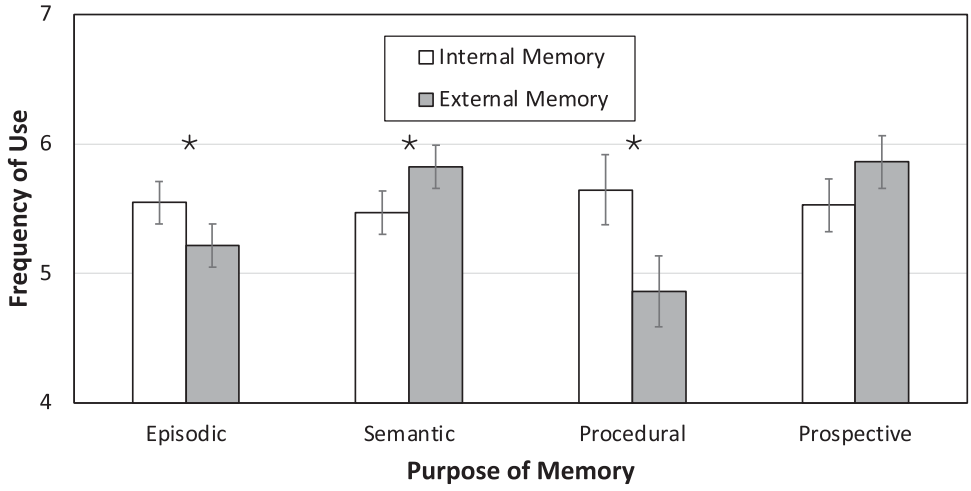

Figure 2. Mean Frequency of Use for Internal and External Memory Across General Purposes in Experiment 1.

Note. Error bars represent the standard error of difference scores for internal versus external memory. Asterisks indicate a statistically significant difference between internal and external memory. 1 = never, 7 = 11 or more times in the last two weeks (See Table 2).

interaction, $t(50) = 3.20$, $p = .002$, $d = 0.57$, 95% CI [0.21, 0.94]. This replicates the key finding from Finley et al. (2018), reprinted in Figure 1.

Considering just internal memory, a one-way within-subjects ANOVA showed that frequency of use for internal memory did not differ across all four memory purposes, $F(3, 150) = 0.28$, $MSE = 0.97$, $p = .838$, $\hat{\omega}^2 < .001$. This can be seen in Figure 2: the bars for internal memory are all similar heights. Considering just external memory, a one-way within-subjects ANOVA showed that frequency of use for external memory certainly did differ across the four purposes, $F(2.53, 126.31) = 9.17$, $MSE = 1.56$, $p < .001$, $\hat{\omega}^2 = .062$. External memory was reported as more frequently used for semantic purposes than episodic purposes, $t(50) = 3.10$, $p = .003$, $d = 0.40$, 95% CI [0.14, 0.68], while internal memory was not reported as used differently across purposes, $t(50) = 0.37$, $p = .709$, $d = 0.06$, 95% CI [−0.23, 0.34].

Part 2: specific memory aids

Participants' frequency ratings for various memory aids are shown in Table 5, separated across purposes (episodic, semantic, procedural, and prospective) and by internal versus external memory. The memory aid with the highest mean frequency rating was the internet, for semantic purposes. The memory aid with the lowest mean frequency ratings was "diary, journal, or blog" for both episodic and prospective purposes. We suspect ratings would be much higher for the latter category if we included social media, which could be described as microblogging (Mickes et al., 2013) and can serve both as communication and as memory.

For each purpose, we separately calculated the mean frequency rating across internal aids and external aids, for each participant. For episodic purposes, there was no difference between internal ($M = 4.76$, $SD = 1.23$) and external ($M = 4.58$, $SD = 1.43$), $t(50) = 0.82$, $p = .416$, $d = 0.13$, 95% CI [−0.19, 0.46]. For semantic purposes, the mean was *lower* for internal aids ($M = 4.81$, $SD = 1.24$) versus external aids ($M = 5.40$, $SD = 1.23$), $t(50) = 3.19$, $p = .002$, $d = 0.47$, 95% CI [0.18, 0.78]. For procedural

Table 5. Mean (and SD) of Rating for Specific Memory Aids (in Part 2), Experiment 1.

Memory Aid	Frequency of Use
Episodic Purposes	
Internal	
Tie to other life events	5.00 (1.41)
Mental rehearsing	4.65 (1.54)
Retracing your steps	4.65 (1.72)
External	
Calendar	5.24 (1.91)
Diary, Journal, or Blog	3.47 (2.13)
Photos	5.04 (1.80)
Semantic Purposes	
Internal	
Tie to other life events	4.34 (1.66)
Mental rehearsing	5.08 (1.59)
Mental imagery	5.02 (1.59)
External	
Notes	5.61 (1.40)
Text/Reference books	4.52 (1.87)
Internet	6.08 (1.40)
Procedural Purposes	
Internal	
Practicing	5.49 (1.60)
Recall the last experience	5.08 (1.57)
Mental imagery	4.78 (1.72)
External	
Notes while doing the task	4.22 (2.03)
Looking up text/reference books	4.12 (2.06)
Video tutorials	4.29 (1.93)
Prospective Purposes	
Internal	
Imagine yourself in the future situation	4.24 (2.06)
Repeating to yourself	5.37 (1.56)
Mental Imagery	4.12 (1.87)
External	
Calendar	5.42 (1.70)
Diary, Journal or Blog	3.00 (2.14)
Reminder notes	4.94 (2.03)

Note. Frequency was rated on a 1–7 scale. See Table 2.

purposes, the mean was *higher* for internal aids ($M = 5.12$, $SD = 1.33$) versus external aids ($M = 4.21$, $SD = 1.51$), $t(50) = 4.55$, $p < .001$, $d = 0.63$, 95% CI [0.35, 0.93]. For prospective purposes, there was no difference between internal ($M = 4.58$, $SD = 1.48$) and external ($M = 4.46$, $SD = 1.47$), $t(50) = 0.47$, $p = .638$, $d = 0.08$, 95% CI [−0.25, 0.41].

Part 3: prompts with specific examples

The mean (and standard deviation) of ratings in Part 3 are shown in Table 6. There is an overall pattern that differs somewhat from that of Part 1. When we asked about more specific instances of the four purposes of memory here in Part 3, participants consistently rated external memory higher than internal memory across frequency, dependability, and ease of use. However, the effects were not statistically significant in every case.

