

Jason R. Finley · Farah Naaz
Francine W. Goh

Memory and Technology

How We Use Information in the Brain
and the World

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Preface

Humanity has always been the species that extends itself into the environment. Memory is no exception. Internal memory is information stored in one's brain, and external memory is information stored outside of one's brain (either socially or technologically). Humans have a long history of using external memory, and we interact extensively with it in our everyday lives.

External memory is integral to human cognition and behavior, though twenty-first-century technology (e.g., smartphones, the Internet) may be changing how we use it and how we use our own internal memory as well. However, psychological research and theory on this overall topic has so far been limited and fragmentary. With this book, we seek to rectify that.

The story of how this book came to be is one of friendship, fruitful disagreement, scientific curiosity, ingenuity, and perseverance. This project arose from conversations (debates, really) between the first two authors, JRF and FN, about the extent to which technology was helping or hurting human cognition. It was 2013, and we were both postdoctoral researchers at Washington University in St. Louis. In lab meetings, and over fruity cocktails at happy hour, we debated. Is human memory getting worse? Is high-tech external memory supplanting us or augmenting us? Like any good scientists, we decided that the only way to settle our lively disagreements was empirically. But we found that barely any psychological data existed yet on this important topic. So we joined forces to gather some.

But we did not have any funding. That is, until we discovered the crowdfunding platform, Experiment.com. In 2014, with help from the SciFund Challenge and the generous support of many backers (see Acknowledgments), we raised the funds needed to develop and run a large survey in which we could ask just about every question we could think of that we wanted answers to. We ran the survey in 2015 and then painstakingly analyzed our rich trove of new data over the next year or two, with third author FWG joining us to lend a big assist with the qualitative data. Naturally, each exciting answer led to more questions, and as we developed a framework to make sense of our data, we also saw the ways that our questions connected to a constellation of other research both within and beyond psychology, which no one had yet brought together to review in one place. As we undertook such a review

ourselves, working on academic breaks and weekends, it became clear that this side project of ours had bloomed into a larger endeavor than we had foreseen and one that was unlikely to fit in the confines of a typical journal article. We had, in fact, ended up writing a book.

Fortunately, the prospect of publication became a reality after JRF met with Springer editor, Lilith Dorko, at the 2017 annual meeting of the Psychonomic Society in Vancouver. After much revision, and peer review, the result is the book that you are currently reading. The organization of the book is somewhat atypical. There are three parts, which we characterize as the present, the past, and the future. In Part I, the present, we report the results of our comprehensive survey on the interplay of internal and external memory in everyday life and how that is changing in the early twenty-first century ($N = 476$ Mechanical Turk participants). The survey included quantitative and qualitative questions about attitudes, beliefs, behaviors, and experiences. In Part II, the past, we provide a thorough interdisciplinary review of the disparate prior literature on external memory, including relevant theoretical frameworks from disciplines across the sciences, arts, and humanities. In Part III, the future, we synthesize our results with our review of the literature to offer a new theoretical framework for understanding the interplay of internal and external memory. We also provide a guide to important dimensions, questions, and methods for future research.

Briefly, our work reveals an overall picture of a growing symbiosis between internal and external memory. The two complement and depend on each other. Technological external memory (both low-tech and high-tech) is augmenting internal memory for episodic purposes and supplanting internal memory for semantic and prospective purposes. The main strengths of internal memory are rapid convenient access to frequently used information, rich vivid representations including sensations and emotions, personal meaning, creativity, and security. The main strengths of technological external memory are access to infrequently used information, accuracy, precision, longevity, capacity, fidelity, and social sharing.

This book should be of interest to scholars and students of memory from a variety of disciplines, psychology in particular, as well as anyone curious about how technology is affecting human memory. Internal and external memories have mutually shaped each other for tens of thousands of years and will continue to do so into the future. Although we may not have settled every debate, with this book, we have laid the groundwork for much-needed future work, both empirical and theoretical.

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Part I
Empirical Report (The Present)

Chapter 1

Introduction and Method



Introduction

...the greater part of our memory exists outside us.... (Proust, 1919/2015, p. 240)

A hallmark of humanity is our creation and use of tools to transcend our limitations. We have always been the species that extends itself into the environment. Memory is no exception. Memory provides a way of transferring information across time. The ability to store and retrieve information outside of an individual human brain—*external memory*—is a defining and tremendously adaptive characteristic of our species. With external memory we can preserve records of our own experience and learn from the experiences of others. We can expand our knowledge and pass information on to future generations so they do not have to learn everything from scratch. With external memory, knowledge becomes cumulative. For tens of thousands of years, we have offloaded memory to external mediums: songs and legends of oral tradition, cave paintings, cuneiform clay tablets, quipu knot records, pen and paper, printed books, wall calendars, computers, the Internet, and smartphones. The dazzling technology of the early twenty-first century is a continuation of an ancient trajectory (d’Errico, 2001; Rumsey, 2016; Staley, 2014). But as we shape our tools, to what extent do they also shape us (Culkin, 1967; McLuhan, 1962)?

Rapid technological advancement has put the world’s knowledge at our fingertips (smartphones, the Internet). It has also made it easier than ever to record information to external memory (cf. lifelogging, Sellen & Whittaker, 2010) and to rely less on our *internal memory*—information stored in one’s brain. How does this change us (Sparrow & Chatman, 2013a, 2013b; Donald, 2001)? Is external memory empowering us to do more and function better (Clark, 2003; Thompson, 2013)? Is it diminishing our own abilities to remember (Carr, 2011, 2014; Greenfield, 2014)? Is external memory *augmenting* internal memory, or *supplanting* it? To what extent both (Brockman, 2011; Ward, 2013b)? Our broad question is this: what is the interplay between internal memory and external memory, and how is technology changing that interplay?

These are fundamental questions for psychological science. We echo others in emphasizing that the use of external memory should be included in models of human memory (Hertel, 1993; Intons-Peterson & Fournier, 1986; Nestojko, Finley, & Roediger, 2013; Schönplflug, 1986a).¹ In Chapters 5 and 6, we will review a variety of theoretical perspectives on the interplay between internal and external memory, from psychology and other disciplines. For now, we focus on empirical research. Although there has been increasing discussion of everyday external memory in the popular press (e.g., Biegler, 2016; Carr, 2011, 2014; Naughton, 2010; Tan, 2016; Thompson, 2013; Turney, 2013; Wagner, 2015; Wegner & Ward, 2013), there has still been fairly little empirical psychological research on the topic.² As a field, we have been slow to take on this important challenge, but we are making progress.

In early work on trade-offs between internal and external memory, Schönplflug (1986b, 1988) investigated how people strategically delegate encoding of information to internal versus external stores based on the information's relevance to their current task (in his task, preparing a report about colonization of a fictional extrasolar planet) and based on the costs in time and effort of creating external records (printing to paper). Increased relevance lead to greater use of external memory, while increased printing costs lead to less use of external memory. In more recent years, some laboratory-based studies have made progress in showing how retrieving information from the Internet can potentially influence aspects of cognition. Reported effects include inflating confidence in our own knowledge (Fisher, Goddu, & Keil, 2015; Ward 2013a) but also making us less likely to volunteer answers to trivia questions from our own memory (Ferguson, McLean, & Risko, 2015) and more likely to use the Internet to retrieve answers to additional trivia questions (Storm, Stone, & Benjamin, 2016).

Studies have also shown that when people expect to have future access to external memory for some information, they reduce their use of internal memory for that information (Macias, Yung, Hemmer, & Kidd, 2015; Sparrow, Liu, & Wegner, 2011, Experiment 2), they potentially reallocate internal memory efforts to different information (Kobayashi & Kawaguchi, 2016; Storm & Stone, 2015), and/or they shift to using their internal memory to remember how and where to access the external memory (Eskritt, Lee, & Donald, 2001; Sparrow et al., 2011, Experiments 3–4). Other studies have shown that internal memory can be influenced by the very act of making external memory records such as photos (Henkel, 2014) or notes (Intons-Peterson & Fournier, 1986, Experiment 3; Kobayashi, 2005).

Despite these valuable experimental findings (see also a review by Loh & Kanai, 2016, and a critique of the “Google effect” by Heersmink, 2016), there is still a dearth of data on the interplay of internal and external memory in everyday life.

¹Mullin, Herrmann, and Searleman (1993): “although the use of external aids is ubiquitous, memory research and theory does not consider how external aids affect memory.” Wegner (1987, p. 187): “It is surprising, actually, that the psychological study of memory has dwelt so little upon the extraordinary human tendency to record items in external storage media.”

²An exception is the use of retrieval cues in laboratory studies of memory retrieval processes (Roediger & Guynn, 1996).

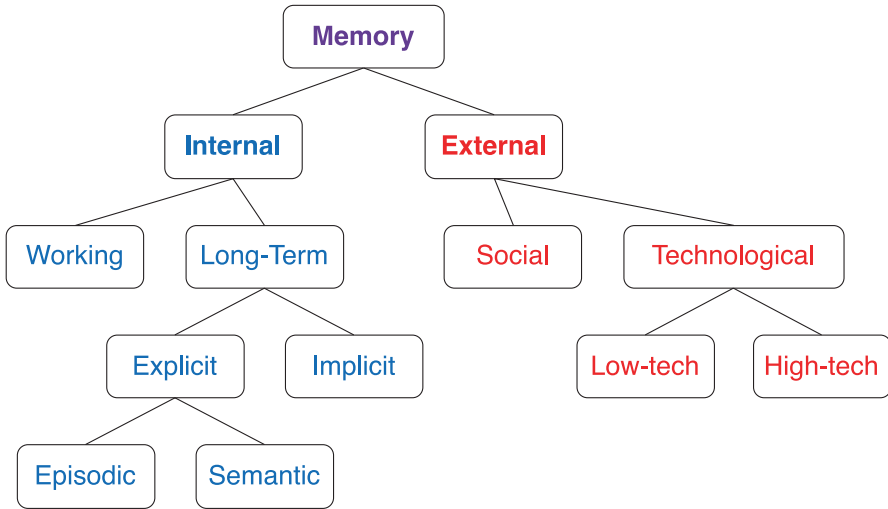


Fig. 1.1 Basic taxonomy of memory, including internal and external

Therefore, in the current study, we developed and conducted a comprehensive survey to explore this interplay. We drew inspiration from several previous studies on external memory aids (Harris, 1980; Intons-Peterson & Fournier, 1986; Schryer & Ross 2013; Memory Compensation Questionnaire, de Frias & Dixon, 2005), studies on failures of internal memory (Everyday Memory Questionnaire, Sunderland, Harris, & Gleave, 1984), and studies on general beliefs about internal memory (Magnussen et al., 2006; Simons & Chabris, 2011, 2012).

Let us make our terminology clear. Internal memory is information stored in an individual’s brain. External memory is information stored outside of an individual’s brain. The terms internal and external are relative to an individual human being, which is the traditional unit of analysis in most of psychology. We distinguish between three forms of external memory: social, low-tech, and high-tech. Social external memory is information stored in other people (cf. transactive memory, Wegner, Giuliano, & Hertel, 1985). Technological external memory, both low-tech and high-tech, is information stored in the inanimate environment. We consider technological external memory as low-tech if it does not require a power source to operate (e.g., paper) and high-tech if it does require a power source to operate (e.g., computer).³ Fig. 1.1 shows a basic taxonomy of memory, including terms commonly

³Other terms for what we are calling internal memory include organic memory or O-memory (Clowes, 2013) and biological memory or bio-memory (Bell, Gemmell, & Gates, 2009). Other terms for what we are calling high-tech external memory include electronic memory or E-memory (Clowes, 2013) and digital memory. Other terms for external memory in general include artificial memory, distributed memory (which includes both internal and external components), material memory, extended memory, outboard memory, external symbolic storage, and exosomatic memory. In computer science, the term “external memory” refers to computer storage such as hard drives, which are external to a computer’s main memory (RAM).

used in theories of internal memory (cf. Schacter & Tulving, 1994; Squire, 2004), and expanded to include our terms for external memory. Note that later in this book, we will also consider procedural memory, which is a type of implicit long-term internal memory, and prospective memory, which does not fit neatly into the taxonomy. Finally, the term offloading, or externalizing, refers to the delegation of some information⁴ or cognitive task to external resources rather than internal ones.

What makes something a *memory* is that it is information from the past that may be recovered in the present. Memory is information transmitted across time. Psychologists are accustomed to the term memory being exclusive to internal memory, generally referring to information in the brain already experienced by the individual. But traditional theoretical conceptions of memory in psychology fall short of fully encompassing common human experience, even with regard to information in the brain. An individual brain indeed contains information from past specific experiences (episodic), learned facts (semantic), and skills (procedural); but it also contains merged representations of repeated events (repisodes; Neisser, 1981) and representations of things that never actually happened (false memories, imagined experiences, and mediated experiences), and it can easily imagine future or counterfactual events (Özbek, Bohn, & Berntsen, 2017). Zacks (2017) proposed that humans use a working memory structure called an *event model* by which we can mentally represent a directly lived experience or a mediated experience (e.g., a movie, book, or oral story). Rubin and Umanath (2015) proposed the theoretical construct of *event memory* as “the mental construction of a scene, real or imagined, for the past or the future.” Our point here is that the definition of memory should not be restricted to information from direct previous experience nor to information stored in an individual brain.

Our conception of memory, as information transmitted across time, allows us to consider both internal and external types of memory. What all does external memory encompass? Any information stored outside of your brain, for example, a note that you write down on paper or a digital photograph that you take would both be external memory (low-tech and high-tech, respectively). Your friend’s recollection of a party you both attended would be social external memory (external relative to you). Monuments, newspapers, documentary movies, recordings of national anthems, and history books form external memories of entire societies (see Chapter 6, collective memory). By our definition, information in an unread science fiction novel on your bookshelf counts as external memory, even though you have not yet read it and even though it depicts experiences that you will likely never have. It is still information from the past that can be recovered in the present. The same holds for web pages, whether you have previously visited them or not. Memory is information transmitted across time, whether stored inside your brain (internal memory) or outside of it (external memory).

By using this broad conception of memory, the current study was more comprehensive than prior work. The study included questions about internal memory,

⁴For a discussion of definitions of *information*, see Case & Given (2016, pp. 55–78). For our purposes, settling on a single precise definition of information is unnecessary.

external memory, and their interaction. It used mixed methods (i.e., both quantitative and qualitative measures). Its purpose was *not* hypothesis testing; its purpose was instead both descriptive (to measure and report variables) and exploratory (to identify new questions worthy of further research). How are people using early twenty-first century technology in their everyday lives to support, enhance, or replace human memory? How does this impact their emotional and social lives? What are their attitudes and beliefs about the interplay between internal and external memory?

Here in Part I of this book, we will describe our method and present our results. In Part II, we will provide a thorough literature review of relevant theoretical frameworks from a variety of disciplines. Finally, in Part III, we will present a framework for understanding the interplay of internal and external memory and for guiding future research.

Method

Participants

Participants were 476 people recruited over the Internet using Amazon's Mechanical Turk (MTurk; Crump, McDonnell, & Gureckis, 2013; DeSoto, 2016; Hitlin, 2016; Paolacci & Chandler, 2014) and paid \$2 each. All participants had completed at least 500 previous HITs (human intelligence tasks) on Mechanical Turk, had at least a 95% approval rate on those HITs, were located in the United States, and reported English as their primary language. Participant age ranged from 18 to 75 years ($M = 34.7$, $SD = 11.2$, $Mdn = 32$) and was non-normally distributed, with skewness of 1.01 ($SE = 0.11$) and kurtosis of 0.49 ($SE = 0.22$). Figure 1.2 shows a histogram of participant age. The positive skew means that we had more participants in young and middle adulthood than older adulthood. Table 1.1 shows further participant demographics, including sex, education level, income, number of fluent languages, student status, and relationship status. For participants who were currently in a relationship, the mean age of that relationship was 8.7 years ($SD = 8.3$, $Mdn = 6$, range: 0–47).

Data were collected from an additional 18 participants but were excluded from analysis for the following reasons: one gave an impossible age (127 years), three reported that English was not their primary language, and fourteen reported that they had had a neurological problem. Ten participants completed the survey twice; only the data from their first completion of the survey are included in analyses.

It is worth noting that our sample is not strictly representative of the population at large. Nonrepresentativeness is a concern with any convenience sample (e.g., the US college undergraduates recruited for many psychology studies or the Mechanical Turk workers recruited for our study). Paolacci and Chandler (2014) reviewed the general characteristics of Mechanical Turk workers as compared to the populations they are drawn from (e.g., US residents) and stated that although they are diverse,

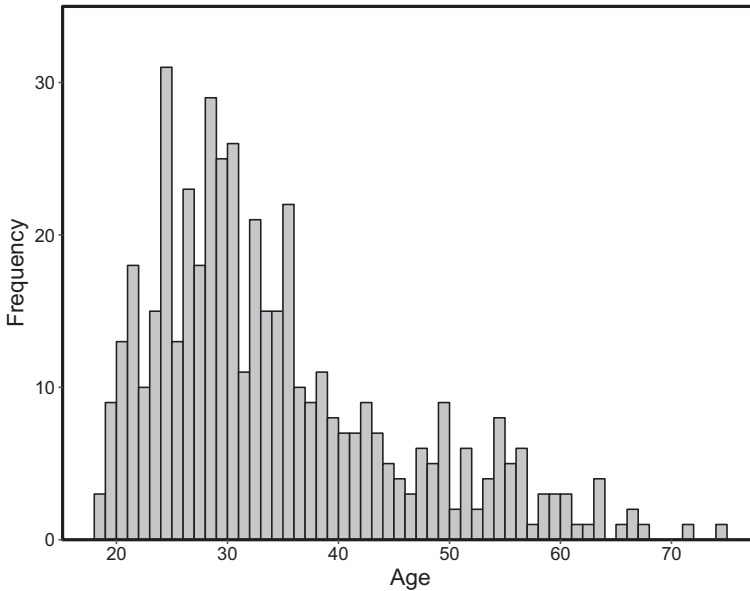


Fig. 1.2 Histogram of participant age

the Mechanical Turk workers “tend to be younger (about 30 years old), overeducated, underemployed, less religious, and more liberal than the general population.” That said, in an earlier paper, Paolacci, Chandler, and Ipeirotis (2010) stated that Mechanical Turk workers were demographically “arguably closer to the U.S. population as a whole than subjects recruited from traditional university subject pools.” Berinsky, Huber, and Lenz (2012) concluded that an “MTurk sample does not perfectly match the demographic and attitudinal characteristics of the U.S. population but does not present a wildly distorted view of the U.S. population either.” Encouragingly, Paolacci et al. (2010) found equivalent results on judgment and decision-making tasks with a Mechanical Turk sample as compared to a college undergraduate sample, as did Berinsky et al. (2012). Importantly for our study, our participants were necessarily technologically savvy enough to use such an Internet-based platform as Mechanical Turk, and they self-selected to participate in a study about memory and technology. Thus, their attitudes and behaviors regarding technology, and perhaps even memory, may differ from the general population. Somewhat encouragingly, Simons and Chabris (2011, 2012) found similar beliefs about memory in a Mechanical Turk sample as compared to a nationally representative phone sample. Nevertheless, when interpreting our results, we should cautiously keep in mind the characteristics of our sample.

Table 1.1 Participant demographics

	Number	Percent
Sex		
Male	257	54
Female	215	45
No response	4	<1
Highest achieved education level		
Some high school	1	<1
High school graduate	62	13
Some college, no degree	136	29
Associate degree	57	12
Bachelor degree	176	37
Graduate degree	44	9
Annual household income		
<\$12,500	36	8
\$12,500–\$24,999	82	17
\$25,000–\$37,499	84	18
\$37,500–\$49,999	78	16
\$50,000–\$62,499	52	11
\$62,500–\$74,999	44	9
\$75,000–\$87,499	32	7
\$87,500–\$99,999	21	4
>\$100,000	46	10
No response	1	<1
Number of languages fluent in		
1	413	87
2	45	9
3+	12	3
Currently a student or taking classes		
Yes	68	14
No	408	86
Currently in a relationship		
Yes	319	67
No	156	33
No response	1	<1

Design and Materials

The design was a mixed methods cross-sectional survey. The survey questionnaire consisted of 136 questions, including both quantitative (closed-ended) and qualitative (open-ended) questions, administered over the Internet using Google Forms. The qualitative questions were included to allow us to discover themes from participants' self-reports of their attitudes and experiences with external memory in their

everyday lives. The complete questionnaire is given in Appendix A. Some questions were adapted from previous studies, as noted in Appendix B. Throughout this book we refer to individual questions by question number (e.g., Q1 for question 1).

Procedure

This study received ethical approval from the Institutional Review Board of Washington University in St. Louis (protocol number 201404016, title MemoryTech). The survey was run from June 12 to July 9, 2015. It was listed on Mechanical Turk under the title “Memory & Technology Survey” with the following description: “Answer questions about how people use technology in their everyday lives to support memory.” Participants were directed from Mechanical Turk to the survey questionnaire on Google Forms, which began with informed consent and then continued to the 136 questions. The questions were exactly as worded in Appendix A, except that response options for closed-ended questions, which are listed in brackets in Appendix A, were implemented as radio buttons or in some cases drop-down menus. Also, Q111 was not added until after the first nine participants. Participants could skip any questions they did not wish to answer. The same fixed order of questions was used for all participants. We used a fixed order to make the questionnaire more coherent for participants, grouping together questions that covered similar topics and/or used similar response scales, and placing the majority of open-ended questions toward the end. It is possible that this order influenced participant responses, though we see no obvious theoretical reasons to suspect such distortion as would invalidate the major conclusions we will make from these data. That said, future shorter versions of the questionnaire could manipulate question order to test for order effects.

Sometimes researchers include “attention check” questions in Mechanical Turk tasks, to catch participants paying insufficient attention and exclude their data from analysis (e.g., Oppenheimer, Meyvis, & Davidenko, 2009). We did not include any such questions. Peer, Vosgerau, and Acquisti (2014) showed that setting a high reputation criterion for participants, as we did in our study, obviates the need for attention checks. Furthermore, using attention checks can aggravate participants and distort data (Vannette, 2017). Participants’ coherent responses to the open-ended questions in our questionnaire satisfied us that they were paying attention. Furthermore, several reverse-worded questions allowed us to check against response sets (e.g., yea-saying or nay-saying). For example, Q37–41 were about memory failures (higher responses meant worse memory), and these all showed appropriately negative correlations with Q12, in which higher responses meant better memory (see Supplemental Materials for correlations). That said, it would be helpful for any future surveys to include a few more reverse-worded or repeated questions.

Participants were given a time window of 8 h to complete the questionnaire after accepting the HIT on MTurk (4 h for the first nine participants). We do not know exactly how long each participant spent specifically on the questionnaire, only the

amount of time that elapsed between when they accepted the HIT and when they submitted their complete survey ($M = 93$ min, $SD = 119$, $Mdn = 37$); it is possible, indeed likely, that many participants did other things during that duration. We estimate that actual completion of the questionnaire likely took 10–45 min for most participants.

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Chapter 2

Results: Attitudes and Beliefs About Internal and External Memory



In the current chapter, after first describing data cleaning and scoring, we will report the descriptive statistics for questions about attitudes and beliefs (internal memory, external memory, and their interplay). In Chapter 3, we will report the descriptive statistics for questions about behaviors and experiences (internal memory and external memory). Finally, in Chapter 4 we will report on the qualitative data on the interplay between internal and external memory, as well as correlational analyses. As we report our results, we will also compare them to relevant other studies.

Data Cleaning and Scoring

First, some notes on statistics as used throughout this book. An alpha level of .05 was used for tests of statistical significance except where Bonferroni corrections are noted. Standard deviations (*SDs*) are reported raw (i.e., calculated using N , not $N - 1$), on the grounds that the *SD* is a descriptive statistic, and the $N - 1$ adjustment should be reserved for use in inferential statistics. Within-subjects comparisons of ordinal variables were conducted using Wilcoxon signed-rank tests, and between-subjects comparisons of ordinal variables were conducted using Mann-Whitney tests. For both tests, effect sizes are reported as $r = Z / \sqrt{N}$. Comparisons of ratio variables were conducted using *t*-tests.

We began data cleaning by identifying 28 records to exclude from analysis (see Participants section in Chapter 1). In addition, one participant listed their age as -67 , which we corrected to 67. All other instances of negative numerical responses were replaced with empty cells. Text responses to numerical questions were converted when unambiguous (e.g., “6 years” converted to 6, “none” converted to 0) and were replaced with empty cells when ambiguous (e.g., “several”).

The questionnaire featured a number of open-ended questions (Qs 98, 112, 114–116, 119–133). The qualitative data from these questions were coded by author FWG, working with author JRF through several iterations to develop categories of

common themes of responses for each question and to resolve coding of ambiguous responses through discussion. Notes on the coding process can be found in Appendix C. We decided that one coder was adequate for the purposes of this initial exploratory study. It would be ideal for future studies to employ multiple coders and establish interrater reliability.

Most questions used ordinal response scales (e.g., strongly disagree to strongly agree). Consecutive integers were assigned to each response option for calculation of correlations and for comparisons (Wilcoxon signed-rank and Mann-Whitney). Spearman’s rho (r_s) was used for correlations, because most questions were ordinal, and also in order to reduce the influence of outliers and skew for the few questions that were ratio and unbounded (e.g., age, number of phone numbers memorized). No transformations were used on those questions, and no outlier data points were removed except in cases of obviously impossible values (e.g., see Footnote regarding Q106 in Chapter 3). Composite variables were created by a procedure we will describe in the Correlations section of Chapter 4.

Although our sample of participants was not representative of the general US population (e.g., participants were likely more technologically savvy, more educated, and younger), we did not perform any weighting adjustments to the data.

Attitudes and Beliefs: Internal Memory

What were participants’ attitudes and beliefs about internal memory? Table 2.1 shows results on general beliefs about memory. A slight majority of participants (56% yes) said they think there is a limit to the amount of information the brain is

Table 2.1 General beliefs about memory: response frequencies

Item		Response options					<i>n</i>
			No		Yes		
15.	Most people are exposed to large amounts of new information each day. Do you think there is a limit to the amount of information the brain is able to store?		43%		56%		473
16.	Physical exercise makes the body stronger. Do you think it is possible to train memory in an analogous fashion?		10%		89%		475
		Strongly disagree	Disagree	Neutral	Agree	Strongly agree	
18.	Once someone has experienced an event and formed a memory of it, that memory does not change.	16%	56%	13%	14%	1%	473
19.	Human memory works like a video camera, accurately recording the events we see and hear so that we can review and inspect them later.	16%	39%	18%	24%	2%	476

able to store (Q15, 43% no; cf. Magnussen et al., 2006: 69% yes, 26% no). A large majority of participants (89% yes) said they think it is possible to train memory analogous to physical exercise making the body stronger (Q16, 10% no; cf. Magnussen et al., 2006: 93% yes, 4% no). A majority of participants (72%) correctly disagreed with the statement that memory does not change (Q18, 14% incorrectly agreed; cf. Simons & Chabris, 2012: 28% incorrectly agreed). A majority of participants (56%) correctly disagreed with the statement that human memory works like a video camera (Q19, 26% incorrectly agreed; cf. Simons & Chabris, 2012: 47% incorrectly agreed).

Table 2.2 shows results on self-evaluations of memory performance. It is important to note that people’s actual memory abilities and performance may not match their self-evaluations (Beaudoin & Desrichard, 2011). According to their responses, many participants thought that their memory was about the same as most people of their own age (42%), while 33% thought their memory was better and 25% thought it was worse. This is somewhat different from the results reported by Magnussen et al. (2006, Sample 2: 70% “as good as”). With regard to changes in memory, participants mostly thought that their memory was either unchanged in the past 5 years (46%) or had gotten somewhat worse (40%), comparable to the results of Magnussen et al. (2006, Fig. 6). Furthermore, they mostly predicted that their memory would either remain unchanged in the next 5 years (45%) or get somewhat worse (38%).

Table 2.2 Self-evaluations of memory: response frequencies

Item		Response options					<i>n</i>
		Much worse	Somewhat worse	[The same as] [Unchanged] ^a	Somewhat better	Much better	
12.	Do you think your memory is worse, the same as, or better than most people of your own age?	3%	21%	42%	28%	6%	476
13.	Do you think your own memory has become better or worse during the last 5 years, or is it unchanged?	2%	40%	46%	11%	1%	474
14.	Do you think your own memory will become better or worse during the next 5 years, or will it be unchanged?	3%	38%	45%	11%	3%	476
		Very bad	Pretty bad	Neither good nor bad	Pretty good	Very good	
17.	How good are you at judging the reliability of your own memory?	1%	9%	30%	55%	5%	475

Note. ^aQuestion 12 used option “the same as” and questions 13–14 used option “unchanged”.

Table 2.3 Cross-tabulation of past and future self-evaluations of memory

	Memory change in the next 5 years				
Memory change in last 5 years	Much worse	Somewhat worse	Unchanged	Somewhat better	Much better
Much worse	1%	1%	0%	0%	0%
Somewhat worse	2%	25%	9%	3%	<1%
Unchanged	<1%	10%	32%	3%	1%
Somewhat better	<1%	2%	3%	5%	1%
Much better	0%	0%	0%	<1%	1%

Note. Last 5 years, Question 13; Next 5 years, Question 14.

Table 2.3 shows a cross-tabulation of questions 13 and 14. Most participants saw their 10-year trend as either stable (32%) or steadily somewhat declining (25%). Almost equal numbers of participants saw their trend as a previous decline that would not continue (9%) or a previous stability that would begin to decline (10%). Age was not correlated with current memory (Q12, $r_s = -.055$, $n = 476$, $p = .228$) but was negatively correlated with changes in past memory (Q13, $r_s = -.267$, $n = 474$, $p < .001$) and predicted changes in memory (Q14, $r_s = -.323$, $n = 476$, $p < .001$). A majority of participants (55%) thought that their metamemory (how well they can judge the reliability of their own memory) was pretty good, while 30% thought it was neither good nor bad (Q17, cf., Magnussen et al., 2006: 59% pretty good, 21% neither good nor bad).

Attitudes and Beliefs: External Memory

What were participants’ attitudes and beliefs about external memory? Table 2.4 shows results. A majority of participants (69%) reported that they are more functional with the help of technology for memory purposes (Q46, 8% less functional); some specific reasons participants gave for increased functionality will be covered in Chapter 4 (Q123). Without the help of technology, 44% of participants reported that they would still be able to function well or very well with just their human memory, while only 22% reported they would function poorly or very poorly (Q47). A slight majority (51%) reported feeling that using technology for memory purposes enhances them as a person (Q44), and a majority (63%) reported that using technology for memory purposes allows them to do things they could not otherwise do (Q45). Only 14% of participants reported feeling uneasy about how much they rely on technology for memory purposes (Q43, 71% disagreed). This is much less than what was found in a 2016 survey of 6,000 European consumers (aged 16 and up) by Kaspersky Lab software security company, which reported 42% of respondents saying “quite concerned” or “very concerned” in response to the question, “How concerned are you about how reliant you are on smartphone technology to store/remember information?” It is worth noting, as discussed in the Participants

Table 2.4 Attitudes about external memory: response frequencies

Item		Response options					<i>n</i>
		Much less functional	Somewhat less functional	Neither less nor more functional	Somewhat more functional	Much more functional	
46.	With the help of technology for memory purposes, are you less functional or more functional?	1%	7%	23%	47%	23%	475
		Very poorly	Poorly	Neither poorly nor well	Well	Very well	
47.	Without the help of technology for memory purposes, how well would you be able to function with just your human memory?	2%	20%	34%	36%	8%	474
48.	How well do you understand the technology you use for memory purposes?	0%	3%	13%	52%	31%	475
		Strongly disagree	Disagree	Neutral	Agree	Strongly agree	
43.	I feel uneasy about how much I rely on technology for memory purposes.	24%	48%	15%	13%	1%	473
44.	I feel that using technology for memory purposes enhances me as a person.	5%	15%	29%	43%	8%	476
45.	Using technology for memory purposes allows me to do things that I could not otherwise do.	4%	12%	21%	51%	12%	475
91.	I consider my external memories to be part of me.	2%	11%	24%	56%	7%	475
92.	My external memories are valuable to me.	1%	4%	13%	63%	18%	473

(continued)

Table 2.4 (continued)

Item		Response options					<i>n</i>
93.	If I lost all my external memories I would feel devastated.	4%	17%	20%	38%	21%	471
94.	If I lost all my external memories I would feel relief or release.	34%	47%	13%	4%	2%	474
95.	If I lost all my external memories I would be inconvenienced.	2%	6%	14%	51%	27%	475

section in Chapter 1, that our sample of participants was likely more technologically savvy, more educated, and younger than the general US population, and so their apparent lack of unease may not be representative.

Cross-tabulation showed that of the 106 participants who said they would do poorly without technology (Q47), 65 said they do not feel uneasy about relying on technology (Q43), while only 23 said they do feel uneasy ($r_s = -.19$, $n = 471$, $p = 2.5 \times 10^{-5}$). Those who were not uneasy (the majority) may feel that way because they do not expect to lose access to external memory and/or because they use external memory as a fail-safe for things that they could use internal memory for if they had to. Those who were uneasy may feel that way because of concern that their internal memory abilities are atrophying. We will return to these issues in Chapter 4. One participant’s response to Q124 summed up a consensus: “Using external memory simply makes your life easier. There is no doubt in my mind that without external memory, I could easily remember all the things that I would need to remember.” *The overall pattern, based on participants’ self-reports, is that most people think external memory helps them function, but they would also do fine without it, and they do not feel uneasy about relying on it. External memory is seen as augmenting human capability, not supplanting it.*

Our results here are consistent with a December 2014 survey by the Pew Research Center (Purcell & Rainie, 2014) which found that a majority of participants said the Internet and cell phones have improved their ability to learn new things (53% “a lot” and 34% “some”). A February 2014 Pew survey (Fox & Rainie, 2014) found that 53% of participants said it would be very hard to give up the Internet (up from 38% in 2006) and 49% said the same of their cell phones (up from 43% in 2006). The discrepancy between that finding and our Q47 is likely due to people relying on these technologies for more than just memory purposes.

Questions 91–95 concern the value that people place in their external memories (which could include both low-tech and high-tech). Interestingly, 63% of participants considered their external memories to be part of them (Q91, only 13% disagreed), and 81% considered their external memories valuable (Q92, only 6% disagreed). If they were to lose all their external memories, 60% agreed they would

feel devastated (Q93), 78% agreed they would feel inconvenienced (Q95; cf. Q124), and only 6% agreed they would feel relief or release (Q94). *Thus, people generally put considerable value in their external memories.*

Finally, a large majority of participants (84%) reported that they understand the technology they use for memory purposes well or very well (Q48), which is important for making effective use of external memory. It is worth noting that these participants, as experienced Mechanical Turk workers, presumably have high technological literacy. Participants expected technology to change significantly over the next 10 years (Q134: 0% not at all, 1% slightly, 18% moderately, 45% very much, and 35% extremely much). They expected human life to change somewhat less so (Q135: 1% not at all, 13% slightly, 38% moderately, 30% very much, and 18% extremely much). This implies that they do not think changing technology will impact their lives much, although their responses to other questions indicate that it has done so up to this point (Q46, 124–125).

Attitudes and Beliefs: Interplay Between Internal and External Memory

Table 2.5 shows results on attitudes about the interplay between internal and external memory. According to their responses, participants mostly believed that human and machine memory are good at different things (Q49, 86% agreed), but only a slight majority (56%) believed that human and machine memory work differently. Nevertheless, 49% believed that human memory is getting worse overall, while only 14% believed it is getting better (Q51). This is in apparent contrast to the attitude that technology mostly helps participants function and that participants are mostly not troubled by reliance on technology. Perhaps even if people believe that human internal memory is getting worse (presumably due to reliance on external memory), they may still believe that we are better off overall with the improvements that external memory provides. Also, people's attitudes about human memory in general may diverge from their attitudes about their own personal situation.

Participants were about evenly split on whether it is more important to remember how to find some piece of information versus to remember the information itself (Q66; cf. Sparrow, Liu, & Wegner, 2011, Experiments 3–4). This is noteworthy: it highlights the common but not universal practice of offloading knowledge to references beyond one's own brain. In a May 2015 survey of 1,000 US consumers (aged 16 and up) by Kaspersky Lab, 61% of respondents agreed with a more specific statement: "I don't need to remember facts that I've found online — but I do need to remember where I found them." External memory offers us a vast and deep extended pool of knowledge, but only if we remember how to access it.

Questions 61–63 concerned the interplay of experience and recording. A large majority of participants (86%) said they felt it is important to be present and aware for meaningful experiences (Q61), and a slight majority (52%) said they felt it is

Table 2.5 Attitudes and beliefs about the interplay between internal and external memory: response frequencies

Item		Response options					<i>n</i>
		Strongly disagree	Disagree	Neutral	Agree	Strongly agree	
49.	Human memory and machine memory (computers) are good at different things.	<1%	4%	10%	60%	27%	472
50.	Human memory and machine memory (computers) work roughly in the same way.	15%	41%	23%	20%	1%	475
61.	It is important to me to be present and aware for meaningful experiences.	<1%	3%	11%	55%	31%	474
62.	It is important to me to make external records of meaningful experiences.	3%	19%	26%	45%	7%	474
63.	The act of recording an experience takes away from the experience.	11%	40%	17%	25%	7%	474
66.	It is more important to remember how to find some piece of information again rather than remembering the information itself.	3%	26%	33%	33%	6%	473
		Much worse	Somewhat worse	Neither worse nor better	Somewhat better	Much better	
51.	Overall, do you think human memory is getting better or worse?	6%	42%	37%	13%	1%	476

important to make external records of meaningful experiences (Q62). Participants were more split on whether the act of recording takes away from the experience (Q63, note the bimodal distribution). There was no significant correlation between Q61 and Q62 ($r_s = .06$, $n = 472$, $p = .211$) nor between Q61 and Q63 ($r_s = -.05$, $n = 472$, $p = .244$); however, there was a significant negative correlation between Q62 and Q63 ($r_s = -.29$, $n = 472$, $p < .001$): the greater the importance participants put on making external records, the less they tended to feel that recording detracts from the experience. Perhaps having an external record of an experience helps validate for some people that the experience actually happened. This could be an example of tension between what Kahneman called the experiencing self and the remembering self (2011, Chapter 35).

Cross-tabulation of questions 61–63 showed that 216 participants (46% of total) said they felt that being mentally present and recording are *both* important; of those 216 participants, 42 (9% of total) also said they felt that recording takes away from the experience, which puts them in a bind. Is it worth creating personally valuable records (e.g., videos, pictures) at the cost of being fully engaged in an experience? Conversely, is it worth fully engaging oneself in an experience at the cost of having any external records to serve as powerful cues in the future? Is full engagement even possible if denying one's desire to record? For many people their sense of self is distributed across internal and external memory (cf. Q91–93, Q74–78; Barnier, 2010; Belk, 2013; Ward, 2013). Thus the trade-off between forging one type of memory or the other presents an existential dilemma. Improvement of automatic recording devices (Silva, Pinho, Macedo, & Moulin, 2018) may alleviate this dilemma in time, and research on less disruptive capturing strategies is ongoing (Mols, Broekhuijsen, van den Hoven, Markopoulos, & Eggen, 2015). But this is certainly a relevant issue for early twenty-first century life, and research continues to develop (Barasch, Diehl, Silverman, & Zauberman, 2017; Diehl, Zauberman, & Barasch, 2016; Henkel, 2014; Henkel, Nash, & Paton, *in press*; Henkel, Parisi, & Weber, 2016; Niforatos, Cinel, Mack, Langheinrich, & Ward, 2017; Soares & Storm, 2018).

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Chapter 3

Results: Behaviors and Experiences with Internal and External Memory



Behaviors and Experiences: Internal Memory

What were participants' behaviors and experiences with internal memory? Question 20 asked participants how often they have involuntary memories (adapted from Berntsen & Rubin, 2002). Response frequencies were as follows: 3% never, 27% several times a year, 34% several times a month, 27% several times a week, and 9% several times a day. For those 9% ($n = 42$), the mean number they estimated per day was 5 ($Mdn = 5$; $SD = 2.7$; $range = 2-15$; $Q21$).

Table 3.1 shows results on failures of internal memory, using questions adapted from Sunderland, Harris, and Gleave (1984; see also Herrmann & Neisser, 1978). Losing things around the house and experiencing a tip-of-the-tongue state were the most common frequently reported failures. Very few participants reported daily experiences of memory failures. However it is worth noting that even in healthy populations, those with worse memory may be less likely to remember memory failures (Sunderland, Harris, & Baddeley, 1983). Also noteworthy is that 61% of participants reported having trouble remembering without external aids at least *sometimes* and only 5% *never* (Q52). Finally, we should keep in mind that, as discussed in the Participants section in Chapter 1, our sample of participants was likely more technologically savvy, more educated, and younger than the general US population.

Behaviors and Experiences: External Memory

What were participants' behaviors and experiences with external memory? We will organize results into sections, beginning with general use.

Table 3.1 Internal memory failures: response frequencies

Item		Response options					<i>n</i>
		Not at all 3 months	1+ per 3 months	1+ per month	1+ per week	1+ per day	
37.	Forgetting where you have put something. Losing things around the house.	10%	34%	27%	23%	5%	476
38.	Completely forgetting to take things with you, or leaving things behind and having to go back for them.	14%	39%	29%	16%	1%	476
39.	Finding that a word is “on the tip of your tongue”. You know what it is but cannot quite find it.	8%	26%	33%	26%	7%	475
40.	Completely forgetting to do things you said you would do and things you planned to do.	28%	37%	22%	10%	3%	476
41.	Forgetting to tell somebody something important. Perhaps forgetting to pass on a message or remind someone of something.	34%	36%	22%	7%	2%	476
		Never	Seldom	Sometimes	Often	Always	
52.	I have trouble remembering things without external aids.	5%	33%	47%	13%	1%	476

Note. Response scale for Q37–41 condensed from nine options to five.

General Use

Table 3.2 shows results on general use of external memory and estimated changes in its use over time. According to participants’ self-reports, the use of high-tech external memory (e.g., computers, phone, Internet) was widespread and frequent, use of low-tech external memory (e.g., writing on paper) was slightly less so, and use of social external memory (i.e., other people) was fairly infrequent. Wilcoxon signed-rank tests showed that reported frequency of external memory use was higher for high-tech than low-tech ($Z = 6.62$; $p < .001$; $r = .30$), higher for high-tech than social ($Z = 13.46$; $p < .001$; $r = .62$), and higher for low-tech than social ($Z = 9.10$; $p < .001$; $r = .42$). Harris, Barnier, Sutton, and Keil (2014) interviewed older couples, who similarly reported less reliance on social support for memory than on external memory aids (presumably low-tech). Henkel and Rajaram (2011) gathered data on self-reported beliefs about collaborative memory in young and older adults. One question asked how frequently participants rely on others to remember information (1 = never, 5 = very often), and the mean ratings were 2.49 for younger adults and 2.42 for older adults. Those results are quite similar to results from our Q24 ($M = 2.53$, $SD = 0.86$) and Q33 ($M = 2.31$, $SD = 1.03$), which used a

Table 3.2 External memory use, changes over time: response frequencies

Item	Response options					<i>n</i>
	Never	Seldom	Sometimes	Often	Always	
22. I use low-tech external memory to help me remember things (e.g., writing on paper).	4%	21%	39%	32%	4%	475
23. I use high-tech external memory to help me remember things (e.g., computers, phones, Internet).	3%	11%	33%	43%	10%	474
24. I use other people to help me remember things.	11%	39%	38%	12%	1%	475
	Much less often	Less often	No difference	More often	Much more often	
25. Do you use low-tech external memory to help you remember things more or less often compared to 5 years ago?	8%	25%	46%	18%	3%	474
26. Do you use high-tech external memory to help you remember things more or less often compared to 5 years ago?	1%	3%	27%	51%	18%	474
27. Do you use other people to help you remember things more or less often compared to 5 years ago?	5%	13%	67%	14%	1%	471
28. In 5 years do you think you will use low-tech external memory to help you remember things more or less often compared to now?	8%	22%	45%	22%	3%	474
29. In 5 years do you think you will use high-tech external memory to help you remember things more or less often compared to now?	1%	3%	31%	54%	12%	471
30. In 5 years do you think you will use other people to help you remember things more or less often compared to now?	4%	13%	61%	20%	2%	476

similar 5-point scale. Henkel and Rajaram (2011) also asked how participants' reliance on others for memory had changed in the past 10 years (1 = much more often, 5 = much less often), and the mean ratings were 3.09 for younger adults and 2.67 for older adults. The results from their young adults are very similar to the results from our Q27, when converted to use the same values for response options ($M = 3.07$, $SD = 0.71$). However, whereas Henkel and Rajaram (2011) found a significant difference between younger and older adults, we found no significant correlation between our Q27 and age (Q1), $r_s = -.02$, $p = .702$, perhaps in part because we asked about a 5-year period instead of a 10-year period.

Table 3.3 Everyday/low-tech external memory strategies: response frequencies

Item	Response options					<i>n</i>
	Never	Seldom	Sometimes	Often	Always	
31. Do you use shopping lists when you go shopping?	8%	18%	26%	24%	24%	475
32. When you are reading a [physical] book, do you use a bookmark to indicate where you stopped reading last time?	4%	10%	16%	24%	45%	475
34. Do you post notes on a board or other prominent place to help you remember things for the future (e.g., meetings or dates)?	14%	25%	32%	20%	8%	472
35. Do you put things (e.g., glasses or keys) in particular places to remember where they are for future purposes?	4%	10%	24%	37%	25%	473
36. Do you put things in obvious places (e.g., in front of the door) in order to remember them when you're going out?	4%	11%	37%	35%	13%	476

A striking majority of participants (69%) reported increased use of high-tech external memory in the past 5 years, and 66% predicted further increases in the next 5 years. Use of low-tech external memory appears to be on the decline, and use of social external memory appears to be mostly stable. In the 2016 Kaspersky Lab survey, 79% of respondents said their reliance on digital devices has increased in the last 5 years for accessing information (e.g., Google), 65% for remembering information such as calendar and diary entries, and 74% for wayfinding. *There is a clear message here: for many, technology plays a large and increasing role in supporting human memory.*

Everyday/Low-Tech Strategies

Table 3.3 shows results on the use of everyday and/or low-tech external memory strategies.¹ Fully 99% of participants reported using one or more of these low-tech strategies at least *sometimes* (89% *often* or *always*). Furthermore, 93% of participants reported putting objects in specific or obvious places to help find them again or serve as reminders at least *sometimes* (70% *often* or *always*). Previous research by Winograd and Soloway (1986) explored why people sometimes forget the locations of objects they put in a special place.

¹Q31 asked about “shopping lists” which we intended to mean lists written on paper (low-tech) but which could also have been interpreted as lists on a device such as a mobile phone (high-tech).

Further insight into how participants use the physical environment to support cognition is found in their responses to an open-ended question (Q133) that asked them to describe an example of using the environment to help them remember. Responses revealed that 71% of participants make use of the environment to help them remember by placing the needed object in prominent places. Common responses included placing items by the door (e.g., “I put everything I need by the door so I can’t miss them”) and keeping certain items in a designated location (e.g., “Keys, wallet, glasses, smartphone always go in the same place”). Additionally, 2% of participants reported that they make use of existing landmarks in the physical environment to help them remember directions to locations (e.g., “I was doing a hike a while back and there was markers all over the trees that were helpful. I also went to a new friend’s house and had to get directions. On the way back I remembered the stores and roads that I turned on, so I could find my way back home”) and where they place their items (e.g., “The layout in my apartment helps me remember where I usually put tools, clothing, and other items”). Another 2% of participants reported that they make use of the environment to remember by associating items in the environment with tasks that they have to complete (e.g., “When I try to remember things while laying in bed, I will throw a pillow on the ground and try to use that as a cue for when I wake up in the morning to remember what I was thinking the night before”). Only 19% of participants reported that they do not use the physical environment to help them remember things. These results highlight the importance and immediacy of the physical environment and its affordances in supporting cognition, even in this technological age (cf. embodied, situated, and/or distributed approaches to understanding cognition, Greeno, 1998; Hutchins, 1995; Norman, 1993; Wilson, 2002).

Specific Forms of External Memory

In several open-ended questions, participants were asked to describe specific memory aids or memory devices that they use to help themselves remember (Q112), forms of external memory they carry with them regularly (Q114), forms of external memory they have around their living spaces (Q115) and work spaces (Q116), and tools to remind them of events or appointments in their everyday life (Q128). Table 3.4 shows the most frequently mentioned forms of external memory across these questions. For Q112, 54% mentioned at least two different forms of external memory. Two additional forms that were mentioned fairly frequently but could not be fit into the table were alarms (including alarm clock devices and software alarms/alerts/notifications/reminders on phone or computer; Q112, 8%; Q128, 17%) and apps (software programs on phone or computer; Q128, 19%). In Q128, there were at least 15 different apps mentioned (e.g., Google Calendar, Microsoft Outlook, My Effectiveness, Mint, Cozi), and in Q112 in the digital notes category alone, there were at least 18 different apps mentioned (e.g., Evernote, Multilist, Wunderlist, Trello, Moleskine, Google Keep, Microsoft Word). The use of phone apps in particular merits further research.

Table 3.4 Specific forms of external memory: percentage of participants who mentioned

Item		Form of external memory used							
		Phone	Computer	Tablet	Camera	Physical notes	Digital notes	Physical calendar	Digital calendar
112.	Please describe any specific memory aids or memory devices that you use to help yourself remember.	37%	25%	4%	6%	44%	38%	5%	11%
114.	What forms of external memory do you carry with you regularly?	85%	17%	9%	1%	41%	—	7%	—
115.	What forms of external memory do you have around your living space?	64%	78%	27%	5%	68%	1	17%	—
116.	What forms of external memory do you have around your working space?	56%	73%	11%	2%	62%	2	13%	—
128.	Do you rely on some form of tool to remind you of events/appointments in your everyday life?	39%	8%	1%	—	16%	—	21%	34%

Note. $N = 476$. These questions were open-ended. Phone category includes both smartphones and non-smartphones. Computer category includes both laptop and desktop computers. Physical notes category includes physical notes (e.g., pen and paper, sticky notes), notebooks, whiteboards, and other physical references. Apps were 19% Q128. Alarms were 8% Q112, 17% Q128.

Less frequently mentioned forms of external memory included other people (Q112, 1.5%; Q115, 0.8%; Q116, 0.4%; Q128, 0.8%), video or audio recording (Q112, 2.5%; Q115, 0.4%; Q116, 0.6%), external hard drive (Q112, 2%; Q114, 0.8%; Q115, 7%), USB flash drive (Q114, 2%; Q115, 5%; Q116, 4%), social media (Q112, 2%; Q128, 1%), cloud storage (e.g., Dropbox, Google Drive;

Q112, 1%), miscellaneous Internet (e.g., browser bookmarks, Google, online banking; Q112, 3%), texting (Q112, 1.5%), email (Q112, 6.5%; Q128, 1%), digital assistant (e.g., GPS, Siri, Google Now, Amazon Echo; Q112, 0.8%; Q115, 0.2%; Q116, 0.8%), e-reader (e.g., Kindle; Q114, 0.6%; Q115, 0.8%; Q116, 0.4%), wearable technology (e.g., Apple watch, smart watch; Q114, 0.4%; Q116, 0.2%; Q128, 0.2%), DVR (Q115, 0.6%), and CD (Q115, 2%; Q116, 0.4%). Although they are not forms of external memory, we note that in response to Q112, participants also mentioned internal memory strategies such as various mnemonics (14%) and rote rehearsal (13%).

It is important to remember that these were responses to open-ended questions, and thus the percentages only reflect the number of participants who thought to mention each form of external memory. Closed-ended questions that listed the forms of external memory identified here would almost certainly yield higher percentages.

In the 2016 Kaspersky Lab survey, respondents were asked where they typically stored information they needed to remember and were asked to check all that applied from a list of options. The percentage who checked each option were 53% notes function on phone, 51% paper or notebook, 33% paper calendar, 32% online calendar, 30% email or text to self, 21% internal memory, and 12% voice memo on phone. For earlier frequency ratings on a variety of memory aids (both internal and external), see also Harris (1980), Intons-Peterson and Fournier (1986), and Walker and Andrews (2001). Each of those studies found more frequent self-reported everyday use of external memory aids than internal memory strategies.

Taking Notes

Table 3.5 shows results on note-taking. A majority of participants reported taking notes at least sometimes (74% for paper, 79% for computer). The difference in frequency of taking notes on paper versus computer did not reach statistical

Table 3.5 Note-taking: response frequencies

Item		Response options					n
		Never	Seldom	Sometimes	Often	Always	
54.	I take notes, on paper.	4%	22%	40%	29%	5%	475
55.	I take notes, on a computer or other electronic device.	4%	17%	37%	35%	6%	472
58.	I write on my hand.	63%	23%	10%	3%	1%	475
		Strongly disagree	Disagree	Neutral	Agree	Strongly agree	
56.	When I take notes, I take a lot of notes.	8%	40%	24%	24%	5%	475
57.	Taking notes improves my memory.	2%	7%	20%	59%	11%	473

significance, $Z = 1.895$, $p = .058$, $r = .09$. A majority reported believing that taking notes improves their memory (Q57, 71% agreed), a belief that is generally supported by research (Friedman, 2014; Kiewra, 1989; Kobayashi, 2005). Only 37% of participants reported ever writing on their hands (Q58), which is perhaps the most immediate form of external memory available to humans. Harris (1980) found that writing on one’s hand was reported by 53% of his sample of college students (mean age 21) and 37% of his sample of women from the Cambridge, UK community (mean age 46). Consistent with Harris’s findings, in our study, writing on one’s hand was negatively correlated with age, $r_s = -.20$, and positively correlated with being a student, $r_s = .18$. Future research should look into this practice as a form of temporary external memory and also explore the possible influences of skin tone and daily work activities on the feasibility of this practice.