The results of the two-way within-subjects ANOVAs were as follows. For frequency, there was a main effect of form of memory (internal vs. external), $F(1, 48) = 4.05$, $MSE = 3.64$, $p = .050$, $\hat{\omega}_p^2 = .026$, and a marginally significant interaction, $F(3, 144) = 2.59$, $MSE = 1.49$, $p = .055$, $\hat{\omega}_p^2 = .015$. For dependability, there was a main effect of form of memory, $F(1, 48) = 23.34$, $MSE = 3.66$, $p < .001$, $\hat{\omega}_p^2 = .172$, and no significant interaction, $F(2.15, 103.35) = 1.69$, $MSE = 1.64$, $p = .188$, $\hat{\omega}_p^2 = .006$. For ease of use, there was a main effect of form of memory, $F(1, 49) = 23.38$, $MSE = 2.84$, $p < .001$, $\hat{\omega}_p^2 = .114$, and a marginally significant interaction, $F(3, 147) = 2.38$, $MSE = 1.33$, $p = .072$, $\hat{\omega}_p^2 = .010$. Next, we performed our pre-planned pairwise comparisons.

For more specific *episodic* purposes: frequency was not rated differently for external versus internal, $t(49) = -1.31$, $p = .197$, $d = -0.22$, 95% CI [−0.56, 0.12]; dependability was rated higher for external than internal, $t(49) = -3.65$, $p < .001$, $d = -0.63$, 95% CI [−1.00, −0.28]; and ease of use was rated marginally significantly higher for external than internal, $t(50) = -1.90$, $p = .064$, $d = -0.30$, 95% CI [−0.61, 0.02].

For more specific *semantic* purposes: frequency was rated higher for external than internal, $t(50) = -3.89$, $p < .001$, $d = -0.66$, 95% CI [−1.02, −0.31]; dependability was rated higher for external than internal, $t(50) = -4.19$, $p < .001$, $d = -0.84$, 95% CI [−1.26, −0.43]; and ease of use was rated higher for external than internal, $t(50) = -4.69$, $p < .001$, $d = -0.84$, 95% CI [−1.22, −0.47].

For more specific *procedural* purposes: frequency was not rated differently for internal and external, $t(49) = -0.33$, $p = .746$, $d = -0.06$, 95% CI [−0.46, 0.33]; dependability was rated marginally significantly higher for external than internal, $t(49) = -1.96$, $p = .056$, $d = -0.42$, 95% CI [−0.86, 0.01]; and ease of use was rated higher for external than internal, $t(49) = -2.21$, $p = .032$, $d = -0.43$, 95% CI [−0.82, −0.04].

For more specific *prospective* purposes: frequency was not rated differently for internal and external, $t(49) = -0.46$, $p = .650$, $d = -0.09$, 95% CI [−0.46, 0.29]; dependability was rated higher for external than internal, $t(49) = -4.99$, $p < .001$, $d = -0.84$, 95% CI [−1.21, −0.49]; and ease of use was rated higher for external than internal, $t(49) = -3.76$, $p < .001$, $d = -0.61$, 95% CI [−0.95, −0.28].

The frequency ratings from Part 3 are shown in Figure 3. Unlike in Part 1, for episodic purposes, there was no statistically significant difference between internal and external memory. But for semantic purposes, external memory was reported as more frequently used than internal memory, just like in Part 1. The quantitative difference in patterns between episodic and semantic amounted to only a marginally statistically significant interaction, $t(48) = 1.85$, $p = .070$, $d = 0.34$ 95% CI [0.01, 0.71].

One-way within-subjects ANOVAs showed that frequency of use for internal memory did not significantly differ across all four memory purposes, $F(3, 144) = 0.67$, $MSE = 1.60$, $p = .574$, $\hat{\omega}^2 < .001$, whereas frequency of use for external memory certainly did differ across the four purposes, $F(3, 147) = 3.67$, $MSE = 1.46$, $p = .014$, $\hat{\omega}^2 = .023$. Again, external memory was reported as more frequently used for semantic purposes than episodic purposes, $t(50) = 2.30$, $p = .025$, $d = 0.34$, 95% CI [0.04, 0.65].

Part 4: self-rated internal memory ability

Self-rated internal memory ability (on a 5-point scale) was consistently negatively correlated with frequency of external memory use. Averaged across all four purposes and across Parts 1 and 3, $r_s(49) = -.41$, $p = .003$. This replicates our previous finding (Finley et al., 2018, Table 4.5) of a negative correlation between self-rated internal memory ability and use of low-tech external memory (e.g., paper; $r_s(474) = -.25$) and use of high-tech external memory (e.g., computers; $r_s(474) = -.18$). Further correlational results can be found in the Supplemental Materials.

Discussion

The results of Experiment 1 showed that people report using internal memory and external memory to varying extents for different purposes. The results from Part 1

Table 6. Mean (and SD) of Ratings in Part 3 (Prompts with Specific Examples), Experiment 1.

	Frequency		Dependability		Ease of Use	
Purpose	Internal	External	Internal	External	Internal	External
Episodic	4.96 (1.34)	5.24 (1.70)	5.00 (1.36)	5.84 (1.12)	5.45 (1.35)	5.86 (1.37)
Semantic	4.80 (1.56)	5.76 (1.29)	4.59 (1.51)	5.78 (1.27)	4.59 (1.51)	5.82 (1.37)
Procedural	4.94 (1.54)	5.04 (1.50)	4.98 (1.35)	5.60 (1.54)	4.84 (1.55)	5.52 (1.58)
Prospective	5.18 (1.45)	5.32 (1.74)	4.86 (1.46)	5.98 (1.14)	5.12 (1.58)	6.02 (1.30)

Note. Ratings were on 1–7 scales. See Table 2.

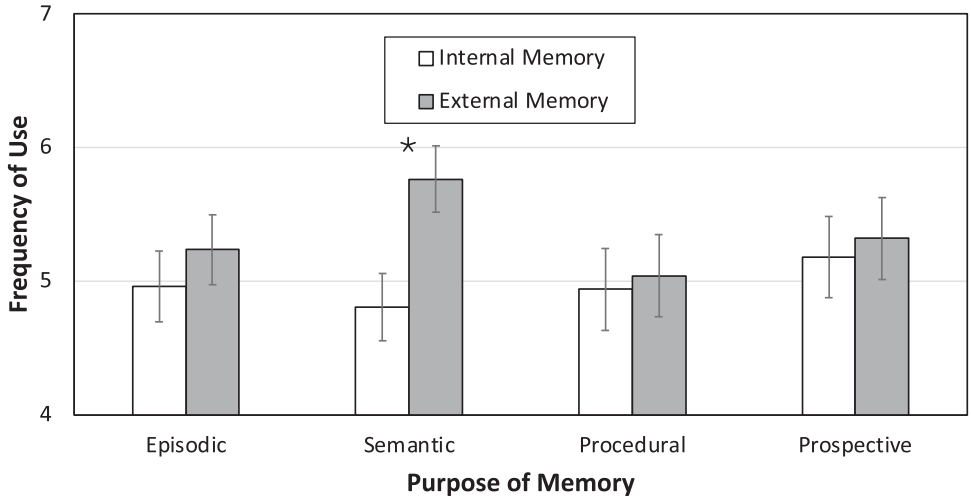

Figure 3. Mean Frequency of Use for Internal and External Memory Across Purposes with Specific Examples in Experiment 1.