External Memory Retrieval Failures

Table 3.6 shows results on difficulty using external memory, specifically regarding failure to find information that participants know is stored externally. Such external memory retrieval failures appear to be widespread but infrequent. Only 10% of participants reported this problem happening on a weekly or daily basis (Q42), but only 17% reported never having such a problem (Q53).

Further insight into how participants have had difficulty using external memory is found in their responses to an open-ended question (Q131) that asked them to describe an instance when external memory had failed them on something important. Forty-nine percent of participants reported that external memory has never failed them. The remaining responses were split between external memory device errors and human errors in using external memory. With regard to device errors, 18% of participants reported outright device failure (e.g., “There are times when a hard drive fails and I am no longer able to recover important data that is stored on that

Table 3.6 External memory retrieval failure: response frequencies

Item		Response options					n
		Not at all 3 months	1+ per 3 months	1+ per month	1+ per week	1+ per day	
42.	Knowing that you have some piece of information stored in external memory somewhere but being unable to find it.	36%	32%	22%	8%	2%	475
		Never	Seldom	Sometimes	Often	Always	
53.	I have trouble finding information that I have stored externally (e.g., on paper or in your computer).	17%	47%	28%	6%	2%	476

Note. Response scale for Q42 condensed from nine options to five for reporting.

drive”), and 5% reported that external memory had failed them when their devices ran out of battery or when there was a power failure (e.g., “If my battery dies or we have a power failure, then I can’t get to my contacts and I’m unable to call anyone back because I certainly can’t remember everyone’s phone numbers anymore”).

On the other hand, participant responses also indicated failures of external memory caused by human error. Thirteen percent of participants reported that external memory failed them because they had either lost the record (e.g., “Once, I wrote everything down I needed for a meeting in a memo pad, but I lost the pad”) or accidentally deleted the stored information (e.g., “I accidentally deleted the info on my computer and couldn’t get it back”). Other human causes of external memory failure included erroneous recording of information by the participant (9%; e.g., “My external memory failed me because of human error. I entered the wrong time”), illegible writing (e.g., “I have occasionally been unable to read or understand my own notes written on paper.”), accidentally breaking the device (2%; e.g., “I accidentally dropped my external hard drive, and I was not able to recover photos from an entire year”), and forgetting to check their external memory (2%; e.g., “There have been times when I have put things in the calendar on my phone that were important but then forgot to look at the calendar and so I didn’t remember the event”). One participant summed up several types of human errors:

External memory is only as good as what has been input. If I delete an important email, or accidentally erase a note to myself then that’s a failure. If I write something down, and can’t find the piece of paper, then that’s a failure. One thing I fail at repeatedly is that I write down a phone number on a post it note, and then can’t remember who’s phone number is it, or why it’s important.

These errors highlight the importance of human cognition in the effective use of external memory, a topic we will return to in Chapter 4 in the section on Symbiosis of Internal and External Memory. In Chapter 4 we will also discuss a composite variable about external memory retrieval failures. Other research has shown that retrieval of digital photos from one’s personal collection can be fraught with failure (Whittaker, Bergman, & Clough, 2010), in part due to inadequate organization (Hartman, 2014; Whittaker, 2011). We will consider the problem of organization more in Chapter 6 in the section on Personal Information Management.

Information Use and Management

Table 3.7 shows results on information use and management. Eighty-six percent of participants reported that they look something up instead of trying to remember it at least *sometimes* (Q65). Ninety-one percent reported that they can remember how or where to find information in external memory if they cannot remember the information themselves at least *sometimes* (Q67). These results are consistent with the 2015 Kaspersky Lab survey, which found 91% agreement with “I use the Internet as an online extension of my brain,” and 44% agreement with “my smartphone is my

Table 3.7 Information use and management: response frequencies

Item		Response options					<i>n</i>
		Strongly disagree	Disagree	Neutral	Agree	Strongly agree	
59.	I keep information on my computer well-organized.	2%	14%	17%	50%	17%	475
60.	I rely on search functions to find information on my computer.	9%	24%	19%	39%	10%	476
		Never	Seldom	Sometimes	Often	Always	
65.	How often do you look something up instead of trying to remember it?	2%	12%	52%	31%	3%	475
67.	If I can't remember something, I can remember how/where to find that same information in external memory.	1%	8%	27%	51%	13%	475
68.	I use external memory to store and retrieve personal experiences.	7%	24%	45%	22%	3%	475
69.	I use external memory to store and retrieve factual knowledge.	3%	9%	35%	44%	9%	471

memory—almost everything I need to recall or know is on it.” That survey also asked respondents a forced choice question: “If you want to find the answer to a question, what is the first thing you would do?” Fifty percent chose “search online” and 39% chose “try to remember.” See also Poundstone (2016) for a relevant exploration of knowledge and ignorance in the Internet age. Overall these results demonstrate the extension of human knowledge into the environment.

What kinds of information did participants use external memory for? A majority of participants reported using external memory at least *sometimes* for personal experiences (70%, Q68) and for factual knowledge (88%, Q69), with factual knowledge being significantly more frequent than personal experience as shown by a Wilcoxon signed-rank test, $Z = 10.34$, $p < .001$, $r = .48$. *We propose a distinction between episodic external memory and semantic external memory, in parallel to the episodic/semantic distinction made in theories of internal memory* (Schacter & Tulving, 1982; Tulving, 1972). We will further address this distinction in Chapters 4 and 8.

The types of technology that participants reported owning (Q113) were as follows: 86% smartphone (e.g., iPhone, Android, Windows phone), 17% regular cellular/mobile phone, 80% laptop computer, 61% desktop computer, and 49% tablet computer. Ninety-six percent said they owned at least two of these five options (e.g., a smartphone and a laptop). This, along with responses to Q112, illustrates the potential for information fragmentation (see Chapter 6 Personal Information Management). Combining laptop and desktop computers, 98% said they owned a

computer. Our data are largely similar to those gathered in a 2015 survey of US adults by the Pew Research Center (Anderson, 2015), which found that 92% owned a cellular/mobile phone (including smartphones), 68% owned a smartphone specifically, 73% owned a computer (including desktop and laptop), and 45% owned a tablet computer. Their data showed that tablet and smartphone ownership have been on the rise since 2011, while laptop/desktop computer ownership has been stable. Compared to the Pew study, our sample had higher computer ownership (98% vs. 73%) and higher smartphone ownership (86% vs. 68%). The 2015 Kaspersky Lab survey found that 81% of respondents owned a smartphone, 84% owned a laptop, and 66% owned a tablet.

The self-reported estimates of daily communication (Q79–82) were as follows: emails received per day ($M = 28$, $Mdn = 15$, $SD = 57$, $range = 0–1,000$), emails sent per day ($M = 5$, $Mdn = 2$, $SD = 10$, $range = 0–150$), texts received per day ($M = 29$, $Mdn = 10$, $SD = 63$, $range = 0–600$), and texts sent per day ($M = 24$, $Mdn = 6.5$, $SD = 51$, $range = 0–500$).

Emotions and Cues

Table 3.8 shows results on emotional responses and internal memory responses to external memory cues. A majority of participants said they had experienced powerful emotional responses from looking at external memories from their past (69% for pictures, 65% for videos, and 55% for text). Studies of domestic photography have shown that pictures can evoke intense emotions (Rose, 2004). Our participants' responses indicated that external memories are effective cues for invoking internal remembering, both for things that they wanted to remember (92% at least *sometimes*, Q77) and to a lesser extent things they did not want to remember (60% at least *sometimes*, Q78). That difference ($Z = 14.45$, $p < .001$, $r = .66$) may be due to a tendency to create, keep, and review fewer external memories for negative than positive experiences (cf. Konrad, Isaacs, & Whittaker, 2016). For example, the contents of family photo albums tend to underrepresent negative experiences (Frohlich, 2004, p. 39; Hirsch, 1981, p. 32) and serve to communicate family unity and happiness (Boerdam & Martinius, 1980; Cronin, 1998; Spence & Holland, 1991; Williams, 1997).

Regardless, the effectiveness of pictures and videos at cueing internal memory (Q74, Q75) is consistent with both anecdotal and experimental data on people's responses to pictures from wearable cameras, which can trigger rich multisensory experiences of recollection (Bell & Gemmell, 2009, p. 57; Finley & Brewer, 2018; Finley, Brewer, & Benjamin, 2011; Hodges, Berry, & Wood, 2011; Silva, Pinho, Macedo, & Moulin, 2016). Even text can be a powerful memory cue (Q76), as in the case of annual reminder tools like Timehop (Thompson, 2013, p. 38) or simply browsing old emails (Marshall, 2007, p. 71). Proust stated that "the greater part of our memory exists outside us" in the form of cues that can revive the otherwise irrecoverable past (1919/2015, p. 240).

Table 3.8 Emotions and cues: response frequencies

Item	Response options						<i>n</i>
		Strongly disagree	Disagree	Neutral	Agree	Strongly agree	
74.	I have experienced powerful emotional responses from looking at <i>PICTURES</i> from my past.	2%	12%	16%	52%	17%	471
75.	I have experienced powerful emotional responses from looking at <i>VIDEO</i> from my past.	4%	16%	15%	45%	20%	472
76.	I have experienced powerful emotional responses from looking at <i>TEXT</i> from my past.	5%	22%	18%	44%	10%	471
		Never	Seldom	Sometimes	Often	Always	
77.	External memory has caused me to remember things that <i>I DID</i> want to remember.	1%	7%	31%	51%	10%	474
78.	External memory has caused me to remember things that <i>I DID NOT</i> want to remember.	8%	32%	44%	15%	1%	476

Passwords

Participants' estimates of the number of different passwords they had (Q101) were as follows: $M = 17$; $Mdn = 7$; $Mode = 5$; $SD = 43$; $range = 0\text{--}500$, with skewness of 7.85 ($SE = 0.11$) and kurtosis of 75.27 ($SE = 0.22$). Furthermore, 46% of participants reported that they keep their passwords written down or saved someplace (Q102), with a remarkable 54% apparently keeping their passwords stored only in internal memory. People who kept an external record of their passwords tended to have more different passwords ($M = 24.7$, $Mdn = 10.0$, $SD = 51.2$) than people who did not keep an external record of their passwords ($M = 10.5$, $Mdn = 5.0$, $SD = 33.2$), $t(469) = 3.49$, $p = .001$, $d = 0.33$.

The reported frequencies of forgetting a password and having to recover it over email (Q103) were as follows: 20% never, 67% several times a year, 13% several times a month, and <1% several times a week or day. Thus this appears to be a widespread but infrequent experience in this population. People who kept an external record of their passwords tended to experience password forgetting/recovery at a higher frequency than people who did not keep an external record of their passwords, as shown by a Mann-Whitney test: $U = 22450.5$, $z = 4.328$, $p < .001$, $r = .20$. The correlation between frequency of forgetting (coded as 0–4) and number of passwords was $r_s = .155$, $n = 474$, $p = .001$. Table 3.9 shows the mean number of passwords as a function of record keeping and forgetting frequency.

Table 3.9 Mean (and standard deviation) number of passwords as a function of record keeping and forgetting frequency

	About how often do you forget a password and have to recover it over email?		
Do you keep your passwords written down or saved someplace?	Never	Several times a year	Several times a month
Yes	17 (22) <i>n</i> = 26	28 (59) <i>n</i> = 155	17 (23) <i>n</i> = 35
No	9 (17) <i>n</i> = 70	11 (40) <i>n</i> = 158	10 (11) <i>n</i> = 24

Table 3.10 Phone number statistics

Item		<i>M</i>	<i>Mdn</i>	<i>SD</i>	<i>Range</i>	<i>n</i>
104.	Approximately how many phone numbers do you currently have memorized (not including your own)?	5.9	4	7.0	0–70	473
105.	Approximately how many phone numbers do you currently have stored (in a phone, computer, address book, on paper, etc.)?	81.2	40	146.4	0–2,000	474
106.	For approximately how many years have you had a cellular/mobile phone?	10.5	10	4.9	0–31	473
107.	What percentage of your FAMILYS’/RELATIVES’ phone numbers do you have memorized?	24.9	9	31.3	0–100	473
108.	What percentage of your FRIENDS’ phone numbers do you have memorized?	12.8	1	23.8	0–100	473
109.	What percentage of your BUSINESS/WORK CONTACTS’ phone numbers do you have memorized?	6.5	0	16.1	0–100	474

Phone Numbers

Tables 3.10 and 3.11 show results on internal and external storage of phone numbers.² On average, participants reported about 6 phone numbers committed to internal memory (not including their own phone number) and about 81 stored in external memory: $t(472) = 11.28$; $p < .001$; $d = 0.73$. Notably, 8.5% of participants ($n = 40$) reported zero phone numbers memorized. Fully 96% of participants reported more phone numbers stored in external memory than internal memory. Of those participants, the mean ratio of their memorized numbers to their externally stored numbers was a mere 0.14 ($Mdn = 0.10$; $SD = 0.14$; $range = 0–0.80$). That is, they only had 14% of their total phone numbers memorized (assuming the numbers they had memorized were also stored externally). Which phone numbers are more likely to be memorized? Family, followed by friends, followed by business (Table 3.10). These results are mostly consistent with the 2015 Kaspersky Lab survey in which

²Q106: Two participants claimed to have had a cellular/mobile phone for an impossible number of years (greater than their age and earlier than mobile phones were widely available, which was the early 1980s). Their data were excluded from analyses for just the questions in this section.

Table 3.11 Phone number changes in memorization: response frequencies

Item		Response options					<i>n</i>
		Many fewer	Fewer	The same	More	Many more	
110.	How many phone numbers do you have memorized now as compared to 5 years ago?	28%	32%	30%	10%	0%	473
111.	How many phone numbers do you think you will have memorized in 5 years as compared to now?	21%	23%	44%	11%	1%	464

70% of respondents said they could remember the phone number of their partner/spouse, 68% for parents, 43% for friends, and 45% for workplace. In a 2012 survey of 2,000 UK adult smartphone users by BullGuard software security company, respondents reported an average of 50 phone numbers stored on their phones and an average of only 2 memorized. Although 40% of the BullGuard respondents said that they memorize important numbers for emergencies, only 17% had their spouse’s phone number memorized (more had their mother’s phone number memorized).

How is memory for phone numbers changing? A majority of participants (59%) reported that they had *fewer* or *many fewer* phone numbers memorized compared to 5 years prior, while 30% reported *the same*, and only 10% reported that they had *more* memorized. In the 2012 BullGuard survey, 60% responded that there is no need to mentally store phone numbers anymore, and approximately 67% said they still could remember old phone numbers from years ago that are no longer in use. Clearly people are memorizing fewer phone numbers than they did in the past. However it is hard to gauge the extent of the decline. It is possible that the 5-year timeframe of our question 110 was too short to capture the extent of the decline in memorization that has occurred along with the widespread adoption of mobile phones. Eighty-two percent of participants reported having had mobile phones for longer than 5 years. Most of the decline may have already happened before the year 2010. In a report from the Pew Research Center (Anderson, 2015), over 80% of US adults owned cellphones by 2010 (increasing to 92% by 2015, with 68% ownership of smartphones). It is also regrettable that we have to rely on post hoc self-reported estimates of phone number memorization. Although the decline in memorization of phone numbers is an obvious and widespread phenomenon, we are not aware of any empirical data on this subject from before 2012, though some data may conceivably have been collected by phone companies or government organizations (cf. grey literature, deep web). If so, we hope they come to light.

As for future predictions, 44% of participants predicted they would have *fewer* or *many fewer* phone numbers memorized in 5 years, 44% predicted the number would stay about *the same*, and only 12% predicted they would have *more* or *many more* memorized.

Phone numbers are one area where external memory is clearly supplanting internal memory. People are becoming increasingly reliant on external memory

(primarily the phone devices themselves) to store and retrieve phone numbers. Participants expressed this in some of their open-ended responses. Fifteen percent specifically talked about having memorized fewer phone numbers, in response to questions 124–125. For example, in response to question 124, one participant wrote: “I used to pride myself on being able to remember phone numbers. Now, it doesn’t matter and I don’t bother to remember them because they’re in my phone and I’ll say my phone will remember for me.” Another wrote: “I used to know dozens of phone numbers before I had a cell phone and had to dial everything manually. Now I remember very few phone numbers because there’s almost no immediate need to do so.” In response to question 125, one participant wrote: “Before them (cell phones), everyone knew everyone else’s home phone number by memory. Now, hardly anyone knows each other’s numbers...” This shift in memory use is quite sensible as phone numbers are arbitrary information without inherent meaning and they must be stored and retrieved exactly without any error in order to work properly. This is the kind of information that external memory (high-tech in particular) is extremely well suited for, whereas internal memory is not.

Table 3.12 shows Spearman correlations among the questions related to phone numbers, including age. Age is significantly correlated with number of years having had a mobile phone and percent of business phone numbers memorized. Age was not significantly correlated with changes in number of phone numbers memorized (Q110, Q111). One interesting question is whether people who have had a mobile phone for a greater *proportion* of their lives tend to rely to a lesser extent on internal versus external memory for phone numbers. We answered this question by calculating the Spearman correlation between (a) number of years with phone divided by age and (b) number of phone numbers memorized divided by number stored in external memory. That correlation was $-.133$, $n = 466$, $p = .00409$, suggesting a small trend such that those who have spent more of their lives with mobile phones tend keep fewer of their phone numbers memorized versus stored externally.

Table 3.12 Phone number correlations

Item		1.	104.	105.	106.	107.	108.	109.	110.	111.
1.	Age	–								
104.	Numbers memorized	.09	–							
105.	Numbers in external memory	.02	.33	–						
106.	Years with mobile phone	.30	.24	.35	–					
107.	Percent family numbers memorized	.00	.62	.13	.12	–				
108.	Percent friend numbers memorized	.04	.63	.11	.07	.57	–			
109.	Percent business numbers memorized	.16	.51	.14	.16	.45	.56	–		
110.	Numbers memorized vs. 5 years ago	–.10	.26	–.11	–.05	.24	.29	.22	–	
111.	Numbers memorized 5 years from now	–.09	.12	–.13	–.08	.11	.15	.10	.59	–

Note. Spearman’s rho correlations. *N* per cell ranged from 463 to 474. Correlations of absolute size $\geq .15$ are significant at $p < .00139$ (family-wise Bonferroni-adjusted alpha level of $.05/36$).

Table 3.13 Backup practices: response frequencies

Item		Response options					<i>n</i>
		Never	Yearly	Monthly	Weekly	Daily	
96.	About how often do you backup all the data on your computer?	24%	29%	30%	11%	6%	474
		Never	Last year	Last month	Last week	Yesterday	
97.	When was the last time you backed up all the data on your computer?	24%	25%	27%	17%	8%	475

Backup

Table 3.13 shows results on backup practices. Almost one quarter (24%) of participants reported that they never back up all the data on their computer (Q96–97). When asked in an open-ended question (Q98) to describe their backup practices, only 16% said that they do not back up (or gave a response such as “0” or “n/a”). The discrepancy is likely because many people back up only some files, not all of their data (Marshall, 2008a, 2008b; Marshall, Bly, & Brun-Cottan, 2006). In fact, 29% mentioned treating certain files differently or only backing up some files (e.g., photos, important files). With regard to what methods they do use, 48% said that they use physical external hard drives, 35% said cloud (Internet), and 11% said USB flash drives; these three categories were not mutually exclusive, with 18% listing more than one of them. Note that many “cloud” (i.e., Internet) services are likely only backing up certain files and most USB flash drives can likely only fit a subset of all personal data. The variety and incompleteness of backup strategies we found are comparable to earlier work by Marshall (2008a, 2008b), who conducted a series of field interviews with experienced computer users in the mid-2000s, and found a general theme of people using a multifaceted but haphazard patchwork of strategies for backing up, which left copies of files distributed across multiple stores and made recovery challenging.

Backup behavior has been slowly increasing in recent years, according to reports from Internet backup company Backblaze (backblaze.com), which has gathered and published survey data for Backup Awareness Month since 2008 (Klein, 2016). From 2008 to 2016, the percentage of their survey respondents who said they never back up all the data on their computer fell from 38% to 24%, while the percentage who said they back up monthly rose from 13% to 17% and the percentage who said yearly rose from 19% to 25%. Note that response frequencies for our question 96 (Table 3.13) are quite comparable to the 2015 data from Backblaze (never, 25%; yearly, 39%; monthly, 19%; weekly, 9%; daily, 8%), with more of our participants reporting monthly backups.

Did people who value their external memories back up their computers more frequently? No. The Spearman correlation between Q93 (feeling devastated upon loss of external memory) and Q96 (backup frequency) was $-.004, p = .927$. Attitudes

apparently did not influence behavior. Marshall (2008a, 2008b) reported people's attitudes were a mix of concern about the vulnerability of digital external memories and fatalism about the long-term reliability of technology and their ability to keep up with changes.

With regard to restoring from backups, 61% of participants reported that they have attempted to restore files from a backup at least once (Q99). For those participants, the mean reported success rate (Q100/Q99) was 95% ($SD = 15\%$, $range = 0\text{--}100\%$), which is impressive and promising.

Social Media and Social Use of Memory

In order to investigate the interplay between memory and our social environment (both online and offline), we asked participants to report their social media use. The majority of participants reported using Facebook (Q86, 85%); the mean self-reported number of Facebook friends was 206 ($SD = 300$, $Mdn = 120$, $range = 0\text{--}3,897$). Approximately 69% of the participants reported spending less than 6 h on Facebook per week, while 18% reported 7–14 h spent on Facebook per week (<1 h/week, 22%; 1–2 h/week, 21%; 3–6 h/week, 26%; 7–14 h/week, 12%; 14+ h/week, 6%; N/A, 12%). Other forms of social media that participants reported using (Q85) were as follows: YouTube, 81%; Instagram, 31%; Pinterest, 28%; Google Plus, 22%; Spotify, 18%; Snapchat, 16%; Tumblr, 12%; Twitter, 7%; and Reddit as a write-in, 3%.

Table 3.14 shows results on social activity and memory. A finding of particular interest is the positive correlation between online and offline social activity, ($r_s = .235$, $n = 473$, $p < .001$): those who reported engaging in more social interaction online (virtual) also reported engaging in more social interaction offline (in-person). An interesting question is the relative role of online versus offline interactions (cf. Mesch & Talmud, 2007). For memory purposes, we can say that participants reported that social media helps them remember experiences that they otherwise would not have (Q89, 54% agree or strongly agree); and a majority of participants agreed that technology enables collaborative remembering (Q90, 69% agree or strongly agree). In response to a later open-ended question (Q125), one participant said: “The technology makes it more convenient and also easier to share things with others, than human memory does.” These results are consistent with a December 2014 Pew survey (Purcell & Rainie, 2014) in which a majority of participants said that the Internet and cell phones have improved their ability to share their ideas and creations with others (38% “a lot” and 34% “some”), numbers that have increased from a 2006 Pew survey. For a thoughtful look at the issues of ownership and persistent value of Facebook content, see Marshall and Shipman (2015).

The reported frequency of using the help of others to remember specific upcoming events (Q33) was lower than the reported frequency of using the help of others for memory more generally (Q24, Table 3.2), $Z = 4.595$, $p < .001$, $r = .21$. This is likely because people make effective use of low-tech or high-tech calendars, or

Table 3.14 Social activity and memory: response frequencies

Item		Response options					<i>n</i>
		Very low	Low	Neither low nor high	High	Very high	
83.	Please rate your overall level of online social activity.	11%	22%	28%	27%	12%	473
84.	Please rate your overall level of offline social activity.	11%	29%	37%	21%	3%	476
		Strongly disagree	Disagree	Neutral	Agree	Strongly agree	
89.	Social media has helped me remember experiences that I would not have otherwise.	8%	19%	19%	46%	7%	475
90.	Technology helps me COLLABORATIVELY remember experiences with friends/family.	4%	8%	19%	58%	11%	474
		Never	Seldom	Sometimes	Often	Always	
33.	When you want to remember an event such as a birthday, do you ask somebody else (e.g., partner or friend) to help you remember?	25%	35%	26%	12%	2%	475
64.	I have used external memory to settle a disagreement.	11%	27%	45%	16%	2%	475

other tools such as Facebook to remember birthdays and other events. In an open-ended question (Q129), participants were asked if they find people in their life helpful in reminding them about important dates/events. Only 38% said yes, while 53% said no. Some responses highlighted the collaborative social nature of memory, especially in close relationships. For example, one participant spoke of her husband of 30 years: “We have so much history together that we’ll remind the other of something that happened.” This interplay of knowledge between people illustrates how couples form socially distributed memory systems (Harris et al., 2014) or what Wegner termed transactive memory (Wegner, Giuliano, & Hertel, 1985).

Eighty-nine percent of participants said they have used external memory to settle a disagreement with someone (Q64). In the early twenty-first century, it is now commonplace to get out a phone to check the Internet for some fact instead of just arguing about it endlessly. Participants were asked in an open-ended question (Q132) if they had ever used external memory to settle a disagreement and to describe such an episode if they had done so. While 24% of participants said that they have never done so, 61% said that they have used external memory to check facts such as dates of historical events (e.g., “when the civil war started”), dates of personal events (e.g., the date of a concert both people had attended), directions to locations (e.g., “One time a friend argued with me about directions so I looked it up on a map”), movie information (e.g., “My husband will see an actor on TV and say

‘That’s so and so’ and I’ll disagree. We’ll use IMDb to determine who is right”), and general trivia (e.g., “I have used Google countless times to dispute a trivia question with persons I am with”). Additionally, a few participants mentioned that they have used external memory for fact-checking purposes when they doubt another person’s accuracy (e.g., “My husband is somewhat of a know-it-all and likes to spit out facts. One day, something that he was saying just didn’t sit right with me, so I looked it up and showed him that he was mistaken. He wasn’t too pleased with me for that”) and when they want to gather more information on the subject being disagreed upon (e.g., “I had a disagreement with someone on a message board and responded by doing research about MTurk”). Forty-nine percent of participants said they have made use of the Internet to search for the information that they needed to settle their disagreement. One participant summarized: “The internet is a great tool for solving meaningless barstool arguments.”

In addition to providing factual (semantic) information, external memory can also provide direct evidence of previous experiences (episodic), which can be useful during disagreements. For instance, some participants said that they have used photos (e.g., “I used a photo of an open drawer to remind someone they used to leave drawers open all the time”), videos (e.g., “There are times where me and my sister will be arguing about something one another said and we (will) go online to a video we recorded to prove who was right”), and text (e.g., “Sometimes my husband and I will fight and he’ll say something like, ‘well you sent this rude text message’ or something and I will be able to research it in our phones and show him that, no, I did not”). Finally, low-tech or high-tech external memory can also facilitate communication and understanding between people: “One time my husband and I were having a disagreement and I wrote him a letter to get out what I wanted to say. It helped bring everything out into the open and I think it made him understand me better.”

Cameras and Photos

Ninety-one percent of participants reported that they regularly carry a device with them that can take photos (e.g., a camera or a phone with a camera; Q117). The mean number of photos that participants estimated taking per day was a modest 2.68 ($SD = 5.98$, $Mdn = 1$, $range = 0-100$, $n = 472$). This likely represents everyday use; we suspect more photos are taken during travel and other special occasions. By comparison, in a 2013 survey of 1,000 North American consumers, Hartman (2013) found that participants estimated taking a mean of 1.80 photos per day (54/month) on smartphones and 1.37 photos per day (41/month) on digital cameras. In a 2017 survey, Hartman (2017) found estimates increased to a mean of 2.56/day (77/month, $Mdn = 35$) for smartphones and 2.80/day (84/month, $Mdn = 20$) for digital cameras, though fewer people were using the digital cameras versus smartphones (537 vs. 963).

Question 119 asked participants for the main reasons they take photos. Fifty-two percent of participants’ responses were about memory (e.g., “to preserve memories

of people and places,” “to capture a moment,” “To have something to remember and look at of someone or something after they are gone,” “To document something interesting”). In most cases, it is likely that participants were talking about episodic memory; 31% of participants mentioned people, pets, moments, or events. However there were also clear cases (6%) of using photos for semantic memory (e.g., passwords, license plate numbers, directions, serial numbers, recipes, clothing sizes, parking location). Some responses illustrated both episodic and semantic memory purposes of photos: “Pictures of friends/family, but also sometimes a piece of information I want to remember—a photo of a receipt, a handwritten to do list that will be easier to have digitally, etc.” There has been only a small body of research yet on the cognitive and affective effects of taking photos (Henkel, Nash, & Paton, [in press](#)). Henkel (2014) found that taking overall photos of objects in a museum can decrease internal memory but that taking photos while zooming in on specific features of objects can increase internal memory (see also Henkel, Parisi, & Weber, 2016). In a laboratory study, Soares and Storm (2018) showed participants paintings on a computer screen and had participants either simply observe, take a picture that they expected to see again during a memory test, or take a picture that they did not expect to see again. Internal memory on an expected multiple-choice test about details of the paintings was impaired when photos had been taken, even when participants did not expect to be able to see the photos again. These results suggested that participants were not merely offloading the responsibility to remember onto the photos but rather that the act of taking a photo disrupted attention (perhaps in addition to any offloading effect). However, Diehl, Zauberman, and Barasch (2016) found that taking photos can increase engagement with experiences. Barasch, Diehl, Silverman, and Zauberman (2017) found that taking photos during a museum visit improved visual recognition of artifacts at a short delay (even for non-photographed artifacts) but impaired performance on multiple-choice questions based on the audio tour they had heard during their visit and did so regardless of whether participants expected their photos to be saved or deleted. They argued that photo-taking serves to redirect attention and that participants were not offloading the need to remember (although note that the memory tests were unexpected).

With regard to the effects of *viewing* photos, in one study using wearable cameras, Finley et al. (2011) found that reviewing photos at the end of the day improved later memory for the day’s experiences. In another study using wearable cameras, Finley and Brewer (2018) found that participants remembered an average of 23% more of their everyday experiences from a week or a month ago when they were able to look at photos of the experiences at the time of recall. Niforatos, Cinel, Mack, Langheinrich, and Ward (2017) found that when participants reviewed manually captured photos (handheld camera), they showed greater gains in memory for a museum visit than did participants who reviewed automatically captured photos (wearable camera). The manually captured photos were also rated as more subjectively meaningful to participants.

Aside from memory-related reasons for taking photos, 22% of participants mentioned social reasons (e.g., “To share the moment with someone else who is not there,” “To post on social media”). Twenty-five percent of participants gave aesthetic

reasons for taking photos (e.g., beautiful, interesting, funny, cute). Nine percent gave reasons related to work, school, or hobbies. We will review other research on people's reasons for taking photos in the Chapter 6 section on Photography.

Question 120 asked participants what they do with photos they have taken. Thirty-nine percent mentioned sharing photos with others (22% specifically mentioned social media). For reference, in 2015 the mean number of photos shared on Facebook per user per day was approximately 1.4 (Evans, 2015). Other uses of photos that participants mentioned included for work or evidence purposes and for art. Only 14% of participants mentioned reviewing or referring to the photos at a later time. Similarly, in a 2014 survey of 1,212 North American smartphone camera users aged 24–44, Hartman (2014) found that only 11% sorted through their photos “routinely,” 16% “quite often,” 44% “occasionally,” and 30% “almost never.” When Hartman’s (2014) participants were asked about how organized their digital photos were, only 13% responded “very organized,” 30% responded “quite, just needs a little more work,” 38% responded “somewhat, needs a lot of work,” and 19% responded “largely disorganized.” Our participants also talked about the specific ways that they save/store photos: 25% said they store photos on computers or hard drives, 12% online, 13% on phones, 11% print, 3% USB drives, 2% SD cards, and 2% CDs. See Whittaker et al. (2010) for more data on photo storage and organization.

The social uses of photos highlight the social context of memory and how external memory can facilitate social ties by enabling the sharing of experiences. The profusion of digital cameras has allowed external memory to become ever more distributed across social groups. In response to Q119, one participant said: “I used to take a LOT more pics, back when I was the only one with a digital camera, but now everyone has one, so I don’t feel the need to take as many, since I’ll see everyone else’s on Facebook and can save them from there if I want to.” Also note that this is clearly a case of external memory extending or augmenting human ability, not supplanting it, because photos can be easily shared in a way that internal memories of an experience cannot.

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Chapter 4

Results: The Interplay Between Internal and External Memory



Qualitative Data on the Interplay Between Internal and External Memory

In this section we report the themes that emerged from qualitative analysis of participants' rich and varied responses to the open-ended questions 121–127. These data provide fertile ground for further research into specific aspects of internal and external memory. Some themes were only mentioned by a low percentage of participants, but we nevertheless found them compelling enough to report; further research that addresses these themes directly (e.g., using closed-ended questions) would be fruitful. As a reminder, responses to the open-ended questions were coded by author FWG, working with author JRF through several iterations to develop categories of common themes of responses for each question and to resolve coding of ambiguous responses through discussion. Notes on the coding process can be found in Appendix C.

For questions 121–122 and 126–127, each participant's responses were coded as 0 (no) or 1 (yes) for each of four theoretical types of memory commonly described in psychological research (Roediger, Marsh, & Lee, 2002; Tulving, 1985): episodic, semantic, procedural, and prospective. See Appendix C for notes on the coding process. Briefly, episodic memory is for specific events, semantic memory is for general knowledge, procedural memory is about how to perform tasks, and prospective memory is for remembering to do things in the future. Note that the distinction among these constructs is not always clear when they are applied to descriptions of memory use in everyday life (see Rubin & Umanath, 2015 for an alternative theoretical framework: event memory).

Internal Memory: Relative Strengths and Uses

Participants were asked to describe circumstances in which they use internal memory instead of external memory (Q121) and to state something for which internal memory works better (Q126).

Episodic

Twenty-four percent (Q121) and 64% (Q126) of participants mentioned episodic purposes for internal memory, such as personal experiences and history, moments, situations, stories, life events (e.g., vacations, weddings, birth of children, parties), emotions, sensations, conversations, childhood memories, and faces.¹ One participant described the value of internal over external memory for episodic information as follows: “Storing and replaying the most precious and nostalgic moments of our lives. No computer could ever do that.” For questions 121 and 126, 8% of participants used words such as important, meaningful, significant, sentimental, or nostalgic.

Internal memory was favored particularly for accessing the phenomenology of the human experience. Emotions were mentioned by 3% (Q121) and 31% (Q126) of participants. For example, “Remembering emotions and how you feel, no external memory can take the place of a touch, a feeling, anything that comes from within your soul.” Sensations (sight, sound, smell, touch, taste) were mentioned by 1% (Q121) and 11% (Q126) of participants. For example, “Smells! The smell of a home cooked meal! The way something feels to hold or touch. There is no external device I know that can replicate those kinds of memories.” Internal memory provides a richer representation of experience (2% Q121, 5% Q126), as explained by one participant: “How I felt about a certain event, a specific person, a taste, a smell, and how it related to my emotional state are much more vivid in human memory than anything that can be recorded technologically.” Another participant said that internal memory was better for “personal identity.” Finally, internal memory may be favored for episodic information because of privacy: “I use it for very personal experiences that I don’t care to record externally as well.”

Additionally, 1% of participants (both Q121 and 126) mentioned that they use internal memory when they experience involuntary memories. For example, “Human memory works better as far as it works on ‘triggers’ such as smell or sight. It remembers things in a random way and sometimes useful way. You have to be much more deliberate with external memory.” The ten participants who mentioned involuntary memory did not report rates of involuntary memory (Q20) significantly different from the rest of participants, Mann-Whitney $U = 1573$, $Z = -1.83$, $p = .067$, $r = .08$.

¹Remembering faces was coded as both episodic and semantic, because recognizing someone’s face could involve memory for a specific episode (e.g., someone you only just met yesterday) and/or more generalized memory (e.g., a colleague you see nearly every day). We thank Hal Pashler, Roddy Roediger, Sharda Umanath, and Carolina Kuepper-Tetzel for their thoughtful comments on this point.

Semantic

Thirty-seven percent (Q121) and 31% (Q126) of participants mentioned semantic purposes for internal memory, such as passwords, some phone numbers, some dates, directions, trivia, facts, general knowledge, studying for exams, names, faces, recipes, shopping lists, and to-do lists.² One reason participants favored internal memory over external memory for such semantic information was speed or ease of access (8% Q121, 6% Q126). For example, “Situations where I have to react quickly, where external memory devices are inconvenient or awkward to use.” Such situations that participants mentioned included frequently used information or simple routine tasks (14% Q121, 7% Q126), as well as conversations, presentations, meetings, and tests.

Another reason participants favored internal memory over external memory for semantic information was security of sensitive information like passwords, social security numbers, and bank account numbers (10% Q121, 5% Q126). For example, “If something needs to be secure, i would rather it be in my mind rather on something that could be compromised by a computer criminal.”

Other

Ten percent (Q121) and 7% (Q126) of participants mentioned *social* purposes for internal memory. For example:

Human memory works better for personal contact with others and remembering others traits, habits, personalities. Human interaction and how to speak and treat others is something that requires human contact and memory. You can't rely on a computer or storage device for human relationship interactions.

Eight percent (Q121) and 2% (Q126) of participants mentioned *prospective* purposes for internal memory (cf. McDaniel & Einstein, 2007), such as chores, errands, short shopping lists, remembering to communicate with others (e.g., send a message), taking medication, daily to-dos, and itinerary. Internal memory was favored for prospective purposes when the timeframe was short and the tasks were simple or few. For example:

Something that I will be doing in the immediate future. For example, if I get in my car to go to the store to pick up a gallon of milk, I am not likely to forget where I am going and what I need to do when I get there. Creating an external reminder for something like that seems unnecessary and probably inconvenient as well.

² Shopping/grocery and to-do lists were coded as both semantic and prospective, because such lists comprise knowledge not tied to a specific past episode, and they indicate tasks to be performed in the future. Unspecified types of lists were coded as just semantic. Note that list-learning in laboratory memory studies is considered an episodic task; however we consider the use of lists in everyday life as semantic and/or prospective, not episodic. For a sociological consideration of recipes as external memory, see Goody (1977, pp. 129–145).

Fourteen percent (Q121) and 5% (Q126) of participants mentioned *procedural* purposes for internal memory, such as cooking, routine tasks at home and work, activities of daily living (e.g., getting dressed), job skills, driving (especially without GPS), directions, games, sports, and riding a bike. One participant noted: “Skills learned for specific reasons. You cannot rely on notes to do everything for you.” Another noted: “Cooking. Recipes are only a guideline. The exact steps are hard to explain, you kind of have to just know.” Another procedural purpose for internal memory, mentioned by participants especially in Q123, was remembering how to access external memory. Relatedly, remembering where information is stored in external memory (e.g., which device, which notebook, which colleague) can be considered as *source memory* (Johnson, Hashtroudi, & Lindsay, 1993).

Fifteen percent (Q121) of participants said that they use internal memory when their access to external memory has been restricted. They may need to revert to internal memory in situations where the use of external memory is socially unacceptable (e.g., during a conversation, date, presentation, job interview, show, or funeral), is forbidden (e.g., during tests, in some job environments), or is dangerous (e.g., while driving). External memory may also be unavailable because the tools themselves are not present (e.g., “when I forget my notes or lists at home,” “When I’m away from my phone,” “no paper handy”) or are inoperative (e.g., “power outage,” “battery dead”). Finally, participants need to rely on internal memory when the information they want was not stored in external memory in the first place: “Memories prior to the invention of smartphones.” See also the section in Chapter 3 on External Memory Retrieval Failures. One participant summed up their preference thus: “Generally I won’t use internal memory unless I don’t have any choice.” In contrast, 14% (Q121) of participants said that they use internal memory in most circumstances. For example, “I use human memory whenever I can. I don’t want to become totally dependent on technology or memory aids.”

Finally, 6% of participants (Q126) said that internal memory is better than external memory for higher-order cognition such as abstract thinking (e.g., “retrieving complex artistic or philosophical information”), associations (e.g., “Remembering how things are connected. Big picture stuff. The intuitive light-bulb connection of pieces of information.”), and creativity (e.g., “I think it works better for imagination. I think that memories should be filtered through emotions and experience. I think sometimes, something like a video, and tamper with a memory by make it more objective”).

External Memory: Relative Strengths and Uses

Participants were asked to describe circumstances in which they use external memory instead of internal memory (Q122) and to state something for which external memory works better (Q127).

Episodic

Eight percent (Q122) and 10% (Q127) of participants mentioned episodic purposes for external memory, mostly photos and video/audio recordings for experiences that they want to remember or share later (“to record events so that other people can have access to them like videotaping a wedding, a birth”), especially when details are desired (“remembering specific details of events”), and retention intervals are long (“remembering events that happened a long time ago, like nostalgic events”). Indeed, external memory provides us with a window into the past, whether our own or someone else’s (cf. Frohlich, 2004, 2016). As one participant said, “pictures and video allow us to remember in clearer form what someone looked like, sounded like, behaved, etc. from another time.” A handful of participants mentioned other episodic uses of external memory, such as taking pictures or notes to document incidents at work and keeping a log when bird-watching. One participant summed up the episodic value of external memory: “You may not be able to remember all the events in your life, readily, but if you have a stored record of that experience, it can enhance your memory.”

Semantic

Sixty-four percent (Q122) and 74% (Q127) of participants mentioned semantic purposes for external memory, such as passwords (especially infrequently used ones), phone numbers, dates, appointments, email addresses, physical addresses, directions, “stone cold facts,” quotes, names, recipes, financial information, numbers, formulas, and shopping or to-do lists (especially longer ones). External memory was favored for infrequently used information (e.g., “Seldom-accessed facts”) and for information that is complex, boring, and/or vast (e.g., “Tedious things like numbers, dates, and very long strings of things that are difficult to memorize”). External memory was valued for its accuracy, precision, longevity, and capacity. Accuracy: “Anything that you need to be 100% certain that it’s remembered correctly.” Precision: “Things that need to be remembered in a specific and precise manner, like serial numbers.” Longevity and capacity: “remembering large amount of information and something that may be needed a long time from now.”

One question is the extent to which people feel overwhelmed by the abundance of information they can access through high-tech external memory. A 2016 Pew survey about information overload (Horrigan, 2016) found that 77% of participants said they like having so much information available, while only 20% feel overloaded with too much information. Humans appear to be quite able to adapt to new information ecologies.

Google and Wikipedia are two salient sources of semantic external memory. When using external memory to settle a disagreement (Q132), 10% of participants mentioned Google, and 3% mentioned Wikipedia. Again, we suspect these numbers underestimate actual usage. For a review of research on Wikipedia as the “sum of all human knowledge,” see Mesgari, Okoli, Mehdi, Nielsen, and Lanamäki (2015).

Other

Thirty percent (Q122) and 26% (Q127) of participants mentioned prospective purposes for external memory, such as making appointments, being reminded of appointments and important dates, keeping a calendar or schedule, and shopping and to-do lists. External memory was favored for prospective purposes when the timeframe was long. For example, “Something that is further in the future. For example, if I want to watch a particular TV show next week or I have a doctor’s appointment in two months.” External memory was also valued for its reliability for prospective purposes (“An alarm will never forget what time something is”), although failures are not unheard of (Q131: “AN ALARM DIDN’T GO OFF AND I WAS LATE FOR AN APPOINTMENT”).

Only 7% (Q122) and 3% (Q127) of participants mentioned procedural purposes for external memory, such as recipes, instructions, walkthroughs, and directions (GPS navigation).

Internal Versus External Memory

Table 4.1 shows the percentages of participants whose responses we coded as episodic, semantic, procedural, and prospective, for internal versus external memory in the questions on circumstances (Q121–122) and on things for which each works better (Q126–127). Figure 4.1 illustrates the latter. For episodic and procedural purposes, internal memory was used and favored more than external memory. For semantic and prospective purposes, external memory was used and favored more than internal memory. Wilcoxon signed-rank tests revealed all eight comparisons between internal and external memory to be statistically significant, $Z \geq 2.33$, $p \leq .020$, $r \geq .11$.

Consistent with the majority beliefs about the malleability of internal memory (Q18) and immutability of external memory (Q19), external memory was valued for its accuracy (true representation of reality) and fidelity (unchangingness), especially relative to internal memory. For example, one participant said: “External memory is better for accurately recalling events that have long past and have become warped in

Table 4.1 Relative uses of internal versus external memory

	Episodic	Semantic	Procedural	Prospective
Circumstances used				
Internal	24%	37%	14%	8%
External	8%	64%	7%	30%
Works better for				
Internal	64%	31%	5%	2%
External	10%	74%	3%	26%

Note. N = 476. Data derived from responses to questions 121–122 and 126–127.

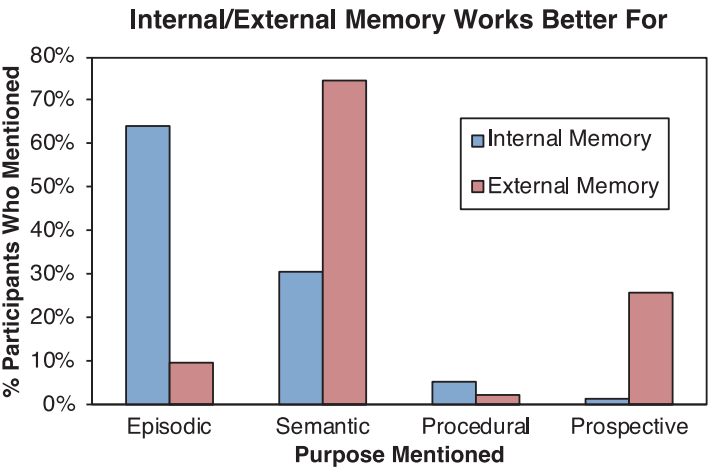


Fig. 4.1 Purposes for internal versus external memory. Note: percentage of participants who mentioned each of four different purposes in their responses to the following open-ended questions: “something that human memory works better for” (internal memory, Q126) and “something that external memory works better for” (Q127). External memory here refers only to technological external memory (including low-tech and high-tech), not social external memory.

my own memory.” Another said: “exact duplication of information-like a photo of a scene, a photo can’t change over time, what is there is there but a memory can distort what was seen.” However, accuracy is not everything. One participant said they use internal memory “when the impression of an experience is more important than a factual record,” and another said “Sometimes the memories we create are just better than what really happened.”

Nevertheless, external memory does provide an accurate record of the past: “It stores things exactly as they happened. It’s way better as far as being accurate in historical context of things.” This accuracy makes external memory valuable for verification purposes. Seven percent (Q122) and 5% (Q127) said that they use external memory to verify the accuracy of internal memory. For example, “When something is particularly important and I want to verify that I have remembered correctly, I will consult external memory.”

Our findings are consistent with Norman’s claim that “highly accurate repetition is not our strength: Imaginative, insightful interpretation is” (1993, p. 138).

In summary, participants’ responses indicated that internal memory is used more than external memory for episodic and procedural purposes, and its strengths are in rich vivid recollection, phenomenology, personal relevance, creativity, and security; external memory is used more than internal memory for semantic and prospective purposes, and its strengths are in accuracy, precision, fidelity, longevity, and capacity. Accuracy refers to the extent to which externally encoded information is a true representation of reality (this only applies to information that is intended to represent reality; it does not apply to fiction). Precision refers to how detailed the information is (e.g., “58 minutes” is more precise than “about an hour”). Fidelity refers

to how little the information becomes distorted over time and reuse. *Longevity* refers to how long the information lasts. *Capacity* refers to the amount of information.

Symbiosis of Internal and External Memory

In response to Q123, participants noted a variety of ways that internal and external memory work together. The types of interplay we identified are listed in Table 4.2 along with illustrative example responses from participants.

External memory serves as a fail-safe and/or verification for internal memory (18% of participants). External memory can be a powerful cue to trigger internal memory (16%), facilitating retrieval of internal memories that may otherwise be inaccessible. However, we note that encountering external memory can disrupt the natural process of internal forgetting, which is sometimes adaptive (Bjork, 2015). Sometimes we wish to remember and sometimes we wish to forget (Q77, 78). The power of external memory in cueing internal memory is consistent with research using photographs from wearable cameras (Silva, Pinho, Macedo, & Moulin, 2016) and handheld cameras (Wu, Birnholtz, Richards, Baecker, & Massimi, 2008). Zhang, Kim, Brooks, Gino, and Norton (2014) found that people tend to overestimate how much they will remember on their own and underestimate the value of external records for interesting future rediscovery of even mundane experiences. We take for granted our everyday surroundings and tend to focus on creating external records (e.g., photos) of special events, not realizing that just one photo of, say, our daily workspace can act as a powerful memory key to our distant future selves.

Both forms of memory can expand on each other. Internal memory can expand on external memory by yielding rich recollections of original experience. External memory can expand on internal memory by providing more detailed information. Several responses illustrated this mutual augmentation (Table 4.2).

Cognition can be augmented by offloading information to external memory to overcome the limited capacity of working memory. Although only a few participants described this kind of use (e.g., solving advanced math problems, using scratch paper), we suspect it is widespread. External memory also alleviates much of the burden of prospective memory and organization, by way of calendars, to-do lists, and reminders or alarms. In their book on mnemonics, Worthen and Hunt (2011, pp. 29–33) distinguished between records of to-be-remembered information (e.g., a shopping list containing all the specific items needed, such as “eggs, bacon, pancake mix, syrup, and orange juice”) and external mnemonics (e.g., a shopping list containing cues to internal memory, such as “breakfast food”).

Importantly, as noted by 13% of participants, internal memory is necessary for the encoding, retrieval, and interpretation of external memory (cf. Intons-Peterson & Newsome, 1992, p. 113). For encoding, one has to (a) remember to make external records in the first place (often based on the metacognitive judgment that one is likely to forget certain information that may be needed in the future), and (b) create and organize the records in such a way as to assist future retrieval (e.g., folder

Table 4.2 Interplay of internal and external memory: example responses

Type of interplay	Example responses
EM as fail-safe and verification for IM	<i>When my human memory fails me, I resort to external memory.</i>
	<i>I use my human memory to study the patterns of a bird (or movie or song), but I like to be able to cross-check on external memory. I'll look something up and double-check whether my intuitive memory was correct.</i>
	<i>I utilize both to study and remember things, and if i cannot remember something internally I know I can look it up externally.</i>
EM triggers IM	<i>Sometimes external memory will jog my human memory of things like remembering vocabulary or remind me of an experience, etc</i>
	<i>Photographs and diaries help me recall memorable and fun times.</i>
	<i>I think notes on paper or my computer, will often trigger memories and help me make connections I wouldn't have just using my brain alone. Occasionally pictures or videos will trigger some hidden memory and it will increase my feelings of nostalgia.</i>
IM expands on EM	<i>Often, though not as often as before, the written note jogs my human memory, and I remember a much more vivid scenario than the external notes depict.</i>
EM expands on IM	<i>The external memories enhance your memories by providing very concrete details of your own memories. I think this is especially true for experiential memories (like vacations, etc.)</i>
Mutual expansion	<i>I use external memory to remember the dates and the names of the places, but I use the human memories to remember the emotions of the time. I piece them together and I can build a story to tell other people about what happened in the past.</i>
	<i>These two types of memory work together well when I am remembering particular experiences, such as a wedding. I have the experience in my mind of what it was like, but I also have pictures and/or video that help me to really get back into that moment.</i>
	<i>I think external memory helps to ignite human memories. Sometimes i have a hard to remembering something, and just a little nudge from a google search will allow a flood of memories to hit me. And then i can write those memories down and they become externalized. And the process of writing them down helps me memorize them.</i>
EM helps cognition	<i>If I have a list of things to do, it's good to write it down to get my thoughts organized and set a plan of action on how to tackle each task or the best method of doing so.</i>
	<i>I use notes that I take to help jog my human memory or to assist me in synthesizing complex ideas</i>
	<i>When I review the things that are put on external memory, it helps to clarify my human memory and also helps me put things together if I'm confused or not seeing the whole picture or missing something.</i>
EM for prospective, organization	<i>I get calendar reminders a day in advance. this alerts and refreshes my internal memory</i>

(continued)

Table 4.2 (continued)

Type of interplay	Example responses
	<i>It also really helps to keep me organized with a to do list that I can check things off and make sure I get done what I need to without forgetting something. It's not that I feel like my human memory is unreliable, but it's easier to not have to think about remembering something because I can write it down or put it on my electronic to do list and refer back to it without having to hold it in my mind.</i>
	<i>My external memory will remind me to move to the next task, and my human memory will remember how to do the task. My external memory will sometimes remind me of how to do a task, and once I get started on the task my human memory will take over.</i>
IM needed for EM: Encoding	<i>I think our human memory works to make the lists and create the things we store into the external memory.</i>
	<i>i have to remember to put things in the phone to remind me to do them later.</i>
	<i>my human memory reminds me to document things in external memory or that I already did.</i>
IM needed for EM: Retrieval	<i>I use my human memory to remind myself to check my external memory.</i>
	<i>Yes, I try to use my human memory like an index for my external memory.</i>
	<i>Well you must learn and remember how to operate the electronic devices which store your external memory. This can often be rather difficult for some.</i>
	<i>My human memory must remember where I stored the notes I need or photos... whether on my laptop computer, desktop computer, iPad, iPhone. I have to remember the apps I use for the notes</i>
IM needed for EM: Interpretation	<i>Well, I sometimes when I take notes I am vague because I know my human memory will fill in the gaps. So they work well together in that way.</i>
	<i>I use my human memory to explain photos and written notes that I have saved with external memory.</i>
	<i>Sometimes I'll write something down in code, and I'll use my memory to remember what the symbols mean.</i>
Encoding in EM strengthens IM	<i>the act of physically writing the notes will often help me remember without having to go back and look. I can often visualize the note.</i>
	<i>sometimes when I am trying to remember something, I remember writing it down or entering it into my phone and that helps me to remember it without having to look.</i>

Note. IM = internal memory, EM = external memory. Responses are from Q123.

structures, descriptive labels on photos, tags, metadata). For retrieval, one has to (a) remember that the information exists in external memory, (b) remember to attempt retrieval, and (c) remember the location and procedure for retrieval (cf. Eskritt, Lee, & Donald, 2001). The procedure of retrieval may furthermore involve both recall (e.g., of search terms) and recognition of target items among candidates. Finally, internal memory is often necessary to interpret and synthesize the information retrieved from external memory (cf. Zhang & Norman, 1994). As Flavell and Wellman (1975, p. 34) noted: “A person may write some key words on his calendar as direct retrieval cues to a whole complex of information.” We find it noteworthy

that our participants' insights also echoed those of Wolfgang Schönplug, who laid out the critical role of internal memory as follows:

External storage is only functional if it is represented internally. ... It is the user who has to initiate and to organize the retrieval at the appropriate time for the purpose given. To be able to do this he has to know the content, the location, the structure and the operational features of the external store. (Schönplug, 1986; cf. Schönplug & Esser, 1995)

In fact, in the current study, one participant's exact words were: "External only functions well if my internal memory can remember it's stored there." Additionally, in order to use external memory, one must have access to the device or record when it is needed. As one participant said: "even I write a list, I have to remember to bring the list with me." See also the section in Chapter 3 on External Memory Retrieval Failures.