Note. Error bars represent the standard error of difference scores for internal versus external memory. Asterisks indicate a statistically significant difference between internal and external memory. 1 = never, 7 = 11 or more times in the last two weeks (See Table 2).

(Figure 2) replicated the crossover interaction from our earlier exploratory work (Finley et al., 2018, shown in Figure 1)—for episodic purposes, internal memory was reported as more frequently used than external memory; for semantic purposes, external memory was reported as more frequently used than internal memory. Furthermore, for procedural purposes internal memory was predominant. In terms of dependability and ease of use, both were generally rated higher for external memory than internal memory (Tables 4 and 6).

The results from Part 2 (Table 5) showed, across purposes, mean frequency ratings for a variety of specific external memory aids as well as specific internal memory aids (strategies). For the particular aids we asked about, there was a pattern that mean frequency ratings were higher for external aids for semantic purposes, and higher for internal aids for procedural purposes. But because the specific aids we asked about were meant to be common but not exhaustive, and were not generated by participants themselves, we should not infer too much from the ratings.

Self-rated memory ability was negatively correlated with frequency of external memory use (Part 4). That is, the better people thought their internal memory was, the less they reported using external memory.

The results from Part 3 of our survey, in which we prompted participants with specific examples for each of the four memory purposes, seemingly contradict our findings from Part 1. Frequency ratings (Figure 3) were higher for external versus internal memory for semantic purposes, but were similar for external and internal memory across the other three purposes. Although this pattern differs from our findings in Part 1, it is consistent with most of the previous findings by other researchers (Harris, 1980; Intons-Peterson & Fournier, 1986; Schryer & Ross, 2013; Walker & Andrews, 2001). Part 3 was planned to probe the participants further on their use of internal and external memory in such a way that they would consider some less obvious instances of episodic, semantic, procedural, and prospective memory. We believe that phrasing the questions to include particular scenarios led to this change in the pattern of results, and we will address this more in the General Discussion. Nevertheless, one goal of Experiment 2 was to seek more clarity than the Experiment 1 results yielded.

Furthermore, according to the memory symbiosis framework, the differential use of internal and external memory across purposes is guided by their relative strengths. However, these strengths must meet the demands of the particular goal, which may vary even within one memory purpose. Thus, in Experiment 2 we included two factors, commonality and timeframe, that could potentially moderate peoples' likely use of internal versus external memory.

Experiment 2

Given the inconsistencies between Parts 1 and 3 of Experiment 1, we designed Experiment 2 to seek both clarification and replication. In Experiment 2 we crafted our questions using very general goals (not specific scenarios), and only mentioned examples of very common specific forms of external memory as needed for clarity (photograph, internet, instructions, how-to, calendar, and alarm). Additionally, reviewers expressed concern that despite the definitions we provided in the Experiment 1 instructions, participants might not have understood the terms or concepts of internal and external memory, or episodic, semantic, procedural, and prospective memory. Thus, we designed Experiment 2 to use the simplest possible language, and we did not mention any of those terms to participants. Furthermore, we used only one simple

prompt that asked about likelihood of use for different goals. This avoids the problem of participants not being particularly accurate at remembering past frequencies of use (Harris, 1980, pp. 36–37; Uttl & Kibreab, 2011).

Additionally, we also added a distinction between common and uncommon goals for semantic and procedural purposes, and near- versus far-term goals for prospective purposes. We did this because our previous work (Finley et al., 2018, Chapter 4) suggested that the relative use of internal versus external memory would depend on characteristics of the goal, and the extent to which those characteristics cater to the strengths and weaknesses of the two forms of memory. For example *commonly used* semantic or procedural information may be better served by the speed of internal memory, whereas *uncommonly used* semantic or procedural information may be better served by the accuracy and duration of external memory. Similarly, the demands of a prospective memory purpose may vary depending on how near or far into the future the task is: a far-future prospective task may be better served by the accuracy and reliability of an external tool such as a calendar or alarm, whereas a near-future task could be equally well served by internal memory.

Method

Design

The experiment used a 2×7 within-subjects design. The independent variables were form of memory (internal vs. external), and purpose of memory (episodic, semantic common, semantic uncommon, procedural common, procedural uncommon, prospective near-term, and prospective far-term). The dependent variable was rating of likely use, made using a 5-point scale.

Participants

Participants were 106 undergraduate students at Southern Illinois University Edwardsville, a medium sized state university, who participated for credit in an introductory psychology course. There were 89 women, 16 men, and one nonbinary person. The mean age was 19.12 ($SD = 2.18$, *range* = 18–31). The racial and ethnic demographics were as follows: 86 White/Caucasian, 16 Black/African, 5 Asian, and 5 Hispanic/Latino. Six participants were multiracial. Demographics on annual household income are available in the Supplemental Materials. In terms of self-rated technological savvy, the mean was 0.53 ($SD = 0.80$) on a scale of −2 to 2, where −2 was very unsavvy, and 2 was very savvy. The mean hours per day using the internet was 6.56 ($SD = 3.05$, *range* = 1–15, $Mdn = 6$). Data were also collected from three additional participants who reported that they had experienced brain disorders affecting their memory; we excluded these data from analysis.

Materials and procedure

This study received ethical approval from the Institutional Review Board of Southern Illinois University Edwardsville (Protocol #1399). The procedure consisted of an online questionnaire, created using Qualtrics, and run in October, 2021. The entire questionnaire is available in the Supplemental Materials. All participants received questions in the same fixed order. Participants completed the questionnaire at their own pace in a single session. The initial instructions were as follows:

> In this survey you will be presented with a number of memory goals. For each goal, your job is to rate how likely you would be to use each of two different types of resources to accomplish the goal: your own brain's memory, and information stored outside your brain. You will make ratings using dropdown menus with the following scale: very unlikely, unlikely, neutral, likely, and very likely. You are free to give whatever answer is most accurate for each of the two resources. That is, you should answer each resource question separately, without regard to what your answer to the other resource was.