Finally, the very act of encoding information in external memory can strengthen internal memory, as mentioned by 5% of participants. This phenomenon was also reported by Intons-Peterson and Fournier (1986, Experiment 3), particularly with respect to taking notes. The act of taking notes has in some studies been found to improve internal memory (for reviews, see Friedman, 2014; Kiewra, 1989; Kobayashi, 2005). One participant even commented on the perceived effectiveness of low-tech versus high-tech external memory: "I think me human memory has gotten worse since I have started using electronic memory aids. Using pencil/paper actually helped human memory." This claim is consistent with research by Mueller and Oppenheimer (2014) which found improved factual and conceptual memory performance for viewers of a presentation who took notes by hand versus typed on a laptop. However, the type of high-tech input used may matter: Kalnikaitė and Whittaker (2008) found no difference in memory performance for participants who had taken notes on paper versus notes on a handheld digital device that let them write with a stylus instead of typing. Study aids such as flash cards are another external memory tool specifically intended to build internal memory.

Changes in the Interplay Between Internal and External Memory

Does using external memory change the way that people use their internal memory? In response to question 124, 24% said no, while 45% said yes in some way, including relying less on internal memory (18%), attempting less memorization (17%), being lazier about trying to remember (5%), and/or being dependent on external memory as a crutch (11%). For example, "I think the ease and accessibility of having external memory available at all times has made me less reliant on human memory and far more dependent on technology to get things done."

Question 125 asked about changes over the years in how participants use their internal versus external memory. In response, 34% said no changes, while 45% said they have increased reliance on external memory (34%) and/or decreased reliance

on internal memory (20%). For example, “I’ve noticed I use external memory more than I use human memory as the years have passed.” Combining responses from both questions 124 and 125, 63% of participants mentioned more external memory use and/or less internal memory use. The shift from internal to external memory is particularly evident for semantic information like phone numbers (mentioned by 15%), email addresses, dates/appointments, facts, or names. Phones are used for phone numbers, email programs for email addresses, calendars for dates/appointments, and Internet searches for facts and names.

The shift from internal to external memory could be due to a combination of several factors: better and more widely available technology, aging, and/or greater quantities of incoming information. Technology: “Technology and the UI’s of tech have become so much more user friendly that they are simply easier and/or more fun to use than my own human memory.” Aging: “I think that as I age my memory gets worse, so I rely on writing things down more to remember it.” Both technology and aging: “Over the years I’ve learned to document more using external memory, in part because technology has improved, but also because my memory isn’t as clear as when I was younger.” More incoming information: “i think i use external memory more now since information is coming at me at alarming speeds theres no way i could remember it all.” For some it has been a shift between different types of external memory (e.g., from low-tech to high-tech): “I’ve switched from making lists and notes on paper to composing emails to myself which I almost never send and just keep as dated drafts I reference later.” Another participant wrote: “No, my habits are pretty much the same as they’ve always been, other than the TYPE of external memory (computer or phone vs pen and paper).”

Some participants stated concern about their internal memory getting weaker or worse (6% Q124, 10% Q125). Some emphasized disuse: “I simply don’t use human memory as much as I used to so I would suspect that is one reason my memory has decreased in the last few years.” With information so readily available in external memory, there is a clear temptation to avoid the kind of effortful retrieval from internal memory that would actually strengthen internal memory (cf. retrieval practice effects or testing effect, Middleton, Schwartz, Rawson, & Garvey, 2015; Roediger & Karpicke, 2006; desirable difficulties, Bjork, 1994) and potentially enhance problem solving (Nestojko, Finley, & Roediger, 2013). Other participants emphasized overreliance on external memory: “I have let myself rely on external memories much more. I think the laziness of that’s come from having a smartphone has made it easier to forget a lot of other things in my life.” One participant summed up discomfort with how much of his knowledge resides in external memory: “It’s a little shameful in a sense—a lot of what I ‘know’ isn’t actually personal knowledge, but things I can look up quickly and easily.”

However, in contrast to the above misgivings, other participants expressed the change in their use of internal memory as a strategic prioritization, often leading to an overall enhancement (7% Q124). One participant gave this summary:

I remember different things based on the need of the situation. If it can be found online and I don’t need the knowledge in my daily life, I have no real reason to memorize a name or a date. This makes it sound like it makes my memory worse, but in actuality it helps because it lets me focus on the important things.

There were several themes in participants’ selective use of their internal memory: less semantic information, more episodic information, more higher-order cognition, and a focus on finding information in external memory. Table 4.3 shows illustrative example responses from participants for these themes. Relatedly, in the 2016 Kaspersky Lab survey, 64% of respondents agreed that storing information on their smartphone allowed them to concentrate on something else.

Finally, participants in our study also noted that external memory reduces stress on internal memory (11% combined across Q123–125). An example for episodic information: “I also feel a sense of security when I have photo back-ups of events.” An example for semantic information: “I do not worry about remembering specific, technical information because i can take a picture of the information or otherwise write it down.” An example for prospective tasks:

I used to wake up a night and fret about things that I needed to remember to do the next day. Now if I wake up worrying about something, I either write myself a note on my phone, or send myself an email. Once that’s done, I can literally wipe the worry out of my brain, and go back to sleep peacefully.

Table 4.3 Selective use of internal memory: example responses

Focus of internal memory	Example responses
Less semantic information	<i>I no longer have to spend time learning and remembering things like phone numbers and addresses. These things need refreshing/repeating in human memory to remain easily accessible, or they fade and get lost. I don't have to waste time repeating these things over and over to remember them.</i>
	<i>I try less hard to remember details and lists, since I know I can look it up later. There are things I know I can just re-google and find so I don't bother to remember details which I would when I was a kid.</i>
	<i>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.</i>
More episodic information	<i>The external memory helps keep me organized with concrete, outer things (numbers, figures, etc.) so my human memory can focus on personal memories</i>
	<i>I think my human memory is mostly now used for nostalgia. I don't have to memorize things</i>
	<i>Yes it allows me to use my human memory more for remembering personal experiences as opposed to remember factual knowledge.</i>
More higher-order cognition	<i>Yes; instead of relying on rote memorization, I'm able to use my human memory for understanding concepts and the larger picture, and use external memory for the nitty gritty details.</i>
	<i>I use my human memory for much shorter term things now and use that brain power to "dream," "think," and "create" rather than rote memory.</i>
Finding information in external memory	<i>If I know that I can access something via external memory, then I put less effort on remembering the detail and more effort on remembering the process to access the external memory.</i>
	<i>I no longer have to remember everything. Just need to remember where I stored it for retrieval.</i>

Note. Responses are from Q123 to Q125.

The overall picture is of a growing symbiosis between internal and external memory. The two complement and depend on each other. To put it broadly, external memory is augmenting internal memory for episodic purposes, and supplanting internal memory for semantic and prospective purposes.

Correlations

In this section we report correlational analyses in order to further investigate the relationship between internal and external memory.

Composite Variables

This survey was exploratory in nature and included several sets of questions intended to converge on latent constructs. Thus we created composite variables by grouping questions together as guided by both theory and iterations of principal component analysis and reliability analysis (Cronbach’s alpha). The ten composite variables we created are listed in Table 4.4. Composite variable scores were calculated for each participant by averaging that participant’s standardized (z) score on the individual questions included in the composite. Standardized scores were used because the response scales and variances differed across questions. The following questions were reverse coded so that their direction matched the others in their respective composites: 37–41, 47, 49, 94, and 103. Appendix C gives details on how qualitative responses (questions 112, 114–116, 128, 129, 133) were coded for inclusion in

Table 4.4 Composite variables

Composite variable label		Individual items included	Cronbach’s alpha
C1.	IM ability	12–14, 37–41, 103	.810
C2.	Belief: IM = EM	18–19, 49–50	.671
C3.	EM use: low-tech	22, 25, 28, 31–32, 34–36, 54, 112, 114–116, 128, 133	.791
C4.	EM use: high-tech	23,26, 29, 55, 112, 114–116, 128	.725
C5.	EM use: social	24, 27, 30, 33, 129	.640
C6.	EM enhancement	44–46	.728
C7.	EM retrieval failure	42, 53	.588
C8.	EM reliance	47, 52	.651
C9.	EM valuable	91–95	.729
C10.	EM emotional response	74–76	.794

Note. IM = internal memory, EM = external memory. Cronbach’s alpha is a measure of reliability, or internal consistency.

Table 4.5 Composite variable correlations

Composite variable		C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
C1.	IM ability	–									
C2.	Belief: IM = EM	.19	–								
C3.	EM use: low-tech	–.25	–.05	–							
C4.	EM use: high-tech	–.18	–.25	.00	–						
C5.	EM use: social	–.31	.04	.18	.04	–					
C6.	EM enhancement	–.10	–.14	.07	.38	.17	–				
C7.	EM retrieval failure	–.56	.04	.20	.03	.32	–.02	–			
C8.	EM reliance	–.57	–.09	.28	.15	.24	.23	.44	–		
C9.	EM valuable	–.22	–.18	.24	.30	.08	.33	.08	.19	–	
C10.	EM emotional response	–.08	–.01	.21	.07	.12	.17	.03	.04	.34	–

Note. Spearman’s rho correlations. $N = 476$. Correlations of absolute size $\geq .15$ are significant at $p < .00111$ (family-wise Bonferroni-adjusted alpha level of .05/45). IM = internal memory, EM = external memory.

the composite variables. P-values for correlations involving composite variables are reported here. P-values for correlations involving only individual variables are available in the Supplemental Materials.

Table 4.5 shows Spearman correlations among the composite variables. The most striking pattern is that self-reported internal memory (IM) ability was negatively correlated with nearly everything about external memory (EM). People with supposedly better IM made less use of EM (low-tech, high-tech, and social),³ experienced less EM retrieval failure, relied less on EM, and put less personal value in their EM. Conversely, people with supposedly worse IM made more use of EM, experienced more EM retrieval failure, relied more on EM, and put more personal value in their EM.

Higher self-reported IM ability was positively correlated with believing that human and machine memory work similarly: someone who rarely forgets may see human memory as a camera; someone who often forgets may see human memory as anything but. The more that people saw human and machine memory as different, the more they used high-tech EM, the more they saw EM as enhancing them, and the more they valued it.

Interestingly, low-tech and high-tech EM use were not at all correlated. The two composite variables appear to be independently normally distributed. They did correlate with several other composite variables. Low-tech EM use was positively correlated with social EM use, EM retrieval failure, reliance on EM, personally valuing EM, and emotionally responding to EM. High-tech EM use was positively correlated with feeling enhanced by EM, relying on EM, and personally valuing EM. That

³In contrast, Schryer and Ross (2013) found no correlation between self-reported memory errors as measured by the Everyday Memory Questionnaire and use of external memory aids as measured by the Memory Compensation Questionnaire, for either younger or older adults (E. Schryer, personal communication, August 7, 2014).

EM retrieval failure was more highly correlated with low-tech than high-tech EM use may speak to the utility of search functions in devices such as computers and phones; notes on paper have no such search functions. As one participant said (Q131): “If I write something down, and can’t find the piece of paper, then that’s a failure.”

Reliance on EM was positively correlated with valuing EM and with experiencing EM retrieval failure. Those people who rely most on EM tended to value it more and also more frequently experience problems finding information in EM. However, partialling out IM ability reduced the first correlation below significance ($r_{s(C8)(C9).(C1)} = .07, p = .103$), but not the second one ($r_{s(C8)(C7).(C1)} = .18, p = 9.2 \times 10^{-5}$). Personally valuing EM was also positively correlated with reliance on EM and with having experienced powerful emotional responses to pictures, video, and/or text from the past.

Complete correlation matrices, both with and without the composite variables, are included in the Supplemental Materials. Here we will consider several individual variables of particular interest. Table 4.6 shows how these variables correlated with the composite variables. Note that none of these individual variables were used in creating the composite variables.

Age

To what extent was participant age related to other variables? Participant age ranged from 18 to 75 years ($M = 34.7, SD = 11.2, Mdn = 32$), and was non-normally distributed, with skewness of 1.01 ($SE = 0.11$) and kurtosis of 0.49 ($SE = 0.22$). See Fig. 1.2 for a histogram of age. The wide distribution of ages in our sample made us well-equipped to investigate correlations, although it is worth noting that the positive skew means that we had more participants in young and middle adulthood than older adulthood. For all correlations, we used Spearman’s rho (r_s), which is non-parametric and does not assume normal distribution of variables.

Age (Q1) was negatively correlated with IM ability, C1, $r_s = -.15, p = 8.5 \times 10^{-4}$, and positively correlated with low-tech EM use, C3, $r_s = .29, p = 1.4 \times 10^{-10}$ (e.g., Q31 shopping lists $r_s = .22$; Q32 bookmarks, $r_s = .19$; Q34 reminder notes, $r_s = .15$; Q35 placing objects in specific places, $r_s = .23$; Q36 placing objects in obvious places, $r_s = .17$; Q54 taking notes on paper, $r_s = .16$). This result is consistent with the findings of Schryer and Ross (2013), who found that older adults reported more use than younger adults of external memory aids, as measured by the Memory Compensation Questionnaire (MCQ, from which our own questions 31–36 were adapted). Bouazzaoui et al. (2010) surveyed adults from age 21 to 80 and found that external memory strategies increased as a function of age whereas internal memory strategies decreased, as measured by the Metamemory in Adulthood instrument (MIA, Dixon, Hultsch, & Hertzog, 1988), which used similar questions to the MCQ. Both MIA and MCQ asked only about low-tech external memory. Similarly, Moscovitch (1982, pp. 74–75) reported that older adults made better use than younger adults of low-tech reminders such as keeping a note near the phone.

Table 4.6 Correlations of some individual variables with composite variables

Item		C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
1.	Age	-.15	-.11	.29	.09	-.04	.03	.01	.14	.11	.13
43.	Unease reliance on EM	-.13	.20	.07	-.04	.14	-.21	.34	.21	-.13	.07
48.	Understand tech	.00	-.18	.02	.27	-.03	.33	-.13	-.07	.22	.11
51.	Human memory improving	.26	.22	-.09	-.09	-.05	.05	-.12	-.17	-.11	-.07
57.	Notes improve memory	-.10	-.15	.35	.19	.07	.23	.02	.05	.20	.16
59.	Computer: well-organized	.21	-.04	.05	.14	-.09	.17	-.30	-.13	.13	.09
60.	Computer: use search	-.17	-.06	.06	.11	.05	.10	.27	.15	.07	.10
61.	Important to be present	-.09	-.28	.18	.14	.05	.17	-.03	-.03	.32	.30
62.	Important to record	-.10	.11	.17	.04	.16	.21	.11	.14	.31	.26
63.	Recording detracts	.05	.03	-.03	-.04	-.03	-.14	.04	-.03	-.21	-.15
65.	Look up vs. remember	-.36	-.16	.18	.20	.18	.17	.28	.32	.16	.09
68.	EM use: episodic	-.05	.16	.17	.06	.12	.13	.23	.07	.21	.25
69.	EM use: semantic	-.17	-.19	.23	.29	.05	.32	.09	.19	.20	.13
70.	Well-organized	.27	.10	.11	.02	-.16	.03	-.33	-.20	.12	.11
71.	Nostalgic	-.05	.01	.14	.02	.11	.06	.05	.05	.32	.49
72.	Collector	-.06	.06	.06	.03	.15	.04	.10	-.02	.13	.25
73.	Distractible	-.27	.07	.11	-.03	.14	-.03	.32	.23	-.07	.01
77.	EM cues wanted recall	-.14	-.03	.22	.17	.12	.23	.09	.13	.34	.27
78.	EM cues unwanted recall	-.17	.04	.11	-.01	.10	.02	.24	.07	.08	.25
83.	Online social activity	-.03	.13	-.03	.18	.17	.16	.07	.03	.20	.19
89.	Social media cues recall	-.17	.03	.10	.14	.21	.26	.15	.16	.29	.25
96.	Backup frequency	.12	.02	-.07	.27	-.04	.17	-.05	-.06	.02	.02

Note. Spearman’s rho correlations. *N* per cell ranged from 471 to 476. Correlations of absolute size $\geq .17$ are significant at $p < 2.2 \times 10^{-5}$ (family-wise Bonferroni-adjusted alpha level of .05/220). See Table 4.4 for composite variable labels. See Appendix A for full wording of questions for individual variables.

In contrast to the relationship between age and low-tech EM use, age was not significantly correlated with high-tech EM use, C4, $r_s = .09$, $p = .041$ (e.g., computers, phones, cameras, Internet). High-tech EM appeared to be used approximately evenly across all ages in our cross section (Q23 $r_s = -.01$) and changing at the same

self-reported rate (Q26 $r_s = .05$, Q29 $r_s = .03$). The world has been changing as we age. More technology becomes available. The youngest people in our sample, born in 1997, grew up in a world with Internet access (digital natives), while older people have had to adapt to new technologies throughout their lives (digital settlers; cf. Prensky, 2001; Palfrey & Gasser, 2008). Low-tech EM use could be lower in younger people because they have had more high-tech options for more of their lives.

Greater use of low-tech EM and greater reliance on EM (C8, $r_s = .14$, $p = .003$) by those of older age are consistent with findings from Schryer and Ross (2013, Tables 1 and 2) who found that older adults self-reported more use of EM than younger adults on the Memory Compensation Questionnaire. Interestingly, they also found in two laboratory studies that older adults were no more likely than younger adults to use an available pen and paper to take notes about a phone message. See also Lindenberger and Mayr (2014). To get a complete accurate picture of how adults of all ages use external memory, it would be valuable for future research to supplement self-report questionnaires and performance in laboratory tasks with naturalistic observation of people's use of external memory aids in their actual everyday settings (cf. Ceci & Bronfenbrenner, 1985; Diehl et al., 2005; Masumoto, Nishimura, Tabuchi, & Fujita, 2011). See Phillips, Henry, and Martin (2008) for an excellent review of research on aging and prospective memory, including directions for further research.

Age was negatively correlated with the belief that human memory is overall getting better (Q51, $r_s = -.15$); that is, older participants were more likely to believe that memory is getting worse. Older participants were less likely to write on their hand (Q58 $r_s = -.20$). Older participants tended to send and receive more emails per day (Q80 $r_s = .29$, Q79 $r_s = .22$) and to send and receive fewer text messages per day (Q82 $r_s = -.20$, Q81 $r_s = -.20$). Older participants tended to have fewer Facebook friends (Q87 $r_s = -.16$), but their self-reported weekly hours spent on Facebook did not differ much from those of younger participants (Q88, $r_s = .10$). Older participants tended to have more passwords (Q101 $r_s = .21$) and be more likely to keep passwords written down or saved somewhere (Q102 $r_s = .30$).

Finally, there was no correlation between age and how much change participants expected in the next 10 years in technology (Q134, $r_s = -.01$) or in human life (Q135, $r_s = -.05$).

Sex

First, we must note that sex was correlated with age ($r_s = .248$), such that the mean age of women in our sample ($M = 37.7$, $SD = 12.1$) was higher than the mean age of men in our sample ($M = 32.1$, $SD = 9.7$), $t(470) = 5.55$, $p = 4.7 \times 10^{-8}$, $d = 10.9$. With the age difference in mind, we will report the following t -tests accompanied by partial correlations between sex (Q2, male coded as 1 and female coded as 2) and the composite variables, partialling out age (Q1). The first p -value is for the t -test,

and the second p -value is for the partial correlation. Men self-rated their IM ability (C1) higher than did women, $t(470) = 2.73$, $p = .006$, $d = 0.62$, $r_{s(Q2)(C1),(Q1)} = -.092$, $p = .045$. Women reported more low-tech EM use (C2) than did men, $t(470) = 6.45$, $p = 2.8 \times 10^{-10}$, $d = 0.47$, $r_{s(Q2)(C2),(Q1)} = .228$, $p = 5.8 \times 10^{-7}$. Women reported more reliance on EM (C8) than did men, $t(470) = 3.31$, $p = .001$, $d = 0.85$, $r_{s(Q2)(C8),(Q1)} = .125$, $p = .007$. Women reported more emotional responses to EM (C10) than did men, $t(470) = 4.98$, $p = 8.9 \times 10^{-7}$, $d = 0.83$, $r_{s(Q2)(C10),(Q1)} = .206$, $p = 7.0 \times 10^{-6}$. There were no statistically significant effects of sex on any of the other composite variables. Additional correlations relating to sex can be found in the Supplemental Materials.

Unease About Reliance on Technology

Participants were more uneasy about their reliance on technology for memory purposes (Q43) to the extent that they believed that human and machine memory work similarly (C2, $r_s = .20$, $p = 1.3 \times 10^{-5}$), felt less enhanced by EM (C6, $r_s = -.21$, $p = 4.2 \times 10^{-6}$), experienced more EM retrieval failure (C7, $r_s = .34$, $p = 4.9 \times 10^{-14}$), relied more on EM (C8, $r_s = .21$, $p = 6.6 \times 10^{-6}$), did not believe it is possible to train memory (Q16, $r_s = -.16$), thought they were less good at judging the reliability of their own memory (Q17, $r_s = -.17$), understood their technology less well (Q48, $r_s = -.28$), took lots of notes (Q56, $r_s = .19$), wrote on their hand (Q58, $r_s = .21$), kept information on their computer less well-organized (Q59, $r_s = -.24$; cf. Hamilton, McIntyre, & Hertel, 2016), felt less strongly that it is important to be present for meaningful experiences (Q61, $r_s = -.19$), felt that recording takes away from the experience (Q63, $r_s = .20$), less frequently remembered where/how to find information in EM that they can't remember themselves (Q67, $r_s = -.21$), and were more frequently distracted (Q73, $r_s = .20$).

Personal Characteristics

Questions 70–73 asked about personal characteristics: general organization, nostalgia, liking to collect things, and distractibility. Nostalgia and liking to collect were positively correlated ($r_s = .28$). Organization and distractibility were negatively correlated ($r_s = -.19$). The other correlations among these four variables were not significant.

Participants who reported being generally better organized (Q70) also tended to report higher internal memory ability (C1, $r_s = .27$, $p = 3.0 \times 10^{-9}$), less experience of EM retrieval failure (C7, $r_s = -.33$, $p = 2.4 \times 10^{-13}$), less reliance on EM (C8, $r_s = -.20$, $p = 8.2 \times 10^{-6}$), and better organized computers (Q59, $r_s = .55$).

Nostalgia (Q71), commonly understood as a wistful longing for the past, showed itself to be a relevant personal characteristic for external memory attitudes and

behaviors. Participants higher in nostalgia valued EM more (C9, $r_s = .32$, $p = 6.7 \times 10^{-13}$), had more emotional responses to EM (C10, $r_s = .49$, $p = 9.0 \times 10^{-30}$), felt more strongly that it is important to be present for meaningful experiences (Q61, $r_s = .22$), felt more strongly that it is important to record meaningful experiences (Q62, $r_s = .26$), spent more time on Facebook (Q88, $r_s = .21$, cf. Davalos, Merchant, Rose, Lessley, & Teredesai, 2015), experienced more remembering due to social media (Q89, $r_s = .20$), did more technological collaborative remembering with family and friends (Q90, $r_s = .23$), and took more photos per day (Q118, $r_s = .18$). Nostalgia would be a fruitful topic for further research on external memory; reviews of the concept and relevant research can be found in Batcho (2013) and Sedikides, Wildschut, Arndt, and Routledge (2008).

Participants who liked to collect things (Q72) had more emotional responses to external memory (C10, $r_s = .25$, $p = 5.0 \times 10^{-8}$), more use of EM for personal experiences (Q68, $r_s = .23$), and more experiences of EM causing unwanted remembering (Q78, $r_s = .21$).

Participants who were more frequently distracted (Q73) also tended to report lower internal memory ability (C1, $r_s = -.27$, $p = 1.1 \times 10^{-9}$), more EM retrieval failure (C7, $r_s = .32$, $p = 5.4 \times 10^{-13}$), more reliance on EM (C8, $r_s = .23$, $p = 3.5 \times 10^{-7}$), more unease about reliance on EM (Q43, $r_s = .20$), greater frequency of writing on their hand (Q58, $r_s = .18$), greater frequency of looking something up instead of trying to remember it (Q65, $r_s = .27$), and more experiences of EM causing unwanted remembering (Q78, $r_s = .22$).

Other Variables

Here we highlight how some individual variables of particular interest correlated with the composite variables, as shown in Table 4.6. Participants who better understood their technology (Q48) were less likely to believe that human and machine memory work similarly (C2, $r_s = -.18$, $p = 6.9 \times 10^{-5}$), made more use of high-tech EM (C4, $r_s = .27$, $p = 1.8 \times 10^{-9}$), and personally valued EM more (C9, $r_s = .22$, $p = 7.6 \times 10^{-7}$). Participants who were more optimistic about human memory (Q51) had higher self-reported IM ability (C1, $r_s = .26$, $p = 1.4 \times 10^{-8}$), were more likely to believe that human and machine memory work similarly (C2, $r_s = .22$, $p = 1.7 \times 10^{-6}$), and relied less on EM (C8, $r_s = -.17$, $p = 1.5 \times 10^{-4}$). Participants who believed that taking notes improves internal memory (Q57) made more use of low-tech EM (C3, $r_s = .35$, $p = 4.0 \times 10^{-15}$) and high-tech EM (C4, $r_s = .19$, $p = 2.2 \times 10^{-5}$), felt more enhanced by EM (C6, $r_s = .23$, $p = 5.7 \times 10^{-7}$), and personally valued EM more (C9, $r_s = .20$, $p = 1.2 \times 10^{-5}$).

Participants who kept a well-organized computer (Q59) tended to report better internal memory ability (C1, $r_s = .21$, $p = 6.5 \times 10^{-6}$) and less EM retrieval failure (C7, $r_s = -.30$, $p = 2.1 \times 10^{-13}$). Participants who relied on search functions to find information on their computer (Q60) tended to report worse internal memory ability (C1, $r_s = -.17$, $p = 2.8 \times 10^{-4}$) and more EM retrieval failure (C7, $r_s = .27$,

$p = 3.7 \times 10^{-9}$). Computer organization and reliance on search were weakly negatively correlated ($r_s = -.13$), as these likely represent different personal information management strategies (see Chapter 6 Personal Information Management).

Participants who felt more strongly that it is important to make external records of meaningful experiences (Q62) felt more enhanced by EM (C6, $r_s = .21$, $p = 4.1 \times 10^{-6}$), personally valued EM more (C9, $r_s = .31$, $p = 7.9 \times 10^{-12}$), had more emotional responses to external memory (C10, $r_s = .26$, $p = 1.1 \times 10^{-8}$), took more notes (Q56, $r_s = .21$), felt less that recording takes away from the experience (Q63, $r_s = -.29$), made more use of EM for personal experiences (Q68, $r_s = .36$), were more nostalgic (Q71, $r_s = .26$), had more experiences of EM causing both wanted and unwanted remembering (Q77, $r_s = .21$; Q78, $r_s = .19$), engaged in more online social activity (Q83, $r_s = .25$; Q88, $r_s = .25$), experienced more remembering due to social media (Q89, $r_s = .27$), did more technological collaborative remembering with family and friends (Q90, $r_s = .26$), and took more photos per day (Q118, $r_s = .24$).

Participants who tended to look up information instead of trying to remember it (Q65) also tended to report worse internal memory ability (C1, $r_s = -.36$, $p = 5.6 \times 10^{-16}$) and made more use of all types of EM (C3, low-tech, $r_s = .18$, $p = 8.6 \times 10^{-5}$; C4, high-tech, $r_s = .20$, $p = 1.3 \times 10^{-5}$; C5, social, $r_s = .18$, $p = 5.2 \times 10^{-5}$). They felt more enhanced by EM (C6, $r_s = .17$, $p = 1.3 \times 10^{-4}$) and valued EM more (C9, $r_s = .16$, $p = 3.8 \times 10^{-4}$) but also experienced more EM retrieval failure (C7, $r_s = .28$, $p = 8.8 \times 10^{-10}$) and relied more on EM (C8, $r_s = .32$, $p = 8.1 \times 10^{-13}$).

Participants who more frequently used EM for personal experiences (Q68, episodic use) also tended to more frequently use EM for factual knowledge (Q69, semantic use), $r_s = .25$. However, there were differences in how these two variables related to the composite variables. For example, episodic EM use was positively correlated with the belief that human and machine memory work similarly (C2), while semantic EM use was negatively correlated with that belief. Semantic EM use was more strongly positively correlated than episodic EM use with high-tech EM use (C4), feeling enhanced by EM (C6), and reliance on EM (C8). Episodic EM use was more strongly positively correlated than semantic EM use with experiencing EM retrieval failure (C7) and emotionally responding to EM (C10). These patterns suggest that episodic and semantic use of EM are different practices and should be distinguished in further research.

Participants with higher levels of online social activity (Q83) personally valued EM more (C9, $r_s = .20$, $p = 1.8 \times 10^{-5}$), had more emotional responses to external memory (C10, $r_s = .19$, $p = 4.5 \times 10^{-5}$), experienced more remembering due to social media (Q89, $r_s = .42$), did more technological collaborative remembering with family and friends (Q90, $r_s = .35$), and took more photos per day (Q118, $r_s = .31$).

This concludes the results from our current study. In Part III of this book, we will tie the results together with a theoretical framework, as well as a guide to important dimensions, questions, and methods for future research. But first, in Part II, we will

provide a thorough interdisciplinary review of the disparate prior literature on external memory, including relevant theoretical frameworks from disciplines across the sciences, arts, and humanities.

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Part II
Literature Review (The Past)

Chapter 5

Theoretical Perspectives from Across Psychology



Relevant scholarship about external memory is scattered across disciplines. As the authors of this book, our perspectives have come from the discipline of cognitive psychology. But progress on a complex topic often requires convergence of disciplinary lenses (cf. astrobiology). Other authors have also argued for interdisciplinarity (Clark, 2001; Michaelian & Sutton, 2013; Sutton, 2010; van Dijck, 2007). Here we hope to provide some guideposts to assist further research. We will review a variety of theoretical perspectives that we see as fruitful for understanding the interplay between internal and external memory (see Turner, 2016, for another relevant review). As we review, we will also weave in relevant insights from our own data, reported in Chapters 2, 3, and 4. In the current chapter, we will review perspectives from across psychology, and in Chapter 6 we will review perspectives from other disciplines. To our knowledge, this book is the first time such a wide range of perspectives on this topic have been gathered together in one place.

Transactive Memory

One theoretical framework in psychology that has been applied to the study of external memory is *transactive memory* (for reviews, see Huebner, 2016; Peltokorpi, 2008; Ren & Argote, 2011; Weigel, Ezell, & Hazen, 2012). This framework was originally developed by Wegner, Giuliano, and Hertel (1985) to study the distributed and collaborative nature of memory in intimate human dyads. They defined transactive memory as having two components:

- (1) an organized store of knowledge that is contained entirely in the individual memory systems of the group members and (2) a set of knowledge-relevant transactive processes that occur among group members. Stated more colloquially, we envision transactive memory to be a combination of individual minds and the communication among them (Wegner et al., 1985).

Importantly, for a transactive memory system to work well, group members must have knowledge (a mental model) of the other group members' knowledge; that is, they must have an idea of who knows what. Examples of transactive processes that a dyad may engage in are dividing up memory tasks based on the partners' relative expertise (a differentiated structure; Wegner, Erber, & Raymond, 1991) or using interactive cueing to jointly remember a shared experience with richer and more emotional detail (an integrated structure; Harris, Barnier, Sutton, & Keil, 2014). Social distribution of memory has a long history. For example, in ancient Rome, enslaved people who were trained in the art of memory were called *graeculi* ("little Greeks"), and their job was to remember information about social and legal issues and thus help their masters when they needed information during debates or speeches. Based on analogy to the use of *graeculi*, Schönplugg and Esser (1995) proposed an idea quite similar to transactive memory.

Note that the transactive memory framework originally applied to *social* external memory, not technological external memory. Wegner (1987, pp. 187–189) did talk about technological external memory and how its use requires humans to internally encode the external location of information; however, he did not at that time relate technological external memory to the transactive memory framework. Only in more recent work have Wegner and others applied the transactive memory framework to one particular form of technological external memory, the Internet (Fisher, Goddu, & Keil, 2015; Sparrow & Chatman, 2013a, 2013b; Sparrow, Liu, & Wegner, 2011; Ward, 2013a, 2013b; Wegner & Ward, 2013). For example, Ward (2013b) conceived the Internet as a partner in people's transactive memory systems and highlighted how it is a supernormal stimulus that is different from human partners (due to its constant availability, depth, and breadth of information) and how this may lead people to both over-rely on it and confuse it for their own memory (cf. Fisher et al., 2015; Sloman & Fernbach, 2017; Ward, 2013a). We agree with Ward (2013b) about the ways that the Internet is quantitatively different from the minds of other people. However, in our view it is problematic to extend the transactive memory framework to encompass technological external memory (e.g., the Internet), because this potentially obscures important *qualitative* differences between social and technological external memory.

First, whereas it is straightforward to identify individual humans as social members of a transactive memory system, it is much less clear what scope should be used to identify technological "members" of a transactive memory system. The wide variety of responses we received to questions 112–116 and 128 shows the varied landscape of technological external memory used in everyday life (see also Adams & Aizawa, 2001, p. 61; Thompson, 2013, p. 131). Should all of a person's digital notes and photo albums be considered a single transactive memory member? What about when such items are stored on separate devices? Should a phone be considered only a single member or multiple members because of the variety of apps people use? The Internet itself is not a monolithic entity (Heersmink, 2016). We might trust the information from one website more than another (see Clowes, 2013, regarding trust), and we use the Internet in many ways. Should different uses of it (e.g., Wikipedia, IMDB, Google Calendar, Google Maps) be counted as

separate members? The fragmented nature of technological external memory is an issue recognized by researchers in personal information management (e.g., Karger, 2007; see also Chapter 6) and one that may be overlooked if we were to consider technological external memory to be a transactive memory partner in the same way that another person is.

Second, the retrieval processes of human and technological memory are fundamentally different. Human memory reconstructs and infers information (Roediger & DeSoto, 2015), whereas technological memory reproduces information. Another difference, as pointed out by Thompson (2013, p. 130), is that with technological external memory, the human user has more control over the retrieval process and can stop it at will without any social consequences (as opposed to interrupting a friend who is giving a lengthy answer).

Third, technological external memory has no agency and little to no mental model of the human user's knowledge. Thus, it cannot contribute to self-regulation of a transactive memory system as a human member could. It cannot collaborate. For this reason, Huebner (2016) argued that when we search the Internet, we are merely exploiting an external information resource (a one-way interaction), not engaging in transactive memory. With that said, technological external memory will likely continue to become less passive in the future¹; it is already active in certain ways: suggestions from Amazon and Netflix based on the previous choices of a user and many others, Facebook's sophisticated algorithm for news feeds, and Google's predictive search results. Artificial intelligence assistants (e.g., Apple's Siri, Amazon's Alexa, Microsoft's Cortana, and Google's Now/Assistant) will likely be able to learn to predict their users' needs and become aware of contexts. But the machine learning underlying such development is still fundamentally different from human memory, and achieving a human level of social awareness will be a difficult feat. For example, Sauter (2017) described cases in which Facebook has prompted users with unwanted reminders of a lost loved one or abusive ex-partner.

Rather than overextending the transactive memory framework, it may be better to apply it to just the social components of external memory, considered as part of a larger distributed cognitive system that includes both social and technological external memory, as suggested by Barnier, Sutton, Harris, and Wilson (2008; see also Sutton, Harris, Keil, & Barnier, 2010). For example, Harris et al. (2014) investigated shared remembering in couples, including the potentially complex interaction of social support and material resources for memory (technological external memory). In two older couples, the wife was the one in charge of regularly referring to a calendar or diary and relaying information to the husband. A parallel finding in our own survey was that, in response to Q98 about backup practices, eight participants reported that they rely on a family member or significant other to backup their computers. Thus, management of technological external memory in everyday life can be socially distributed. This is particularly salient for people with memory impairments, whose family members and caregivers play an essential role in assisting

¹For an in-depth consideration of the tension between artificial intelligence and augmentation of human intelligence, see Markoff (2015). See also Clowes (2013) for a discussion of autonomy.

everyday functioning, for example, by maintaining both physical and electronic calendars (Wu, Birnholtz, Richards, Baecker, & Massimi, 2008).

It is an empirical question the extent to which people do conceive of and interact with social and technological external memory similarly. Our results suggest differences. For example, the use of social external memory (composite variable C5) was only weakly correlated with the use of low-tech external memory (C3) and was not correlated with the use of high-tech external memory (C4, Table 4.5). Social external memory was also less used than both low-tech and high-tech external memory (Table 3.2) and was helpful for only 38% of participants for reminders about important events (Q129). It could be that social external memory has indeed been largely displaced by technological external memory (Ward, 2013b). Further research is needed to explore this and to compare how people use social versus technological external memory.

Some ideas from the transactive memory framework are useful even for nonsocial forms of external memory. For instance, based on our results, it appears that the distribution of information between people and their technological external memories is more integrated for episodic information (e.g., photos cueing 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).

Metacognition (Metamemory)

The use of external memory necessarily involves metacognition or, more specifically, *metamemory*: “people’s knowledge of, monitoring of, and control of their own learning and memory processes” (Dunlosky & Bjork, 2008; see also Dunlosky & Tauber, 2016). An earlier definition of metamemory by Flavell and Wellman (1975) encompassed both internal and external memory: “the individual’s knowledge of and awareness of memory, or of anything pertinent to information storage and retrieval” (p. 4), including “knowledge about how to search the external world intelligently” (p. 8). Flavell and Wellman even spoke to interactions between internal and external memory, using the example of searching for a lost pen: you first think of likely places (internal), and then search those places (external), and then perhaps what you see cues more internal memories about where to search next. They also reviewed research on children’s ability to devise both internal and external memory strategies. However, most subsequent metamemory research has focused on internal memory (Tauber & Dunlosky, 2016).

Our data suggest that in many cases, people are treating external memory as extensions of their own memory (e.g., Q91), and they are internally storing procedural and source knowledge about how and where to find certain information in external memory when it is needed (e.g., Q67, Table 4.3). The decision to look something up instead of trying to remember it (Q65) involves judgments about the likely contents, accuracy, and ease of access for both internal and external memory.

There must also be selection and execution of search strategies for external memory (cf. Jones, 2008), decisions about how long to keep searching, whether to switch strategies, how much information to extract, and judgments of confidence in retrieved information.

A unifying framework for metamemory research has been the one proposed by Nelson and Narens (1990, 1994; for an update see Dunlosky, Serra, & Baker, 2007) which showed the three stages of memory use—acquisition (encoding), retention, and retrieval—and both monitoring and control processes for each stage. It also identified and placed empirical measurements (e.g., judgments of learning, JOLs, which are a measurement of monitoring at the acquisition stage). This framework applies to internal memory; it could perhaps be expanded to encompass external memory as well. Many of the monitoring and control processes listed in Dunlosky, Serra, and Baker (2007, Table 6.1) could be adapted to external memory. The monitoring processes include ease-of-learning judgments, judgments of learning, feeling of knowing judgments, source-monitoring judgments, and confidence in retrieved information. The control processes include selection of kind of processing, item selection, termination of study, selection of search strategy, and termination of search. Koriat, Goldsmith, and Halamish (2008) provided a framework of control processes for internal memory that could be applied to external memory too. They included preretrieval processes (deciding whether to search, choosing a search strategy, and choosing an initial context of search), retrieval processes, postretrieval processes (updating and refining search strategy, evaluating retrieved information, inhibiting incorrect or irrelevant information, and deciding whether to continue searching), and report processes (deciding whether to report an answer and what level of detail to use in reporting).

Risko and Gilbert (2016) presented a framework for metacognition of cognitive offloading. In their framework, a decision between an internal and external strategy to accomplish some cognitive task is guided by beliefs and experiences about both approaches. The outcome of engaging in the selected strategy can influence the beliefs and experiences that will guide future decisions and may thus cause a drift toward relying on one strategy, such as GPS navigation instead of using unaided spatial memory.

Based on work by Schönplflug (1986a, 1986b, 1988), and by analogy to the *grae-culi* system used by the Romans, Schönplflug and Esser (1995) developed the idea of an *extended memory system*, in which a “master memory” was served by several “slave” components, which could be social or technological. The master component must have knowledge of the contents and functional features of its own memory and that of its slaves (*grae-culi*), and can initiate encoding and retrieval among them. The authors noted that social *grae-culi* could have knowledge of the master’s memory deficits and information needs, and thus could actively acquire relevant new information and deliver information to the master when appropriate, without the master having to initiate retrieval. Consider a law clerk who delivers legal documents to a judge for an upcoming case, without having to be asked. This is not so with technological *grae-culi*, which must be controlled by the master component (at least until A.I. becomes much better). Note the parallel to our discussion of transactive memory

earlier in this chapter. The master component's knowledge and control of the extended memory system are metamemory.

Esser (1996, see especially Fig. 1) refined the extended memory system framework by presenting a model of how people prepare for future retrieval by deciding where to encode information they will need later. For frequently encountered types of information, a "representational script" is automatically used (e.g., all information of type "appointments" is to be stored in their Google Calendar). If no applicable script exists, the person must choose from among the potential memory stores that come to mind (e.g., internal memory, spouse, note app on smartphone, writing on hand), and these are evaluated 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. If no acceptable stores are found, the person may search their memory for more potential stores and/or construct a new store. This model fits with Clark's principle of ecological assembly (2008, p. 13).

On the retrieval end, Arango-Muñoz (2013) considered factors that contribute to two aspects of metamemory for external memory: strategy selection and confidence. He proposed that a feeling of knowing about internal memory guides whether someone decides to try external memory instead. He also proposed that endorsement of (or confidence in) information retrieved from an external memory source may be granted automatically for trusted sources or else determined by criteria such as consensus across sources, intelligibility, coherence with held beliefs, and relevance to current goals. In an applied study, Kalnikaitė and Whittaker (2007) found that participants were willing to trade reduced accuracy for increased efficiency when choosing between retrieving information about a conversation from either internal memory or high-tech external memory which consisted of a voice recorder and digital note-taking device. Bray, Reilly, Villa, and Grupe (1997) proposed a neural network model that they used to simulate children's use of external memory strategies in a task that involved putting objects in certain places relative to other objects.

Models such as those reviewed here are useful because they explicitly highlight the metamemory aspects of using external memory and can help organize empirical findings and make new testable predictions. These models of monitoring and control are general and may work even across the variety of types of external memory we have documented in the current study. However, it may turn out that separate models will be needed to account for processes of encoding and retrieval with specific different forms of external memory (e.g., asking a spouse about that time you painted the roof together vs. hunting through a digital photo album for a picture of that episode).

There are several broader metamemory questions to guide research. How accurate are people's mental models of the arsenal of external memory stores available to them? How well do people understand the relative strengths and weaknesses of internal and external memory, and how judiciously do they employ them (cf. Finley, Tullis, & Benjamin, 2010; Intons-Peterson & Fournier, 1986; Serra & Metcalfe, 2009)? One interesting implication of a metamemory perspective is that variance in memory performance may be due in part to how strategically and efficiently someone interacts with their own internal memory and their armamentarium of external

memory, rather than variance being due solely to underlying differences in the characteristics of their internal memory (cf. Benjamin, 2008; Fiechter, Benjamin, & Unsworth, 2016). In a world so rich with external memory, knowing where to find information may well be just as important as knowing the information itself (Heersmink, 2016).

Exograms

Merlin Donald (1991, 1993, 2001) proposed a broad and detailed theory on the origin of modern human cognition and culture. The 1993 paper with commentaries is a good starting point. Donald's theory integrated evolutionary biology, anthropology, linguistics, psychology, and neurobiology. The theory began with the proposition that ancient hominids possessed both procedural and episodic memory. From those ancestors, modern human cognition and culture arose across three evolutionary transitions (2001, Table 7.1) that each added a new form of memory representation: first mimetics (the ability to mime or reenact complex gestures for representational purposes; cf. Ballard, Hayhoe, Pook, & Rao, 1997; Tversky, 2011), then language (speech), and finally *exograms*. Donald defined an exogram as "an external memory record of an idea" (1991, p. 314) and chose the word as a complement to the *engram*, which refers to a biological memory trace in the brain (Semon, 1921; see also Lashley, 1950). Although he conceived of external memory as we have in this book, allowing for both social and technological forms, he wrote mainly about the latter when it came to exograms, later even referring to "symbolic technology" (2001, p. 305). Donald argued that the ability to use exograms was enabled by the development of visuographic symbolic representations, which progressed from pictorial (e.g., sculpture, cave paintings), to ideographic (e.g., cuneiforms, hieroglyphs), to phonetic (e.g., an alphabet). See also Goody (1977), Ong (1982), and McLuhan (1962) regarding writing as technology that transformed human thought.

Donald proposed that exograms have several main properties that contrast with the engrams of internal memory (1991, pp. 314–319, Table 8.1). Exograms can be transferred between physical media, can be reformatted (e.g., using a variety of spatial layouts), can potentially be permanent, have unlimited capacity, can easily be displayed for prolonged availability to perception, and can be redesigned to offer multiple methods of retrieval (as we have seen with advances in computer search in the domain of personal information management). However, Sutton (2010, pp. 206–207) pointed out that not all exograms necessarily have the properties Donald lists; for example, they may be media-dependent.

Importantly, Donald argued that the advent of exograms, over many thousands of years, has had a profound impact on the role of internal memory. First, as others have also suggested, internal memory must be trained in the contents, use, and management of external memory. Second, exograms have allowed humans to circumvent the limitations and instability of internal working memory by providing an "external memory field" which he defined as a "cognitive workspace external to

biological memory” that “usually consists of a temporary array of visual symbols immediately available to the user” (1991, p. 297). For example, the words of this book as you read it are in your external memory field, as would be any notes you jot down in the paper margins or a digital document. The external memory field is the aperture through which we access the entirety of long-term external memory. Conscious mental activity is transformed when internal working memory is paired with the external memory field (2001, pp. 308–315). Some internal processing is delegated to perceptual systems instead of occupying internal working memory. The stable displays of information in the external memory field can be iteratively assembled, manipulated, and refined (think of composing a letter or working out a set of equations), and it is thus possible to develop more advanced and complicated thoughts than if we had been limited to using only internal working memory. This shifts the role of the conscious mind to that of an arbitrator, with the job of dancing between the internal and external memory representation systems (2001, Fig. 8.3), for example, while taking notes from a book (1991, p. 331). It also means that well-crafted artifacts of external memory (e.g., novels, movies, opera, video games) can induce extraordinary programmed experiences (to which we would add the learning experiences produced by intelligent tutoring systems, Aleven, McLaughlin, Glenn, & Koedinger, 2016).

According to Donald, the modern human mind is a multilayered hybrid of internal memory (episodic, mimetic, linguistic) and external memory (exograms). It is also dynamic: individual human minds are nodes that continuously form temporary linkages with different parts of the vast network of external memory, as well as with other minds (1991, Fig. 8.5). In this way, Donalds’ view was similar to the framework of distributed cognition (see also, embodied cognition, situated cognition).

Finally, Donald argued that the external augmentation of working memory is what enabled human cultures to achieve what he called theoretic development: creation of powerfully influential conceptual innovations such as rhetoric, grammar, logic, and eventually scientific theories. Indeed, collective endeavors such as science would be impossible without shared external memory such as the scientific literature. Overall, Donald provided a rich theory that can be mined for further empirical investigations into the interplay of internal and external memory. For further development of these ideas, including statements of explicit principles, see Rowlands (1999, pp. 119–147).

A framework of similar breadth to Donald’s was developed by Goonatilake (1991), who proposed three lineages of information flow that have stored and transmitted information throughout the history of life on this planet: genetic, neural-cultural (including internal memory and social external memory), and exosomatic (technological external memory, e.g., pheromone trails left by ants). Bates (2006, 2015) expanded on Goonatilake’s framework by proposing information forms that correspond to each lineage, as well as adding a fourth lineage, residue (traces of degrading technological external memory). Gillings, Hilbert, and Kemp (2016) considered the total information in the biosphere, and they outlined transitions in information storage and replication across the evolutionary substrates of chemistry, biology, culture, and technology. The trajectory of technological evolution becomes

unpredictable past a theoretical point of *singularity*, at which entities with superhuman intelligence emerge, whether AI or some form of posthuman (e.g., cyborg, uploaded consciousness; cf. Dick, 2003; Kurzweil, 2005; Masci, 2016; Smart, 2012; Vinge, 2008).

Prospective Memory

Prospective memory is “remembering to carry out intended actions at an appropriate point in the future” (McDaniel & Einstein, 2007, p. 1). Researchers of prospective memory have distinguished between time-based tasks (e.g., take the cockatiels to the veterinarian for a checkup at 2:00 pm, take the gluten-free brownies out of the oven after 35 min) and event-based tasks (e.g., buy limes when you next pass a store). Theorizers have given more attention to event-based tasks. As part of an edited volume on prospective memory, Hertzog (2008) provided an overview of several theories about how event-based prospective tasks are accomplished using purely internal processes (see also Dismukes, 2010). These theories generally involved multiple stages of processing: creation of an intention, deciding on conditions for action, maintenance of intention, retrieval of intention upon appropriate conditions, and carrying out the action. According to these theories, although the intention to act does not necessarily occupy working memory during the entire delay, there are nevertheless costs to ongoing performance of other tasks (Smith, 2003). R. E. Smith (2016, Fig. 12.1) presented a framework for the metacognitive monitoring and control processes needed for prospective memory tasks. However, as Smith noted, when people are establishing an intention to act later, they can alternatively choose to set up a reminder in the environment (external memory), such as an alarm or calendar alert, thus relieving their internal memory of the burden of intention maintenance and also converting time-based tasks into event-based tasks (Herrmann, Brubaker, Yoder, Sheets, & Tio, 1999).

Our data show that people are relying more on external than internal memory for prospective tasks (Fig. 4.1). Although R. E. Smith’s framework (2016) allowed for creation of reminders, and McDaniel and Einstein’s multiprocess framework (2000) allowed for exogenous capture of attention (e.g., due to an alarm), major questions remain largely unanswered. What different kinds of external memory aids do people choose to use for prospective tasks? When and why do they choose to use them? What metacognitive judgments are behind these choices? What problems do the aids solve, and what problems do they introduce?

Although the process of offloading is mostly not yet addressed by theories of prospective memory, some help in theorizing about external memory’s role in prospective tasks can be found in clinical work with memory-impaired patients. Thöne-Otto and Walther (2008) reviewed practices for improving impaired prospective memory. Compensatory strategies include internal memory strategies (e.g., visual imagery), social strategies of relying on other people (see Meacham, 1988), and both low-tech and high-tech external memory aids. Thöne-Otto and Walther

provided an excellent review of the advantages and disadvantages of different external memory aids, from paper calendars and post-it notes to specialized computer software and electronic devices. One distinction worth noting is passive versus active memory aids. Passive aids (e.g., to-do lists, writing on hand) simply contain a record of what the intended action is, but do not actively remind the user when to act, and thus are only useful if one remembers to check them, as noted by some of our participants in response to Q123. Active aids (e.g., alarms) do remind the user when to act and may or may not also contain a record of the intended action; a simple kitchen timer tells you when to act but not what to do, while a smartphone calendar alert can tell you both. Some aids also help with determining whether or not one has already done the intended task. For example, in a weekly pill organizer with a box for each day, if today's box is empty, then you can conclude you already took your medication (assuming the organizer is refilled on a weekly basis).