Then there were four separate pages of questions, one page for each of the four memory purposes (episodic, semantic, procedural, and prospective). In this paper, we will continue to use these four terms, as well as the terms internal memory and external memory, though we note that none of these six terms were ever used in the materials themselves for Experiment 2.

Each question consisted of a memory goal ("Your goal is to: Remember ____"), a prompt ("How likely are you to use the following to accomplish this goal?") and two resources: "Your own brain's memory" and "Information stored outside of your brain, such as ____, etc." The memory goal and the external memory example (indicated as "____" in the previous sentence) varied across questions. We used very general external memory examples (photographs, internet, instructions, how-to, calendar, and alarm) based on participant responses from our previous work (Finley et al., 2018, pp. 29–31, 52–54). For each of the two resources, there was a dropdown menu with five response options: very unlikely, unlikely, neutral, likely, and very likely.

On the first page, there was one question about episodic purpose (again, not actually labelled that way for participants). For this question, the goal was to "Remember a *personally experienced past event*." and the external memory label was "Information stored outside of your brain, such as a photograph, etc."

On the second page, there were two questions about semantic purpose. One goal was to "Remember a *common fact* that is not about you personally." The other goal was to "Remember an *uncommon fact* that is not about you personally." In both cases, the external memory label was "Information stored outside of your brain, such as the internet, etc."

On the third page, there were two questions about procedural purpose. One goal was to "Remember how to do *a procedure that you do fairly often*." The other goal was to

"Remember how to do *a procedure that you don't do often*." In both cases, the external memory label was "Information stored outside of your brain, such as instructions or a how-to, etc."

On the fourth page, there were two questions about prospective purpose. One goal was to "Remember *to do something in the near future*, such as later today." The other goal was to "Remember *to do something in the further future*, such as in one month." In both cases, the external memory label was "Information stored outside of your brain, such as a calendar or alarm, etc."

Following those questions, participants completed demographic questions, some questions about perceived changes in technology that are unrelated to the current study, and a final question which asked "Were any of the instructions or questions confusing?" This question was implemented after the first 17 participants, as a check to make sure participants were not confused.

Results

Data and Supplemental Materials are available at https://doi.org/10.17605/OSF.IO/4M8YA. First, we note that out of the 89 participants who we asked, only one stated any confusion about the questions. That is, 98.88% of those participants were apparently not confused by the instructions or questions. The obtained power was increased from that in Experiment 1: with 106 participants, the study had 80% power to detect effect sizes of $r = .14$ ($d = .27$) or greater.

Ratings

The mean (and standard deviation) of the ratings are shown in Table 7 and Figure 4. An initial two-way within-subjects ANOVA confirmed that there was a statistically significant interaction, $F(4.61, 484.11) = 63.41$, $MSE = 1.39$, $p < .001$, $\hat{\omega}_p^2 = .323$. Thus, we proceeded to the pre-planned pairwise comparisons of internal versus external memory for each purposes.

For the *episodic* purpose, likely use was rated higher for internal than external, $t(105) = 2.21$, $p = .030$, $d = 0.28$, 95% CI [0.03, 0.55].

For the *common semantic* purpose, likely use was not rated differently for internal versus external, $t(105) = 1.58$, $p = .116$, $d = 0.23$, 95% CI [−0.07, 0.53]. For the *uncommon semantic* purpose, likely use was rated higher for external than internal, $t(105) = -6.42$, $p < .001$, $d = -0.88$, 95% CI [−1.17, −0.60]. Of particular interest, the difference in patterns between common and uncommon semantic purposes was a statistically significant crossover interaction, $t(105) = 6.46$, $p < .001$, $d = 0.79$, 95% CI [0.54, 1.05], with opposite patterns across the two semantic purposes. If we collapse across common and uncommon facts, that interaction is obscured and instead we see an overall greater likely use for external ($M = 3.81$, $SD = 0.86$) than internal ($M = 3.42$, $SD = 0.78$), $t(105) = -3.25$, $p = .002$, $d = -0.47$, 95% CI [−0.74, −0.21], which is consistent with Experiment 1.

For the *common procedural* purpose, likely use was rated higher for internal than external, $t(105) = 10.40$, $p < .001$, $d = 1.46$, 95% CI [1.15, 1.79]. For the *uncommon procedural* purpose, there was the opposite pattern: likely use was rated higher for external than internal, $t(105) = -10.37$, $p < .001$, $d = -1.43$, 95% CI [−1.75, −1.14]. Again of particular interest, the difference in patterns between common and uncommon procedural purposes was a statistically significant crossover interaction, $t(105) = 13.59$, $p < .001$, $d = 2.01$, 95% CI [1.67, 2.37], with opposite patterns across the two procedural purposes.

For the *near-term prospective* purpose, likely use was not rated differently for internal versus external, $t(105) = -0.96$, $p = .341$, $d = -0.15$, 95% CI [−0.46, 0.16]. For the *far-term prospective* purpose, likely use was rated higher for external than internal, $t(105) = -11.13$, $p < .001$, $d = -1.74$, 95% CI [−2.10, −1.39]. The difference in patterns between near-term and far-term prospective purposes was a statistically significant quantitative interaction, $t(105) = 9.30$, $p < .001$, $d = 0.94$, 95% CI [0.72, 1.16].

One-way within-subjects ANOVAs showed that likely use for internal memory differed across all seven memory purposes, $F(4.87, 511.02) = 71.41$, $MSE = 1.07$, $p < .001$, $\hat{\omega}^2 = .339$, and likely use for external memory also differed across all seven memory purposes, $F(4.32, 453.75) = 17.91$, $MSE = 1.40$, $p < .001$, $\hat{\omega}^2 = .111$.

Table 7. Mean (and SD) of Ratings in Experiment 2.

Purpose		Likely Use	
		Internal	External
Episodic		4.12 (0.93)	3.85 (0.95)
Semantic	Common	3.92 (0.84)	3.69 (1.09)
	Uncommon	2.92 (1.18)	3.92 (1.07)
Procedural	Common	4.58 (0.73)	3.08 (1.24)
	Uncommon	2.64 (0.98)	4.07 (0.99)
Prospective	Near-Term	3.80 (1.02)	3.96 (1.10)
	Far-Term	2.72 (1.10)	4.42 (0.82)

Note. Ratings were on 1–5 scales. 1 = very unlikely, 5 = very likely.

Discussion

The results of Experiment 2 both replicated and extended the results from Experiment 1 Part 1, and from Finley et al. (2018). Using general prompts, we found that participants' predicted likely use of internal memory and external memory varied across purposes. For episodic purposes, internal memory was preferred over external (e.g., photograph), just as we found in Experiment 1 Part 1, and in Finley et al. (2018). For semantic purposes, Experiment 2 provided further insight, showing that the pattern of likely use of internal versus external memory reversed depending on whether the fact to be retrieved was common (internal memory preferred) or uncommon (external memory preferred; e.g., internet). Procedural purposes also showed the same crossover interaction, with internal memory preferred for common tasks and

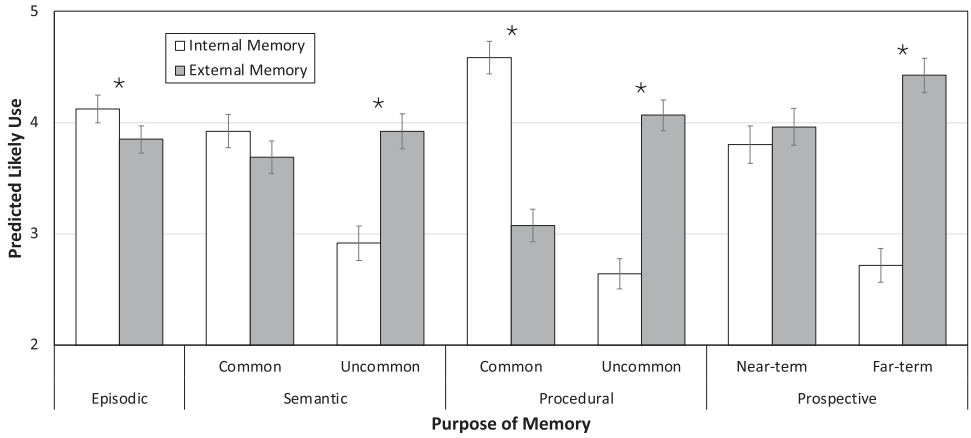

Figure 4. Mean Likely Use for Internal and External Memory Across Purposes in Experiment 2.

Note. Error bars represent the standard error of difference scores for internal versus external memory. Asterisks indicate a statistically significant difference between internal and external memory. 1 = very unlikely, 5 = very likely.

external memory (e.g., instructions, how-to) preferred for uncommon tasks. Finally, for prospective purposes, internal and external memory were rated as approximately equally likely to be used for near-term future tasks, whereas external memory (e.g., calendar, alarm) was strongly preferred over internal memory for far-term future tasks (e.g., one month).

The results from Experiment 2 further support the pattern that likely use of internal versus external memory plays to the strengths of the two types of memory. Internal memory was particularly unlikely to be used for uncommon facts or procedures, and for far-term prospective purposes. Those are exactly the purposes for which internal memory is less reliable than external memory.

General discussion

Summary of results

Across two experiments, we found that people report using internal memory (information in the brain) and external memory (information outside the brain) to varying extents for different purposes. For remembering personal experiences (episodic memory), internal memory was preferred over external memory. For remembering general information overall (semantic memory), Experiment 1 showed that external memory was preferred, and Experiment 2 showed the further distinction that external memory (e.g., the internet) was particularly preferred for uncommon facts as opposed to common facts. For remembering how to do something (procedural memory), Experiment 1 suggested a preference for internal memory (Part 1) or no preference at all (Part 3). Experiment 2 clarified that for common procedures internal memory was strongly preferred, while for uncommon procedures external memory was strongly preferred. Finally, for remembering to do something in the future (prospective memory), Experiment 1 suggested no preference, but Experiment 2 clarified that for far-term tasks external memory was strongly preferred, whereas for near-term tasks both internal and external memory were equally likely to be used.

Dependability and ease of use were generally rated higher for external memory than internal memory (Experiment 1, Tables 4 and 6). This is consistent with the findings of Intons-Peterson and Fournier (1986, Table 4), which was the only prior study that asked about these variables. Finally, self-rated memory ability was negatively correlated with frequency of external memory use (Experiment 1). That is, the better people thought their internal memory was, the less they reported using external memory. This replicates our previous findings (Finley et al., 2018, Table 4.5), which also showed a negative correlation between self-reported internal memory ability and use of both low-tech and high-tech external memory (see also Touron, 2015; Weis & Wiese, 2020).

General versus specific prompts

The way that questions are asked matters. When open-ended or generally-phrased questions are used to prompt participants about their use of internal and external memory (as in Experiment 1 Part 1, Experiment 2; and in Finley et al., 2018), the responses are participant-driven; that is, participants are free to consider the variety of aids/strategies and/or situations that exist in their own lives. In that case, we find the crossovers such that internal memory is predominant for episodic purposes and common procedural purposes, whereas external memory is predominant for uncommon semantic purposes and prospective purposes. In contrast, when specific examples of memory aids/strategies or situations are used (as in Experiment 1 Part 3, and all the previous studies by other researchers), the responses are researcher-driven; that is, participants focus on those specific aids/strategies and/or situations given by the researchers, potentially overlooking more common elements of their own lives.

In that case, we find a general dominance of external memory over internal memory, across purposes. But such results may simply be a function of the specific examples the researchers thought to use. Harris (1980, pp. 37–38) also grappled with the tradeoffs between specific versus general questions, stating that while a participant may struggle to retrieve their own examples of specific memory aids in response to a general prompt, in contrast they may "go no further than the given examples" in response to a specific prompt.

Some light was shed on this issue, particularly for frequency measurements, by Intons-Peterson and Fournier (1986), whose findings can help clarify ours, specifically with respect to the frequency ratings in Experiment 1. They observed:

> In fact, the concept of *frequency* may assume two meanings: one corresponds to the generality of use across situations and the other refers to the frequency with which a memory aid is used in specific situations, given that it is applied at all. (p. 269)

To measure the more specific frequency, in their first experiment they had participants rate how frequently they used each of 18 specific memory aids in 32 different situations (see their Table 2), using the same rating scale that we used in the current study. To measure generality of each aid, they calculated the percent of the situations across which participants rated any use of that aid.