Herrmann et al. (1999) also provided a very helpful review of reminding devices, additionally covering individual characteristics of people more or less likely to buy and use such devices. The use of external memory for prospective tasks is not without potential for failure, as noted by some of our participants (Q131, e.g., losing a piece of paper or entering the wrong date) and noted by Herrmann et al. (1999) and Thöne-Otto and Walther (2008). In both reviews, coverage was given to PDA (personal digital assistants) devices. Although PDAs have been superseded by smartphones as of the early 2010s, most of the points made by the two reviews are still applicable. Current smartphones have the added abilities to use location services (e.g., GPS) and voice recognition (e.g., Siri, Google Now/Assistant, Cortana, Alexa), so, for example, it is possible to say to an iPhone, "Hey Siri, remind me when I get home to call Mom." Updated research covering the phone apps available today would certainly be useful, but we should also realize that this will be a perpetually moving target, and we should work toward theoretical frameworks that can accommodate changing technology.

Some research was done by Gilbert (2015a, 2015b) on participants' choices to make external reminders for prospective tasks in an experimental setting using short retention intervals (seconds). Participants had to drag circles out of the bottom of a box in a certain order but were also instructed to move some circles in a different direction than the others (e.g., right side of the box). They could hold the intention for the special circles in internal memory, or on some trials they could strategically offload the intention by moving the special circles toward their assigned locations at the start of the trial, forming a reminder for later. Gilbert (2015b) found that participants' creation of reminders was independently negatively correlated with both their predicted performance on an initial phase and their actual performance on an initial phase. That is, participants were more likely to offload when they believed their unaided performance would be poor and/or when it was indeed actually poor. Furthermore, the use of reminders improved performance. Gilbert (2015a) found that participants were more likely to offload when there were more special circles to remember (3 vs. 1) and when the task was interrupted by arithmetic problems. He also found a significant positive correlation with age.

Phillips, Henry, and Martin (2008) reviewed research on aging and prospective memory, both inside and outside of the laboratory, including the paradoxical finding that older adults tend to do worse than younger adults on prospective memory tasks in laboratory settings, but better in naturalistic settings (Moscovitch, 1982, pp. 74–75). Although one possible explanation for this pattern is that older adults make better use of reminders (external memory), evidence for this is still largely missing or inconclusive (though see Forsblad, 2016, for an ethnographic study of older adults' use of external memory strategies at home). Phillips et al. gave recommendations for future research on everyday prospective memory in older adults, including a useful table of types of ecological validity (Phillips et al., 2008, Table 8.1), that would be relevant for any external memory research. The variables identified in that table were setting (everyday life, complex real or virtual environment, laboratory), naturally versus artificially occurring tasks, and familiar versus novel tasks. In everyday life, prospective memory tasks involve many factors (Marsh, Hicks, & Landau, 1998). There is a need for further naturalistic data about how people use external memory for prospective tasks in their lives. Such data will contribute to developing the theoretical frameworks of prospective memory to include the use of external memory.

Working Memory

In our current study, described in Chapters 1, 2, 3, and 4, we have been concerned almost entirely with long-term memory (i.e., memory for information from more than a few seconds ago). However, the external world can also be exploited in service of *working memory* (i.e., the temporary limited capacity storage and manipulation of information; see Fig. 1.1). Working memory is a critical bottleneck in human cognition (Atchley & Lane, 2014; Miller, 1956). But humans can use external memory to circumvent the instability and limited capacity of internal working memory. In fact, Donald (1993) argued that the use of an external memory field (EXMF) was key in enabling the complex thoughts needed to develop theories. “In modern human culture, people engaged in a major thought project virtually *always* employ external symbolic material, displayed in the EXMF, as their true ‘working memory’” (1991, p. 329). Similarly, Rowlands (1999, p. 147) argued that working memory should be viewed as hybrid, composed of “both biological processes and processes of external manipulation of relevant information-bearing structures in the environment.” However, see Rupert (2004) for a counterargument to Rowlands, and see Coolidge and Wynn (2005) for an argument that a genetic mutation enhanced human working memory.

Some everyday examples of using external memory to support internal working memory include using pencil and scratch paper to solve math problems, cutting and pasting snippets of text in a word processor to compose one's thoughts, referring to an answer key while grading tests, drawing a map to redesign a garden or living room, and jotting down a cryptic verification code for online banking. Physicist

Richard Feynman once claimed that his old notes were not simply a record of his work, but rather they *were* the work (Clark, 2008, p. xxv).

There has been some research on cognitive offloading for working memory. For example, a number of studies have investigated how people strategically manage the trade-off between internal and external memory in a Blocks World task, in which participants using computers have to click and drag colored squares to recreate a target pattern. Ballard, Hayhoe, and Pelz (1995) found that participants preferred to repeatedly look at the target pattern as they build (external memory strategy) rather than trying to memorize it (internal memory strategy), even though the latter strategy took less time; this suggested that people try to minimize internal memory use rather than minimize time. However, Gray, Sims, Fu, and Schoelles (2006) made a version of the task in which the target pattern only appeared when the mouse cursor hovers over it, and they manipulated the delay of appearance (e.g., after 0 vs. 3 s). The bigger the delay was, the more participants tried to memorize the pattern themselves (internal memory strategy) instead of frequently revisiting the pattern on the screen (external memory strategy). Gray et al. explained their results in terms of a soft constraints hypothesis, in which strategies are chosen based on their cost-benefit trade-offs, and cost is a function of three factors: the time needed to encode the pattern, the time needed to retrieve the pattern, and the probability of successful retrieval. Note the parallels between this line of research and the research by Schönplflug (1986b, 1988) in which the costs of using external memory were manipulated for a long-term memory task. In an extension of the Blocks World research, Patrick et al. (2015) showed that the balance of internal and external strategy use was influenced by both the affordances of the task environment and participants' previous experience with the task. Risko and Dunn (2015) ran experiments using a short-term memory task in which some participants had the choice to write down letter stimuli versus memorizing them. They concluded that participants were motivated to offload in order to maximize accuracy (not minimize effort) and that participants' decisions were influenced by their metacognitive beliefs about the reliability of internal and external memory. That paper situated itself well in this unfolding literature and would be a good point of departure for further research.

Kirsh and Maglio (1994) proposed the idea of *epistemic actions*, which are “performed to uncover information that is hidden or hard to compute mentally.” For example, people playing the computer game Tetris regularly rotate the falling shapes to see where they will best fit, instead of using their own internal working memory to do mental rotation. The time costs of such actions are often outweighed by the benefit of information gained (Maglio, Wenger, & Copeland, 2003; however see also Maehigashi & Miwa, 2015). Cognitive resources dovetail temporarily with elements of the environment, forming what Clark calls “transient extended cognitive systems” (2008, p. 158).

A number of studies have focused on gestures and actions that bind internal and external memory. Tversky (2011) focused on the actions people take to organize things in space, in service of cognition (e.g., arranging food on pantry shelves or clothes in drawers). She called these *spractions*: “actions in space, whether on objects or as gestures, that create abstractions in the mind and patterns in the world,

intertwined so that one primes the others.” Maeda (2012) used Tversky’s framework in observing participants while they assembled Lego blocks. Ballard et al. (1997) adopted an embodied cognition view in which they argued that pointing movements (by eyes and/or hands) are deictic, in that they bind objects in the world to mental representation, which aids working memory (see also Agre, 1988). Along these lines, Carlson, Avraamides, Cary, and Strasberg (2007) investigated the use of pointing one’s finger during a counting task. Solman and Kingstone (2014) investigated head movement versus eye movement versus memory use in visual search tasks. Risko, Medimorec, Chisholm, and Kingstone (2014) investigated rotating one’s head to read tilted text.

Some studies have shown people’s use of external memory to support working memory tasks in everyday contexts. Shirouzu, Miyake, and Masukawa (2002) asked participants to shade $3/4$ of $2/3$ of a piece of origami paper and found that most of them used the external strategy of folding the paper several times to calculate the area, rather than the internal strategy of mental arithmetic ($3/4$ of $2/3$ is $1/2$). Shirouzu et al. also note that the creases in the paper constitute physical traces of participants’ external problem-solving strategy. Beach (1988) found that expert bartenders use a variety of glassware (a material mnemonic strategy) to alleviate the burden on working memory when preparing multiple drink orders quickly. Van Leeuwen, Verstijnen, and Hekkert (1999) proposed—based on case studies—that visual artists rely on sketches to create art in an iterative process of imagination, offloading (sketching), and perception. Several studies (e.g., Rose, 2001; Stevens, 1993) have found that restaurant servers use an array of memory strategies when taking orders, including external ones such as immediately placing syrup in front of a diner who just ordered pancakes. Kirlik (1998) observed cooks using locations on a grill to represent different levels of desired doneness for each order (e.g., rare vs. well done). Kirlik remarked: “Expertise in these everyday tasks clearly owes much to an ability to exploit regularities in the structure of the designed environment.” Altering the environment to serve memory is adaptive.

Zhang and Wang (2009) argued that coordination of information across internal and external representations is crucial for problem-solving (see also van Nimwegen, Tabachneck-Schijf, & van Oostendorp, 2006; Zhang, 1993, 1997; Zhang & Norman, 1994; Zhang & Patel, 2006). Zhang and colleagues have explored the role of external representations in a number of tasks. Zhang (1997, Fig. 1) provided a theoretical framework for the use of external representations during problem-solving. According to that framework, external and internal representations together form a distributed representation. External representations undergo perceptual operations, while internal representations undergo cognitive operations. Intervening between these operations and action are lookahead (mentally imagining actions), learned knowledge, and biases. Processes are coordinated by a central control component. An important aspect of this framework is that external representations can be accessed perceptually and do not need to be fully represented internally. In a sense, we can think of offloading onto external memory as offloading mental effort onto our perceptual systems. Note this is in a short-term problem-solving timeframe (e.g., a game of tic-tac-toe). For longer timeframes, we believe that internal representations of external memory are indeed important.

Walsh and Anderson (2009) found that participants can adaptively shift between mental calculation and use of a computer calculator; this study also disentangled strategy selection and execution by using detailed mouse cursor movement data. Cary and Carlson (2001) found that when participants were allowed to take notes while solving math problems, they did so in a way that was responsive to manipulations of the cost and benefit of making such notes. Using a mix of both external and internal memory requires coordinating between perception and working memory (Carlson, Wenger, & Sullivan, 1993).

All of these studies and frameworks suggest augmentation of internal working memory by exploiting and manipulating information in the world (cf. Brooks, 1991; Kirsh, 1996; Norman, 2013, pp. 74–122; O'Regan, 1992), to the extent that the benefits outweigh the costs. We think the main challenges in this research are in enumerating and operationalizing the costs and benefits on both the internal and external memory sides (e.g., time, glucose), and including other factors such as metacognitive beliefs.

Human Factors

Human factors (or ergonomics) is the study of interactions between humans and the nonhuman elements of a system. One of its major concerns is how to best design tools and interfaces to fit the physical and cognitive abilities of human operators. Human abilities of particular interest include perception, attention, memory, and motor performance. The theoretical approach of human factors is to treat human and machine as coupled components of a single cognitive system working toward a common goal, with each of the two components also having their own subsystems (e.g., input, processing, storage, output). The subsystems on the human side are based on information processing models from cognitive psychology (e.g., Shiffrin & Atkinson, 1969). The human-machine system operates on a particular task in the context of a working environment. Thus, task performance may be influenced by human operator variables, machine variables, and environmental variables (including the demands of the particular task).

In human factors, the interface between human and machine components is particularly important. A machine outputs information through displays, which the human operator perceives. The human operator outputs motor actions, which the machine receives through controls. When the form of information representation does not map well between human and machine, system performance suffers. For example, you pull on a door handle only to find that the door must be pushed. Or you misinterpret a road sign and turn too early or too late. Or you think a nondescript envelope in the mail is a junk advertisement when it is actually your new debit card. Or you think that the pizza delivery webpage is saying your order has been placed, when it is actually asking you to confirm the order one last time. Hutchins, Hollan, and Norman (1986) described the gulf of execution (figuring out how a machine operates) and the gulf of evaluation (understanding a machine's output). It

is particularly important for the human operator to have an accurate mental model of the machine component, which can be achieved by better design, human learning, or both.

This overall framework parallels other viewpoints we will review in Chapter 6, such as personal information management and the extended mind theory in the philosophy of mind. The human factors framework has the added advantage of being well established and fruitfully used in applied domains ranging from aviation to human-computer interaction. The related framework of *distributed cognition* (Hollan, Hutchins, & Kirsh, 2000) furthermore allows for multiple humans to be included in the cognitive system. A team of humans may work in concert with technology and the environment to achieve something that none of the system components could do alone. Hutchins (1995) used cognitive ethnography methods to study ship navigation, which he came to see as a flexible complex system in which computations were carried out by coordinated interactions of the crew with each other and their navigational tools and environment. Task-relevant knowledge is distributed across system components and embedded in cultural practices. Individual humans in the system may not need to know everything, but they do need to know what their role is.

The unit of analysis is the cognitive system. But determining the boundaries of a given system is not trivial (see Hutchins, 2010, on *cognitive ecology*); what components should be included? Norman (1993, p. 43) remarked that external aids to cognition are what make humans smart and that these aids can take the form of social interactions, physical environment, and cognitive artifacts.

In terms of the environment, Kirsh (1995, 1996) argued that management of the physical space immediately around us is an integral part of human cognition and behavior and that space is as limited and important a resource as time, memory, or energy. Using examples from cooking, supermarkets, and assembly lines, Kirsh (1995) proposed three purposes for which humans arrange space around them: simplifying choices, simplifying perception, and simplifying internal computation. In these ways, we adapt the environment to ourselves (Kirsh, 1996; see also Kirlik, 1998; Norman, 1993, pp. 155–184; Tversky, 2011). The same principles readily apply to virtual space (e.g., windows on a computer screen). Ross and Schryer (2015) provided policy recommendations for environmental alterations to support memory in aging adults.

Cognitive artifacts are “human-made, physical objects that functionally contribute to performing a cognitive task” (Heersmink, 2013; see also Hutchins, 1999; Norman, 1991, 1993). Heersmink (2013) proposed a taxonomy of cognitive artifacts with two broad functional categories. Representational artifacts represent other things and may be iconic (e.g., map), indexical (e.g., compass), or symbolic (e.g., abacus). Ecological artifacts exploit the world as its own best model (Brooks, 1991) and may be spatial (e.g., car keys placed on the counter) or symbolic (e.g., shapes in Tetris).

Different cognitive artifacts have different *affordances*: actions or operations that they enable (see Gibson, 1979; Norman, 2013). A printed book affords close reading and reflection. A digital text document (e.g., PDF) affords accurate searching for

specific words. Movies afford engaging experiences. Taking notes on a laptop computer affords rapid entry of text, but not easy drawing of figures. Text messages afford rapid scanning; voice messages do not. Norman (1993, p. 78) described two views of cognitive artifacts: from a personal view, cognitive artifacts change the task the person does; from a system view, the person combined with the cognitive artifact performs better than either alone, and entirely new ways of thinking may emerge. For a discussion of cognitive technologies (a similar concept to cognitive artifacts), see Clark (2001, Chapter 8), Dascal and Dror (2005), Dror and Harnad (2008), and Walker and Herrmann (2004). The introductory overview given by Herrmann (2004) is particularly helpful. Zhang and Norman (1994) discussed the different roles that external representations can play in cognition.

A human factors approach is readily applied to internal and external memory. In our view, all forms of technological external memory qualify as cognitive artifacts. Norman (Norman, 2013, Chapter 3) discussed knowledge in the head versus knowledge in the world, how they combine, and their relative strengths and weaknesses. External memory tools can be better designed to work with internal memory by providing signifiers (perceptual cues to affordances; cf. user interface design, Krug, 2014). Another relevant concept in human factors is *automation*, which is when the machine components of a system perform a function previously performed by human operators. An important part of automation is function allocation, coordinating which component of the system best handles a certain function (Price, 1985). Parasuraman, Sheridan, and Wickens (2000) outlined a framework of different types of automation and noted that “automation does not simply supplant human activity but rather changes it, often in ways unintended and unanticipated by the designers.” This observation applies to the trends we see in our data, with the changing interplay of internal and external memory as more tasks of memory become automated. For a discussion of external memory cues in design, see van den Hoven and Eggen (2014). Van House and Churchill (2008) outlined “technologies of memory” and discussed how they are curated and made accessible; they argued that such technologies will increasingly shape how human memory is used, a trend borne out by our data.

Human factors also provides useful taxonomies for categorization of human errors (see Sharit, 2012, for a thorough review). Human errors can be classified in various ways, such as the type of failure, the type of action that led to the error, the stage of processing the operator was engaged in, and the intentions of the operator (Proctor & van Zandt, 2017). Based on types of action, we can distinguish between errors of omission (e.g., forgetting to buy post-its at the store) and errors of commission (e.g., buying staples when you did not need them). Based on intentions, we can distinguish between slips and mistakes. A slip (also called skill-based error) is when someone performs an action they did not intend; thus it is a failure of execution. Norman (1981, 2013, pp. 170–179) further distinguished between various types of slips, such as memory-lapse slips (e.g., leaving your original document in a photocopier) and mode error slips (e.g., changing the time on an alarm clock when you intended to set the alarm). A mistake is when someone performs an action they did intend, but their intended plan is incorrect; thus it is a failure of planning.

Mistakes may be rule-based or knowledge-based (Rasmussen, 1982; see also Reason, 1990). For a helpful view of human errors that integrates across several taxonomies, see Wickens, Hollands, Banbury, and Parasuraman (2012, Fig. 9.13). For a comprehensive applied framework, see Wiegmann and Shappell (2003).

Participants in our study described a variety of human errors in using external memory (Chapter 3), most of which could be categorized as slips (e.g., accidentally deleting files, entering the wrong time for an event). But many failures of external memory were technological (e.g., hard drive crashing, battery dying) and thus fall outside the taxonomies of human error. Thus, in addition to human errors, it is important to consider technological and organizational causes of failures. Understanding errors can help improve the interplay of internal and external memory. For example, Vemuri and Bender (2004) considered an audio-based memory aid with respect to Schacter's classification of seven sins of memory (2002) and a classification of workplace memory problems by Eldridge, Sellen, and Bekerian (1992) who identified three classes of memory problems: retrospective, prospective, and action slips. Finally, *task analysis* is a relevant method in human factors that can be used to identify the steps of a process by observing ordinary use (Sharit, 2012); this can help us understand exactly how people are using different types of external memory, what cognitive processes are required of them, and where errors may arise. Errors are just one part of *usability* (Lewis, 2012).

Cognitive Rehabilitation and Other Clinical Practices

Human existence is built on modification of the environment. We rely on our tools and surroundings to function. This becomes even more obvious for people with physical or cognitive impairments due to injury, illness, or disability. In the fields of clinical neuropsychology and occupational therapy, *cognitive rehabilitation* is therapy that aims to restore normal functioning or compensate for cognitive deficits. Cognitive rehabilitation includes interventions such as learning new compensatory strategies, adapting the environment to fit the person, and using *assistive technology* (Anson, 2011; Wilson, 2007). The use of assistive technology to help people with memory impairments parallels the use of external memory in people without impairments. Thus, theoretical frameworks used in cognitive rehabilitation are broadly relevant for the study of external memory.

One major framework used in occupational therapy is the Person-Environment-Occupation-Performance (PEOP) model (Christiansen, Baum, & Bass, 2015), which organizes the mutual influences of performance and participation for a meaningful task (occupation), intrinsic factors (person), and extrinsic factors (environment, including social, built, natural, and technological). Note that this framework is similar to others we have reviewed in this chapter (human factors), and that we will review in Chapter 6 (media studies, and anthropology), in that it emphasizes the interaction between person, task, and environment. Some models specifically address assistive technology. The Human Activity Assistive Technology (HAAT)

model (Cook & Polgar, 2015) has human, activity, and technology interacting atop an environmental context. The Human-Environment/Technology Interface (HETI) model (R. O. Smith, 1991) is very similar to human-machine system models used in human factors. For a cognitive psychology perspective on theories of memory improvement, see McEvoy (1992).

Technological external memory can be considered a type of assistive technology. Assistive technologies may be specially designed for rehabilitation, or they may be mainstream. They may be low-tech or high-tech. Low-tech examples include simple paper checklists or visual support tools such as incentive charts that can remind people of goal behaviors and show them their progress. High-tech examples include electronic calendars to remind people of events and electronic pill boxes with alarms to remind people to take medication. The website AbleData.com maintains an index of assistive technology (2016). There have been numerous reviews of external memory aids (or prosthetics) and evidence on their effectiveness (Charness, Best, & Souders, 2012; de Joode, van Heugten, Verhey, & van Boxtel, 2010; Fish, Wilson, & Manly, 2010; Herrmann et al., 1999; Jamieson, Cullen, McGee-Lennon, Brewster, & Evans, 2014; Intons-Peterson & Newsome, 1992; Lopresti, Mihailidis, & Kirsch, 2004; Kapur, Glisky, & Wilson, 2002, 2004; Mahan, Rous, & Adlam, 2017; Thöne-Otto & Walther, 2008; Worthen & Hunt, 2011, pp. 112ff). R. O. Smith (2016) gave an overview of the challenges in measuring outcomes of assistive technology interventions. Research has mostly focused on aids for prospective memory.

Alerts, alarms, and reminders are common forms of external memory often used for prospective purposes, but they are of particular importance in clinical applications. For example, an alert might remind a patient to take their medication or schedule a follow-up appointment. An alert might remind a healthcare worker to conduct a screening examination on a patient, or it might warn them of a patient in need of attention. But having too many alerts is counterproductive, as people can become habituated to them, a phenomenon referred to as “alarm fatigue,” “alert fatigue,” or “reminder fatigue” in the medical literature (Backman, Bayliss, Moore, & Litchfield, 2017; Cvach, 2012; Shivers, Mackowiak, Anhalt, & Zisser, 2013). Green, Nease, and Klinkman (2015) described and tested a system for reducing reminder fatigue, based on principles from human factors and cognitive psychology. This issue illustrates the need to work toward a better symbiosis of internal and external memory and cognition.

There have been a few examples of clinical research on assistive technology for retrospective memory. For example, looking at pictures from a wearable camera helped people with Alzheimer’s disease and other memory impairments to later retrieve episodic memories (Berry et al., 2007; Woodberry et al., 2015). A review of research on wearable cameras as assistive technology for people with impaired memory can be found in Allé et al. (2017; see also Silva, Pinho, Macedo, & Moulin, 2018). Gillespie, Best, and O’Neill (2012) provided a review with a classification of assistive technologies based on functions (e.g., reminding, navigating, storing, and displaying; see also O’Neill & Gillespie, 2015). In an updated review, the same authors further distinguished between technologies that augment versus supplant human function (Best, O’Neill, & Gillespie, 2014).

An emerging clinical application of external memory is to preemptively make records of the life stories and favorite things (e.g., songs, food) of a loved one with declining memory before they have to enter “memory care” assisted living facilities. This way, unrelated caregivers can easily gain background knowledge of the person with dementia, potentially improving interactions (Johnson, 2017; MemoryWell.com). This is a special case of the broader use of high-tech external memory to preserve people’s oral histories (e.g., StoryCorps.org).

Another clinical use of external memory is expressive writing therapy, a subset of art therapy. Having people write about their thoughts and feelings regarding a traumatic experience has been found to improve their mental and physical health. For a review of empirical studies and discussion of potential mechanisms behind the effect, see Pennebaker and Chung (2011). For a review of the use of diaries in clinical psychology, see Thiele, Laireiter, and Baumann (2002). Finally, whereas diaries and expressive writing focus on *encoding* to external memory for therapeutic purposes, bibliotherapy focuses on *retrieval* from external memory, such as reading books, for therapeutic purposes (see McCulliss, 2012, for a review).

Offloading Beyond Memory

For a review of offloading that extends beyond memory to include other cognitive tasks (e.g., perception, arithmetic, counting, and spatial reasoning), see Risko and Gilbert (2016). For an overall framework for thinking about distributed cognition, see Poirier and Chicoisne (2006). For the implications of distributed cognition in education, see Pea (1997). For a view of visual perception that considers the world as an external memory, see O’Regan (1992). For the topic of organizational memory (i.e., memory of an organization or institution, also institutional memory), see Bowker (1997), Linde (2008), and Walsh and Ungson (1991). For an excellent popular press overview of technology’s influences on multiple facets of cognition, see Thompson (2013). For an interdisciplinary scholarly discussion of whether the Internet is changing the way humans think, see Brockman (2011).

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Chapter 6

Theoretical Perspectives from Other Disciplines



Memory is a topic that cuts across numerous scholarly disciplines. This is particularly true for external memory, which has been a subject of inquiry in several disciplines outside of psychology. Having reviewed perspectives from across psychology in Chapter 5, we will now review perspectives from these other disciplines. Such an interdisciplinary review is valuable for informing further empirical and theoretical work on the interplay between internal and external memory.

Philosophy of Mind

To what extent do external objects and processes constitute part of the mind or at least interact closely with it? This question has received vigorous attention and debate from philosophers of mind, more so than from experimental psychologists. The nuanced terminology used in this literature can be confusing to the uninitiated. For an accessible and cogent overview and history, we highly recommend Michaelian and Sutton (2013), which used the banner term *distributed cognition*. That paper also incorporated the perspectives of both philosophy and empirical memory research, with suggestions for how they can inform each other, and ideas for further research. Another helpful point of entry is Wilson's (2002) description of six different views on the term *embodied cognition* (compare especially views 3 and 4: "we offload cognitive work onto the environment" vs. "the environment is part of the cognitive system"). Anderson (2003) provided a more detailed field guide to embodied cognition in the context of artificial intelligence, and Dawson (2013) gives a thorough treatment of embodied cognition in the context of cognitive science.

In a highly influential landmark paper, Clark and Chalmers (1998) proposed the idea of the *extended mind*: the human mind extends into the world, because parts of the world function as parts of our cognitive systems (extended cognition). From this idea, others have developed a view of human cognition as hybrid or integrated (Menary, 2007, 2010a; Rowlands, 1999, 2010; Sutton, 2010; Sutton, Harris, Keil, &

Barnier, 2010; Wilson, 2004), in that it is distributed across biological and non-biological substrates (hence the term distributed cognition; Hutchins, 1995).¹ There has been much debate over whether external objects and processes truly constitute part of cognition (the hypothesis of extended cognition, HEC; e.g., Clark, 2010) or are merely being coupled with a cognitive agent (the hypothesis of embedded cognition, HEMC; e.g., Adams & Aizawa, 2010; Rupert, 2004). See Menary (2010a, Figure 10.1) for one attempt to reconcile the two views.

Whether we decide to label external memory as properly a part of the mind or not (Michaelian, 2012), it is important to understand how people use external memory and how it interacts with internal memory. Fortunately, as explained by Sutton (2010) and Menary (2010a), the philosophical literature has shifted toward emphasis on the *complementarity* of internal and external processes: we integrate external objects and processes that complement rather than duplicate our internal abilities. Tools enhance thinking (Dennett, 2000), and using them is one way we transform difficult problems into easier ones (Sterelny, 2004). Internal and external components of a cognitive system can “play different roles and have different properties while coupling in collective and complementary contributions to flexible thinking and acting” (Sutton, 2010, p. 194). Thus we need to understand “the range and variety of types of cognitive scaffolding, and the different ways in which non-biological scaffoldings can augment (or impair) performance on a task” (Clark 2002, p. 29).