For their frequency-per-situation measure, Intons-Peterson and Fournier (1986) found that external aids were rated as used more frequently than internal aids ($M = 4.39$ vs. 4.04). This is consistent with our Experiment 1 Part 3 results, which prompted participants with specific example situations. For the generality-across-situations measure, they found that external aids had *less* generality than internal aids for retrospective situations (22.7% vs. 28.2%), and more generality for prospective situations (25.2% vs. 23.9%). Although their retrospective situations did not distinguish between episodic and semantic, their finding of a crossover pattern for generality but not specific frequency is similar to our finding of a crossover in Experiment 1 Part 1 (general) but not Part 3 (specific). Neither the frequency-per-situation measure nor the generality-across-situations measure do a complete job of describing someone's use of internal and external memory in everyday life. For that we would need a complete accounting of situations and the frequency of those situations, which may be a worthy target for future research. However, the generally-phrased questions in the current study (Experiment 1 Part 1 and Experiment 2), and the open-ended questions in our previous study (Finley et al., 2018) are at least not restricted to researcher-driven examples.

Strategic use of internal and external memory across purposes

Here we consider how the results of the current study relate to the theories regarding external memory use that we outlined in the Introduction.

Extended memory system

As part of the extended memory system framework (Esser, 1996; Schönpflug & Esser, 1995), the decision between using internal or external memory was proposed to be based on three factors: the importance of remembering the information, the probability of successful future retrieval using that store, and the effort of encoding with that store. Our data cannot speak to the importance factor, but can speak to the other two factors. For someone to gauge the probability of successful retrieval is a metacognitive task, and surely participants foresaw that far-term prospective goals would potentially be forgotten using only internal memory, and thus they favoured external memory (Figure 4). Similarly, participants likely judged common semantic and common procedural information to be reasonably well served by internal memory, and thus did not favour external memory for those purposes (Figure 4). With respect to effort of encoding, our data show that ease correlated with use. In Experiment 1 Part 1 for external memory, greater ease of use correlated with higher frequency: .59 for episodic, .66 for semantic, .44 for procedural, and .75 for prospective ($N = 51$ in each case). Thus, our data showed support for the extended memory system framework.

Cognitive offloading hypothesis

The cognitive offloading hypothesis (Storm & Soares, in press) states that external memory supplants internal memory: when people offload information to the environment, they do not bother to remember it themselves. This implies a mutual exclusivity between internal and external memory. Data from the current study can speak to this hypothesis in a limited way. Cognitive offloading would predict a negative correlation between frequency/likelihood of use for external memory and frequency/likelihood of use for internal memory. In Experiment 1 Part 1, these correlations were .75 for episodic, .57 for semantic, .27 for procedural, and .51 for prospective ($N = 51$ in each case). In Experiment 2, the correlations were .09 for episodic, -.23 for common semantic, -.02 for uncommon semantic, -.08 for common procedural, -.01 for uncommon procedural, -.31 for near-term prospective, and -.33 for far-term prospective ($N = 106$ in each case). We see a negative correlation only in some cases. The case of prospective memory makes the most intuitive sense: whether near-term or far-term, if an external source is used (e.g., alarm, calendar), there is little need to use one's own memory. However, the common semantic case is more interesting, and suggests a potential corollary of the cognitive offloading hypothesis: if something is easily remembered with internal memory (e.g., common facts or frequently used information), there is little need to write it down or look it up. Thus, the current data suggest that the act of cognitive offloading is not simple or universal, but depends on the purpose of memory and kind of information. Consistent with this, open-ended responses from

our previous survey (Finley et al., 2018, pp. 59–62) suggested that using external memory does indeed lead people to use their internal memory less, and to do so strategically for certain kinds of information (e.g., "I try less hard to remember details and lists, since I know I can look it up later." and "I do not need to store volumes of information in my human memory. I selectively store information that is critical or information that I might need quickly.").

Memory symbiosis framework

The memory symbiosis framework (Figure 5; Finley et al., 2018, Chapter 7) predicts an adaptive interplay between internal and external memory, such that humans tend to strategically distribute the work of memory across internal and external resources based on the contextual purpose of memory (episodic, semantic, procedural, and prospective) and the relative strengths and weaknesses of the resources. The very idea of four distinct external memory purposes, which correspond to different types of internal memory, is a novel contribution of this framework and to our knowledge has never been discussed in previous studies beside our own. As we reviewed in the Introduction, previous studies of external memory focused largely on prospective purposes, and did not distinguish between episodic and semantic for retrospective purposes. The results of the current study support a distinction between the four external memory purposes that we first discovered in our large-scale survey study (Finley et al., 2018, p. 55). In that study, when people were asked open-ended questions to compare what internal and external memory are used for and good at, the four different memory purposes emerged from their qualitative responses, as well as the crossover patterns showing that internal memory was predominant for episodic and procedural purposes, and external memory was predominant for semantic and prospective purposes (Figure 1). The current study was a follow-up to see if we would find the same pattern using closed-ended questions and directly asking about the four memory purposes. With the generally phrased questions in Experiment 1 Part 1, and in Experiment 2, we did. Experiment 2 further elucidated the likely uses of external memory by showing that it depends on the commonality of the information or procedure, with external memory being favoured over internal for uncommon information and procedures, and internal memory being favoured over external for common information and procedures. Additionally, Experiment 2 showed that external memory was favoured over internal memory for prospective tasks further in the future.

In line with the memory symbiosis framework, the differential use of external and internal memory for different purposes is strategic and adaptive. The negative correlation in Experiment 1 between self-rated internal memory ability and external memory use suggests that people turn to technology and the environment when they cannot rely on their internal memory. It appears that humans tend to distribute the work of memory

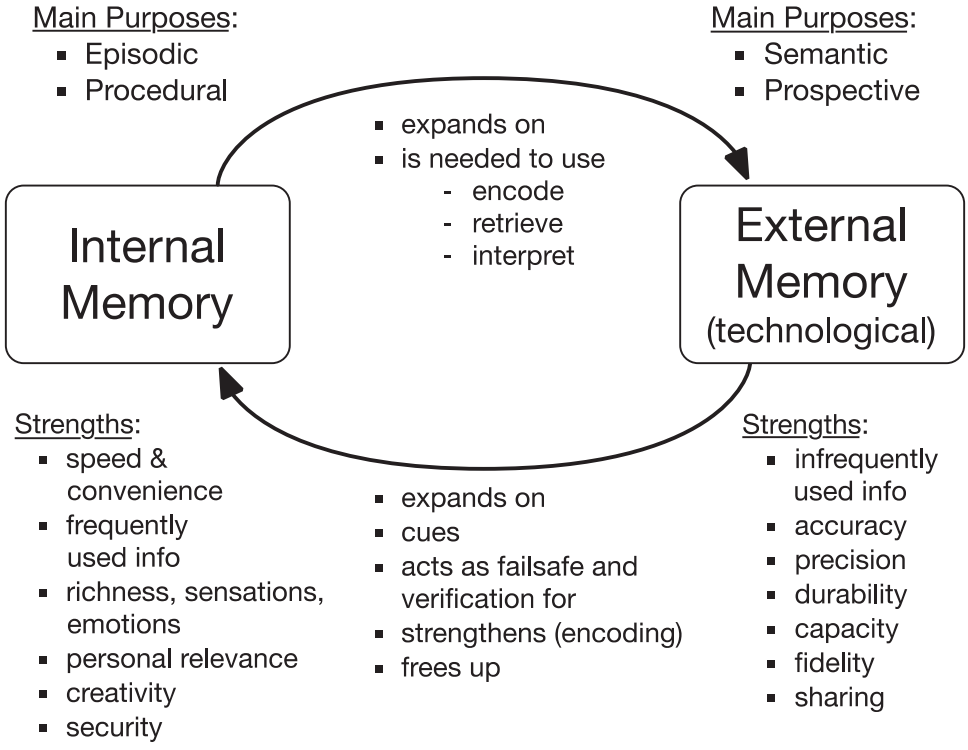

Figure 5. Memory Symbiosis Framework (version 1.0).

Note. Theoretical framework of the interplay of internal and external memory. Reprinted with permission from Finley et al. (2018). Version 1.0. Copyright Springer.

across internal and external resources in ways that play to their strengths. In our previous work (Finley et al., 2018, pp. 50–59, 157–158), we identified the relative strengths of internal and external memory based on the large-scale survey we conducted and our extensive review of relevant literature from psychology and other disciplines. The main strengths of internal memory are: rapid convenient access especially to frequently used information, rich vivid representations that include sensations and emotions (which are not easily recorded to external memory), personally meaningful experiences/information, creativity, and security of private experiences/information. The main strengths of external memory are: access to infrequently used information, accuracy (true representation of reality, where applicable), precision (exactness of details), durability (long-lastingness), capacity (large amounts of information), fidelity (representations do not become distorted over time and reuse), and ease of social sharing (e.g., photos on social media). To note just one additional difference, internal memory is fundamentally associative and reconstructive, while external memory is not.

For most episodic purposes, internal memory is well suited, particularly with the richness and personal meaning of the representations. For most semantic purposes, external memory (e.g., computers and the internet) excels, with strengths in accuracy, precision, and the fact that the information tends to remain stable and accessible over time and reuse. For most procedural purposes, internal memory holds the advantage of being faster and more automatic, at least for well-learned tasks. For most prospective purposes, external memory (e.g., calendars and alarms) reduces the risk of forgetting a task or event, and frees up cognitive resources by alleviating the burden on internal memory. These considerations explain the general pattern of results from Experiment 1, Part 1 (Figure 2) and from our previous study (Figure 1).

However, there are situational exceptions to that overall pattern. For example, the *rapid* access to facts provided by internal memory can make it preferable in situations where using external memory is impractical or socially unacceptable, such as during a fast-paced face-to-face discussion. The speed and simplicity advantage of internal memory is particularly true for common facts, as evidenced by the semantic condition results of Experiment 2 (Figure 4). It is faster and simpler to retrieve common information from your own brain than from an internet-connected device. Internal memory is also more secure for sensitive semantic information such as passwords or secrets.

For procedural purposes, external memory may be preferable for new or uncommon procedures, such as infrequently used recipes; this is consistent with the procedural condition results of Experiment 2 (Figure 4). For prospective purposes, the timescale matters. Whereas far future tasks such as a doctor's appointment next month are best served by the reliability of a calendar, near future tasks such as picking up groceries later today could be accomplished with either internal or external memory; this is consistent with the prospective condition results of Experiment 2 (Figure 4). The specific situations we have mentioned here in this discussion were all told to us by participants in Finley et al. (2018), which shows the important insights that only qualitative data can provide.

We note that the memory symbiosis framework is agnostic about the *process* by which people make choices that tend to appropriately delegate memory tasks across internal and external memory. For example, their choices may be driven to some extent by accumulated direct experience (statistical learning) and a strategy to optimise some aspect of performance (e.g., successful retrieval), and/or driven to some extent by heuristics based on metacognitive beliefs about the dependability and ease of use of internal versus external memory for a given purpose. The question of how people make their strategic choices is more fully explored in the particular context of intention offloading (i.e., prospective memory) as reviewed by Gilbert et al. (2020, 2022; see also Risko & Gilbert, 2016).

An important part of the memory symbiosis framework, and one not directly addressed by the current study, is that internal and external memory work together. For example, a photo of an event can cue internal memory for the experience, which can in turn provide details not present in the photo (Finley & Brewer, 2022). And some internal memory is required to make use of external memory. For example, you must remember to take the photo (encoding), then later remember that it exists and how to find it (retrieval). For our complete list of the ways that internal and external memory interact, along with illustrative quotes from participants, see Finley et al. (2018, Table 4.2). Further empirical investigation of this interplay is an important direction for future research.

Finally, it is worth noting that the frequency and likelihood ratings for external memory in the current study were only rarely very low, showing that external memory is in regular use across purposes in everyday life. This is particularly impressive considering that high-tech external memory (anything requiring a power source) has only been widely available for the most recent few decades of human existence. For the overwhelming majority of human history stretching back some 200,000 years, not even written language was available as a form of external memory, having been invented a mere 5,500 years ago. We are truly a versatile tool-using species, and it is in our nature to strategically augment our abilities and extend ourselves—even our memories—into the environment.

Limitations and future directions

Method and sample

One minor limitation of the current study was the use of a fixed order for the four memory purposes we asked about

(episodic, semantic, procedural, and prospective). We do not think that this order could have artificially produced the crossover interactions, and we find reassurance that the same pattern was found in Finley et al. (2018), which did not mention the four purposes at all, in any order. Nevertheless, it would be prudent for future studies to use a randomised order.

A more obvious limitation is the sample. Future research should seek to expand to other populations. The generality of our current study is constrained because it is based on U.S. college students in the early second decade of the twenty-first century. In addition to socio-economic factors, there is likely variance in external memory use tied to overall skills with digital media (Hargittai & Micheli, 2019). Our participants were necessarily familiar enough with technology to use the online tools that are common for current college courses. The participants in our previous study (Finley et al., 2018) were more diverse in terms of age and employment context, but were also familiar enough with internet technology to use Mechanical Turk. Like the handful of previous studies that have directly investigated external memory (Harris, 1980; Intons-Peterson & Fournier, 1986; Walker & Andrews, 2001; and Schryer & Ross, 2013), our study provides a snapshot at a certain point in time. Ongoing research will be needed as new technology continues to potentially change the interplay of internal and external memory (Smart et al., 2017). We discuss potential future trends in Finley et al. (2018, pp. 59–62, and Chapter 8). A summary of that work is that external memory appears to be *augmenting* internal memory for episodic purposes, and *supplanting* internal memory for semantic and prospective purposes.

Self-report

Another consideration for future research is the validity of participants' self-reports on use of internal and external memory in everyday life, even when they are not biased by specific examples in the questions. Prior research has called into question the validity of self-report about memory ability and behaviour as compared to actual performance and behaviour (Beaudoin & Desrichard, 2011; Schryer & Ross, 2013; Uttl & Kibreab, 2011). People may also misattribute semantic information in external memory to their own internal memory (Fisher et al., 2021; Ward, 2021). Estimating how frequently one uses their own memory for certain purposes is an unusual task, as one of our own participants commented. To assess the validity of the kinds of self-reports that participants made in the current study, we would need to know: to what extent do people actually use internal and external memory in their daily lives? This is an *ethological* question, which traditional survey and laboratory methods are ill-equipped to answer. However, naturalistic observation (Adler & Adler, 1994) or experience sampling methods could do it (Hektner & Csikszentmihalyi, 2002; see also ecological momentary assessment, Kirchner & Shiffman, 2013), and more such research is needed. For example, Rasmussen et al. (2015) succeeded in using handheld mechanical counters and smartphones to measure the frequency of both voluntary and involuntary internal memory retrievals throughout a participants' day. In a different naturalistic approach, Soares (2020, Study 1) interviewed participants about the most recent photos they had taken with their own phone or camera (external memory), gathering valuable quantitative and qualitative data about their memories of the pictured experiences and their goals in taking the photos. Museums have also been used as naturalistic settings for research on photos and memory (Henkel, 2014; Henkel et al., 2016), and social media is another possible setting (Talarico, 2021; Tamir et al., 2018). Research on digital media and communications has already begun focusing on capturing actual naturalistic use of screens ("screenomics", Reeves et al., 2020, 2021).

Another option to track use of internal and external memory would be daily diary studies (Gunthert & Wenze, 2012; Iida et al., 2012). Daily diary methods have been used, for example, to study everyday occurrences of memory failures (Neupert et al., 2006). Harris (1980) concluding by suggesting diary studies for investigating memory aids. Frequency and other ratings for the four different memory purposes, and internal versus external memory, could be accommodated with smartphones, whether using the daily diary or experience sampling approach (Hofmann & Patel, 2015; Kuntsche & Labhart, 2013). Think-aloud protocols (Ericsson & Simon, 1998) could also be useful in naturalistic settings to see how people use internal and external memory in conjunction with each other.

Moderating factors: commonality and timeframe

In Experiment 2, we found two moderating factors for peoples' likely use of external memory across different purposes: commonality (of the information or the procedure), and timeframe (for prospective tasks). The timeframe factor could be explored for episodic purposes as well. It may be that external memory plays a larger role for episodes in the more distant past. For example, when remembering a vacation from several years ago, a photo album would serve as both a powerful cue for internal memory, and a source of information not available in internal memory. Personal importance may also be a factor for episodic purposes. Internal memory is likely more useful for significant episodes such as one's graduation or wedding. External memory is likely more useful for mundane episodes that have less meaning and have been less often retrieved. Memory for episodes is also worthy of further inquiry because internal and/or external resources could be used for retrieving various aspects of an episode (e.g., date, location, people, actions, thoughts, emotions).

Exploring the symbiosis

Finally, we would like to highlight three other points for future research. First, although our inclusion of objective memory measures in Experiment 1 yielded only ambiguous results, we still think it is worthwhile to continue such an approach, in order to better assess any relationship between external memory use and actual internal memory ability beyond self-report. Second, we think an important direction for external memory research is to differentiate between *encoding* and *retrieval* processes for external memory (Finley et al., 2018, pp. 160–161). This is yet another example of how distinctions used in theories of internal memory can continue to be fruitfully applied to external memory, at least by analogy. Third, to better develop the memory symbiosis framework, more work is needed to specifically target the complex ways that internal and external memory work *together* (Figure 5), and how that may differ across purposes. For example, to borrow the terms *integrated* and *differentiated* from the transactive memory framework (Wegner et al., 1985), the distribution of information between people and their external memories may be more integrated for episodic information (e.g., photos cue internal recollection, which then contributes more phenomenological detail) and more differentiated for semantic information (e.g., phone numbers completely offloaded to one's phone and passwords completely retained in one's internal memory). Still other work has highlighted how peoples' awareness of their own knowledge can fail to distinguish between internal and external sources for semantic purposes (Fisher et al., 2021; Ward, 2021), demonstrating how closely intertwined internal and external memory can be. As technology plays an increasing role in everyday life, we see a growing symbiosis between internal and external memory. The two complement and depend on each other. More research is needed to understand this interplay, especially given the extensive use of external memory throughout human history, and increasingly in the information age.

Notes

1. External memory may also be social(i.e., information stored in other people). However, in this paper we refer only to technological external memory, be it low-tech or high-tech.
2. Our use of the term "purpose" does not necessarily imply *intentionality*, though intention could of course be present in some cases; rather, it refers to the function served by a particular use of memory.
3. The term "aid" for internal memory is synonymous with "strategy" or "mnemonic".
4. There have also been a number of laboratory studies investigating external memory use specifically for prospective tasks (e.g., Gilbert, 2015).
5. Intons-Peterson Fournier (1986, Experiment 1) also included a 7-point scale question about accuracy, which was highly correlated with dependability ($r_s(106) = .71$ for internal memory aids and .81 for external) and was dropped in their second study. We chose not to use the accuracy question in the current study.
6. For one-way: $\hat{\omega}^2 = \frac{df_{\text{effect}}(MS_{\text{effect}} - MS_{\text{effect}\times\text{subject}})}{SS_{\text{total}} + MS_{\text{subject}}}$ For two-way: $\hat{\omega}_p^2 = \frac{df_{\text{effect}}(MS_{\text{effect}} - MS_{\text{effect}\times\text{subject}})}{SS_{\text{effect}} + SS_{\text{effect}\times\text{subject}} + SS_{\text{subject}} + MS_{\text{subject}}}$
7. We were not concerned at all with any possible main effects of memory purpose, and the presence of the interactions made any main effects of memory form irrelevant.

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ORCID

Jason R. Finley http://orcid.org/0000-0001-5921-8336
Farah Naaz http://orcid.org/0000-0001-9360-0969

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