Heersmink (2013) proposed a taxonomy of *cognitive artifacts*, which he defined as “human-made, physical objects that functionally contribute to performing a cognitive task.” He proposed three types of representational cognitive artifacts: iconic (e.g., map), indexical (e.g., compass), and symbolic (e.g., abacus); he also proposed two types of nonrepresentational (ecological) cognitive artifacts: spatial (e.g., car keys placed on the counter) and structural (e.g., shapes in Tetris). Menary (2007, 2010a, p. 237) outlined different ways that internal and external components can interact (e.g., biological coupling, epistemic actions, self-correcting actions, cognitive practices). Heersmink (2015) also outlined possible dimensions of integration, including information flow, reliability, durability, trust, procedural transparency, informational transparency, individualization, and transformation.

Clowes (2013) provided a thoughtful discussion of the possible effects on humans of transitioning from low-tech external memory to high-tech external memory (which he calls E-Memory), in the context of both the HEC and HEMC philosophical views. He pointed out that the answer to the question of whether increased reliance on external memory diminishes us as people depends on whether we think of external memory as part of our selves (HEC) or not (HEMC). The former implies a mere reconfiguration of the cognitive agent, the latter a diminishment. Clowes also proposed four key features of E-Memory that afford enhancement of cognition: totality, practical cognitive incorporability, autonomy, and entanglement.

In a further paper, Clowes (2015) applied these ideas to the Internet and wearable technology as external memory. P. Smart (2012) also applied the extended mind

¹ Note that while much of the discussion in this literature has focused on technological extensions, most perspectives have also acknowledged that extensions could be social (cf. Tollefsen, 2006).

idea to the Internet, considering the importance of both technology and social conventions and speculating about how future changes in the Internet might affect humanity. Fiore and Wiltshire (2016) considered both social and technological external cognition in the context of team cognition. Stiegler (2010) considered the historical dependence of human memory on external aids, which he called hypomnesia. Floridi (2014) considered how information and communication technology has altered human identity. All of this work provides a philosophical counterpart to psychological work such as that by Ward (2013), Sparrow, Liu, and Wegner (2011), and Storm, Stone, and Benjamin (2016).

Dynamic Systems

Dynamic/dynamical systems theory (see also complex systems, cybernetics) is an approach for understanding a system in which multiple components continuously and simultaneously influence each other over time. It provides a complement to the representation and computation frameworks traditionally used by cognitive psychology (Clark, 2008, pp. 23–28). For a good introduction to dynamic systems theory in the context of cognition, see Clark (2001, Chapter 7) and van Gelder and Port (1995). Hutchins (2010) provided a history of the influence of the dynamic systems approach on ecological psychology, and Sawyer (2005) illustrated the concept of emergence at multiple levels of analysis in social systems.

Across time, a dynamic system moves on trajectories through a space of possible states. The system may converge toward a subset of state space known as an attractor or away from a subset of state space known as a repellor. Complex patterns (e.g., flocking of birds in flight) can emerge from even simple interactions of system components. Components in a system can be joined in causal feedback loops that are positive (e.g., an arms race) or negative (e.g., the relationship between eating and hunger). Broadly, we can conceive of internal and external memory in a negative feedback loop: the more reliable and efficient one component, the less the other component is used. This is only a very basic example of how dynamic systems theory may be useful for studying the interplay of internal and external memory. The landscape of one's internal memory over time may be governed by attractors and repellers. That is, it may be shaped by factors such as what is easy to save and revisit in external memory, what emotions and stories one most wants to preserve, and what the environment readily reminds one of.

Dynamic systems theory may be useful for the study of external memory in a variety of other ways, for example, formalizing theories to account for distributed cognitive processes such as those carried out by the ship navigators and their tools that Hutchins studied (1995). Greeno (1998) used dynamic systems theory as part of his situative perspective on learning (e.g., analyzing behavior patterns as attractors). For social external memory, there is the interactive cueing of partners in a dyad (Harris, Barnier, Sutton, & Keil, 2014). The development of collective memory in a social network can be analyzed as an emergent property of a dynamic

system (Coman, Momennejad, Drach, & Geana, 2016). Heylighen (2016) described the useful concept of stigmergy: a coordination mechanism whereby an action (e.g., writing) leaves a trace in a medium (e.g., paper) which then prompts further action (e.g., more writing). However, both Hutchins (2010) and Clark (1997, 2008) warn that the dynamic systems approach by itself may be inadequate to account for real-world intelligent actions involving humans.

Personal Information Management

Personal information management (PIM) is a cross-disciplinary field of study that has considered external memory extensively, though not necessarily using the same terminology. PIM “refers to both the practice and the study of the activities people perform in order to acquire, organize, maintain and retrieve information for everyday use” (Jones & Bruce, 2005). We recommend the following as overall references: Bergman and Whittaker (2016), Jones (2007, 2008, 2012, 2013, 2015), Jones and Teevan (2007), Marshall (2008a, 2008b), and Whittaker (2011).

In their description of what constitutes an information item, Jones and Teevan (2007, p. 9) made a clear distinction between internal and external memory: “A person’s memory of an impending doctor’s appointment is not an information item. The scrap of paper containing a written reminder of this appointment is an information item.” PIM also addresses the challenges of managing multiple information forms or types, just as we have discussed low-tech versus high-tech external memory. Jones (2007) proposed a *personal space of information*: an amorphous set of information that a person can access (or should be able to access) and that is personal in one or more of the following ways: is possessed by the person, is about them, is directed toward them, is sent by them, was experienced by them but no longer possessed by them (e.g., library books), and/or is relevant to them.

Note that this conception includes both episodic and semantic forms of external memory. Note also that there are several other dimensions implicit in this conception: who or what created the information (e.g., oneself, another person, or an automated process; cf. Hertel, 1993; and reality monitoring notions from Johnson & Raye, 1981), who is the intended audience of the information, and who or what is the subject of the information. This corresponds to the diamond framework in photography that we will encounter later in this chapter (Frohlich, 2004).

Jones (2007) furthermore proposed that people engage in three major types of PIM activities: keeping, finding/refinding, and meta-level activities. By our interpretation, keeping is the encoding of information into external memory. Finding is the retrieval of new information from external memory. Refinding is the retrieval of previously encountered information from external memory, and this activity may be guided by some internal memory of the previous encounter (e.g., approximately when and where the information was last encountered). Meta-level activities performed on a personal space of information include organizing (e.g., using a folder structure or file tagging scheme), maintaining (e.g., backing up files, updating file

formats, synching information across devices), managing privacy and the inbound and outbound flow of information, and evaluating the efficacy of one's own PIM activities. Jones saw the purpose of PIM activities as mapping between needs (i.e., goals) and information. Whittaker (2011) offered an alternative framework of PIM activities, based on a curation life cycle: keeping, management, and exploitation. He saw exploitation as specifically applied to personal information that one has already kept, whereas Jones's conception of finding/refinding could also apply to public information.

The theoretical frameworks used in the study of PIM are useful because they suggest specific activities where researchers can study the interplay of internal and external memory in everyday life. For example, finding information in external memory appears to often be a multistep process (Jones & Ross, 2007; Lansdale, 1988; Teevan, Capra, & Quiñones, 2007): remembering to look (a challenge that is sometimes met by leaving piles of information as visible reminders), recalling enough about the desired information to initiate navigation or search (e.g., a general location such as the purple filing cabinet or a search term like "wedding photos"), and then recognizing the desired information among candidates returned by the recall-directed search. These last two steps are similar to the generate-recognize strategy for internal memory retrieval (Watkins & Gardiner, 1979). With external memory retrieval, the recall and recognize steps may need to be repeated in iterations, for example, if the initial search returned too many or too few results. There are multiple strategies for retrieval from external memory (e.g., navigating/wayfinding through file structures or using desktop search functions), but all seem to involve some interplay between recall and recognition (Jones, 2007, pp. 93–95). Our data showed interesting contrasts between keeping a well-organized computer (Q59) and relying on search functions to find information (Q60; see Chapter 4 Correlations: Other Variables). It is worth noting that sometimes we simply browse external memory to reminisce, rather than trying to find something specific.

Keeping (i.e., encoding) is also a multifaceted activity, involving decisions about whether some new piece of information is worth saving for the future (a signal detection task; Jones, 2004) and decisions about where and how to keep it. Such decisions are difficult because they require us to predict the needs and contexts of our future selves (cf. Bjork, 1994; Mäntylä & Nilsson, 1988; Rhodes, 2016; Tullis & Benjamin, 2015) and to weigh the costs of keeping too much (interfering with retrieval of relevant information, distraction) against the costs of keeping too little (not having information we end up needing). Whittaker (2011) provided an excellent review of research on keeping practices for several information formats, including paper, email, contacts, webpages, and photos. He also pointed out several factors that influence our keeping decisions, such as uniqueness (privately made items vs. publicly available), whether an item is actionable or not, and loss aversion (Kahneman & Tversky, 1979).

Research reviewed by Whittaker (2011) and some of our own survey data (Q120) suggest that people tend to keep more information than they use, especially with digital technology (photos: Whittaker, Bergman, & Clough, 2010; email: Dabbish, Kraut, Fussell, & Kiesler, 2005). Whether such "overkeeping" is a bad thing depends

on one's view of the purpose of external memory (the two first authors of this book enjoy disagreeing about this). As our survey data show (Q119, 122, 127), people store information in external memory for a variety of reasons, not all of which are easily accommodated by PIM frameworks, which primarily treat keeping activities as serving future intentional retrieval and use. Other research confirms this. Reasons for keeping found by Marshall and Bly (2005) were useful future reference, reminders for action, evoking internal episodic memories, and sharing. Reasons for keeping found by Kaye et al. (2006) were finding information later, building a legacy, sharing resources, insuring against loss, and identity construction. Note that we may sometimes keep information without the intention of specifically searching for it again, but rather as mementos which may incidentally remind us of an experience if we ever happen to come across them (e.g., a concert ticket stub tucked into a shoebox, Marshall, 2007; see also Zhang, Kim, Brooks, Gino, & Norton, 2014).

Whatever the intentions at the time of encoding information to external memory, the organization used will impact any future retrieval attempts. For external memory, encoding is much easier than retrieval. In human history, the development of new external memory technologies, from cuneiform tablets to digital libraries, has followed a pattern: an explosion of encoded information followed by belated scrambling efforts to improve organization and facilitate retrieval (Blair, 2010; Rumsey, 2016; Taylor & Joudrey, 2008, pp. 67–88; Thompson, 2013, pp. 115–146; Whittaker et al., 2010). Also, external memory does not inherently forget, which would act as a check on the volume of information amassed (Locke, 2000; Mayer-Schönberger, 2011). Thus, organization is crucial. Organization practices vary across individuals, task characteristics, and information formats (Gwizdka & Chignell, 2007; Malone, 1983). Often organization efforts are only made at the time of encoding; we rarely take the time to overhaul our entire organizational systems, unless prompted by extrinsic events such as a move or a new job (Whittaker, 2011, p. 17). People do not seek to optimize their external memory tools but rather are more likely to *satisfice* (Simon, 1956)—that is, to adjust their system so it is just good enough to meet their short-term goals.

Two common organization strategies implemented at encoding are filing and piling (Malone, 1983). Filing is the placing of items into a carefully constructed hierarchical folder structure. This can assist retrieval by providing a coherent well-labeled structure to navigate, which can work well for specific projects (e.g., planning a wedding), but less so for general future reference. Filing requires upfront effort and is vexed by the problem that we are generally not good at using labels consistently (Lansdale, 1988). This is in part due to the ambiguity of language (Dumais & Landauer, 1983), and in part due to the fact that items can be classified in multiple ways, and we may not use the same classification or keyword labels at the time of encoding and the time of retrieval. For example, a single photo could reasonably be saved in a folder for an event (“bourbon distillery tour”), a location (“Louisville”), a year (“2016”), or a friend’s name (“Jason” or “Farah”). Retrieval will be difficult if we saved the photo by event but we later try to find it by location or using the term “whiskey” instead of “bourbon.” The multidimensional representations of internal memory (Rosch, 1978) can be difficult to implement in external memory.

As opposed to filing, piling is the placing of similar items into piles that have no deeper structure. These piles, especially physical ones, require less upfront effort than filing and can have the advantage of keeping information visible and exploiting our internal memory for spatial location (Lansdale, 1991). However, this comes at the cost of eventual clutter and visual distraction. Whether filing, piling, or tagging, the organization and labels used in external memory are typically a reflection of the user's categories in internal memory (Jones & Ross, 2007).

New technological tools may automate some of the burden of keeping and organizing (e.g., automatic keyword generation or face recognition for photos), but having to manually handle those very burdens promotes our internal memory representations of our external memory stores (Jones & Ross, 2007). External memory systems that actively engage the human user could circumvent this fault (e.g., Catarci, Dong, Halevy, & Poggi, 2007; Jones, 1986). Technology necessarily intermediates between humans and our information (Jones, 2012, 2013).

In 1945, Vannevar Bush conceived a then-theoretical recording and storage device, *memex*, that would provide an individual with “an enlarged intimate supplement to his memory.” Bush's ideas, which included a head-mounted wearable camera, presaged many of the information management issues that would come with the information age (Toffler, 1970).

Even when we are able to find the information that is currently most relevant, the way the information is displayed can facilitate or impede our use of it. Research on *visualization* is thus also important for external memory. References we recommend are Bederson and Shneiderman (2003), Collins and Ferguson (1993), Kosslyn (2006, 2007), Larkin and Simon (1987), Latour (1986), Novick (2001), Reed (2010), Tversky (2011), Zacks and Taylor (2017), and Zhang (1997).

Even more challenges arise when curating personal archives for the very long term (for an excellent overview, see Marshall, 2008a, 2008b). Marshall (2011) pointed out that most people take an approach of “benign neglect” to personal archiving, which may be sufficient for small volumes of low-tech external memory (e.g., books on a shelf, photos in a box), but is less so for large volumes and for high-tech external memory. This is in part because of the insidious challenges of digital preservation (e.g., hardware and software obsolescence, media degradation; see Anbu & Chibambo, 2009; Borgman, 2000, pp. 202–205; Kuny, 1998; Oliver & Harvey, 2016). Elsewhere, Marshall (2007) wrote:

One of the most provocative problems that arises from personal archiving is one of access. Clearly you can't deliberately look for something that you don't remember you have, so even the most functional desktop search is no panacea (Marshall & Jones 2006). In fact, field studies often reveal that not only do people forget particular items that they've saved; they also forget entire categories of saved material or places that they've stored treasured items (Bruce, Jones, & Dumais 2004; Marshall & Bly 2005; Whittaker & Sidner 1996). They believe they have kept things that they haven't and they are surprised by what they do find in their long-term stores. (Marshall, 2007, pp. 64–65)

These failures echo the ones voiced by our participants (Q131), and they bring us back to the importance of internal memory for effective use of external memory.

One of the biggest challenges that cuts across all PIM activities is that of *information fragmentation*. The totality of one's personal archive is distributed across physical and electronic stores, multiple devices or locations, and multiple information forms or organization schemes (Jones, 2007; Weinberger, 2007). Our participants' responses to Q112 and Q113 show that using multiple forms of external memory is common. Information fragmentation makes it harder to find specific information when we need it and harder to consolidate information. The problem can be compounded when we fail to remember that (or find where) we have already saved something, and thus we save it again in a different place.

Finally, there are also social considerations in the study of PIM, such as the use of shared file servers (e.g., Dropbox) and collaborative authoring tools (e.g., track changes in Microsoft Word). For a review of social issues with PIM, see Lutters, Ackerman, and Zhou (2007) and Jones (2013).

Clearly, the issues covered by PIM research are central to the interplay of internal and external memory in everyday life and will continue to be so as new technology develops (e.g., smart glasses) and forms of data capture proliferate. *Lifelogging* is the automatic recording of many aspects of everyday experience and may include data from wearable cameras and biological sensors (Bell & Gemmel, 2009; Dobbins, Merabti, Fergus, & Llewellyn-Jones, 2014; Gurrin, Smeaton, & Doherty, 2014; Jones, 2012, 2013; Kalnikaitė, Sellen, Whittaker, & Kirk, 2010; Sellen & Whittaker, 2010; Tan et al., 2007; Thompson, 2013, pp. 19–44; van den Hoven, Sas, & Whittaker, 2012; van Dijck 2007, pp. 148–169; Vemuri, 2005). For guidance on further research questions in PIM, we recommend the following references: Bergman (2013), Bergman and Whittaker (2016, pp. 236–238), Jones and Ross (2007), Lansdale (1988), Naumer and Fisher (2007) for naturalistic research, and Whittaker (2011).

Library and Information Science

Whereas the field of personal information management deals with personal external memory, library and information science (LIS) deals more with public external memory (e.g., libraries, archives, museum collections, the Internet). Library and information scientists have been tracking the implications of shifts in the world's knowledge from low-tech to high-tech external memory. For example, Borgman (2000) discussed how information technology and communication technology have converged in a global information infrastructure and how such technology is coevolving with human behavior and human organizations. In a stimulating chapter, White (1992) actually used the term “external memory” as a unifying concept for the field of LIS (see Hartel, 2012 for a helpful review). White defined external memory as “the creation, organization and use of messages or performances stored in durable media other than the memories of living persons” (p. 250).

On the encoding side, LIS is more concerned with formal actions taken by professionals, such as acquisition and cataloging, rather than everyday actions. The organization of external memory is a major focus of the field (Bowker, 2005; Taylor & Joudrey, 2008). For external memory stores such as libraries, encoding is much more closely tied to explicit organizational processes than is the case with internal memory. When new materials are acquired for a collection or archive, they must be carefully catalogued by a librarian using tools such as standard *metadata* (i.e., data about data) and controlled vocabularies or else the materials may be impossible to discover and retrieve. Metadata is a useful concept for the interplay of internal and external memory. In order to use external memory, we must retain internal representations of some metadata about external memory records. For example, we do not have to remember the complete contents of a research article we have read, only a rough idea of what it was about and enough information to be able to find it again (e.g., perhaps an author's name, or a fragment of the title, or which folder we might have saved the PDF in). The concept of *source memory* is essentially memory for metadata.

The preservation and curation of external memory, both physical and digital, is another major topic in LIS (Anbu & Chibambo, 2009; Borgman, 2000, pp. 202–203; Kuny, 1998; Oliver & Harvey, 2016). As software and hardware degrade and become obsolete, careful perpetual effort is necessary to ensure that collections remain accessible into the future.

On the retrieval side, researchers in LIS have studied how and why people seek and access information in external memory across a variety of contexts. Case and Given (2016, pp. 79–96) reviewed work on people's motivations for seeking information (e.g., seeking answers, reducing uncertainty, and making sense). Case and Given (2016, pp. 141–176) also gave detailed descriptions of several models of information-seeking behavior. For example, Krikelas (1983) proposed a model in which an information seeker with an immediate information need can choose between internal memory, social external memory, and technological external memory. Kuhlthau (1991) proposed a model accounting for the feelings, thoughts, and actions a person has at different stages of the information search process. Similar approaches have also been adopted by some cognitive scientists (cf. "information foraging": Fu, 2012; Fu & Pirolli, 2007). Information seeking does not always consist of targeted search. Just as we may browse through our old photos or social media posts for aimless reminiscing, we may also browse or scan public external memory and encounter information serendipitously (Case & Given, 2016, pp. 105–107; Toms, 1999). When engaging in such behavior, we are in a state analogous to what Tulving (1983, pp. 169–171) called "retrieval mode," a state of mind in which one is prepared to remember. Studies of how and why people seek information can be beneficial to the design of external memory tools such as digital libraries (e.g., Borgman et al., 2005).

Media and Cultural Studies

Media is external memory. It is the tools or channels for communicating information, including print, photography, movies, television, radio, and the Internet. Studies of media and culture take place mostly in the humanities, and although the form of discourse in those disciplines may be foreign to scientists, they contain important insights and frameworks. The space where psychology and media studies should overlap is mostly undeveloped turf. Okdie et al. (2014) lamented the dearth of media psychology and argued convincingly for its importance, given the prevalence of media in everyday life. They also outlined variables of media for further study: fidelity, privacy, sensory channel, interactivity, and content. Harris, Cady, and Barlett (2007) reviewed cognitive research relative to media activities (see also the book by Harris & Sanborn, 2013). In the popular press, Beck (2018) sought psychological insights into why we seem to forget so much from the books, movies, and TV shows we consume. Here, we highlight some works from the humanities perspective that are particularly relevant to the interplay of internal and external memory.

In a thoughtful and thorough treatise, van Dijk (2007) proposed the idea of “mediated memories” as both acts and objects that simultaneously mediate between the past and the future (time axis) and between individuals and the collective (identity axis). She described an inextricable three-way interplay between mind, media, and culture, and she explored how digital technology is transforming this interplay (e.g., by facilitating social sharing): “The invention of every new technology—whether photography, video, or the Internet—revises our methods of personal remembrance, and each of these same tools influences the way we imagine and inscribe our selves in relation to the culture at large.” (p. 52). Culture informs our decisions about what to make records of and how (e.g., movies of childhood milestones, photos of family holidays, diaries of a depression). We agree with van Dijk’s rejection of the dichotomy between home and mass media (pp. 18, 172); we consider both to be external memory. We also agree with her emphasis on the mutual shaping (bidirectional causality) of mind and media (i.e., internal and external memory). Finally, van Dijk considered in detail four forms of external memory and how their interplay with internal memory is changing with new technology: writing (from diaries to blogs), recorded popular music, photography, and video. She emphasized morphability, multimodality, and connectivity. See also Wertsch (1998a, 1998b) for ideas on mediated action.

Hayles (2012) took the perspective of contemporary technogenesis—that humans and technology have coevolved—in analyzing how the shift from print to digital media has changed reading, scholarship, and teaching, due to the different affordances and constraints of the two forms of external memory. Changes in our built environment lead to changes in cognitive processes (e.g., attentional habits), which then lead to further changes in the environment, and so on (cf. continuous reciprocal causation, Clark, 2008). For example, accelerated pacing of movies has gone along with faster image processing by viewers. Hayles argued that the information-intensive

environment provided by digital media, particularly text, has led to a shift from deep reading to hyper reading. We can see this as a study of changes in retrieval from external memory, whereas van Dijck (2007, pp. 53–76) considered changes in encoding (i.e., writing; see also Bolter, 2001; Haas, 2013). Kuhn (2000, p. 187) offered several insights on what she called “memory texts” (e.g., memoirs) and also noted that external memories are encoded and retrieved in a social and cultural context. In a survey of memory from multiple disciplinary perspectives, Rider (1995, p. 75) noted that in forms of literary criticism such as poststructuralism and reader-response, “the memory of the reader is as important in the process of interpretation as the memory of the writer is in the creation of the text.”

McLuhan was an influential media theorist who insisted that “the medium is the message” (1964), meaning that the form of the medium (e.g., television, print)—not merely its content—is what influences people’s cognition and perception. He saw communication technology, shaped by humans, as a force that in turn shaped its makers, on the individual and societal scale (1962). For example, perhaps printed language made human thought more linear (Ong, 1982, Chapter 4). McLuhan (1964) proposed a differentiation between “cool” media that were low in definition and thus required greater human participation to extract their information, and “hot” media that were high in definition and thus required less such participation. This framework is relevant to the interplay of internal and external memory. Memory research has shown that impoverished external cues require greater retrieval effort, which yields enhanced internal memory to the extent that such retrieval efforts are successful (Finley, Benjamin, Hays, Bjork, & Kornell, 2011; Mettler, Massey, & Kellman, 2016; Slamecka & Graf, 1978). Actively engaging in “effort after meaning” (Bartlett, 1932; Zaromb & Roediger, 2009), as required by cool media, should affect internal memory differently from the more passive engagement invited by hot media. Chalfen (1998a) observed this in teenagers who reported different ways of remembering prompted by family photos versus videos.

Sturken (2008) provided a good taste of how memory is thought of in media and cultural studies, as did Erll (2011). Several psychological influences on people’s processing of mass media were outlined by Silverblatt, Miller, Smith, and Brown (2014): selective exposure, selective perception, selective retention, and cultural insulation (pp. 20–22). Groes (2016) provided a multidisciplinary edited volume on the changing state of memory, both internal and external, in the twenty-first century. Finally, a related disciplinary lens is *semiotics*, the study of how meaning is made from signs (see Chandler, 2017; Eco, 1976).

Photography

Photographs are a pervasive and powerful form of external memory. In the study of photography, several questions arise: when and why do people take photos; what kinds of photos do they take; how do people keep and organize photos; when, why, and how do they review them and/or share them; and what role do photos play in our

memory? Note that scholarly writing on photography distinguishes between different types of photography, including amateur, art, photojournalism, and commercial. The most relevant for the interplay of internal and external memory in everyday life is amateur photography (also known as domestic photography, personal photography, family photography, or snapshots). For a helpful history of amateur photography, see Holland (2015). For perspectives by photography theorists on the interplay of photography and memory, see Cross and Peck (2010) and Bate (2010). Most photography theory focuses on the content of photos. For discussion of the *materiality* of photos (i.e., their physical printed form), see Edwards and Hart (2004) and Sassoon (2004).

A well-referenced consideration of the role of photography in memory was provided by van Dijck (2007, pp. 98–121, 2008). She noted that photos can serve several purposes: material keepsakes, experience facilitation, identity formation, and communication. She also considered how digital photography, camera phones, and the Internet have shifted the role that photography plays in human life.

Frohlich (2004, pp. 43–46, Figure 3.5), extending earlier work by Barthes (1981), proposed a diamond framework for understanding the memory and social effects of domestic photography. The corners of the diamond correspond to four entities: the photographer (and/or others present at the time of capture but not in the photo), the photograph itself, the subject of the photo, and the audience viewing the photo (not present at the time of capture). The framework included six possible interactions between those four entities. Seeing the photo individually, the photographer experiences recognition, the subject experiences recollection and self-reflection, and the audience experiences interpretation. Seeing the photo together, the photographer and subject reminisce, the photographer tells a third-person story to the audience, and the subject tells a first-person story to the audience. This framework encompasses both internal memory and external memory (social and technological), and the types of interactions Frohlich describes are consistent with our participants' responses to Q119 about why they take photos.

Relevant to the reasons why photos are taken, there have been a number of works on the contents, structure, and uses of family photo albums (Boerdam & Martinius, 1980; Chalfen, 1987; Hirsch, 1981, 1997; King, 1986; Langford, 2001; Spence & Holland, 1991; Williams, 1997). Using sociology and anthropology approaches, these works have often highlighted how the photos serve to construct and communicate family history and identity. The contents of family photo albums tend to underrepresent negative experiences (Frohlich, 2004, p. 39; Hirsch, 1981, p. 32) and serve to communicate family unity and happiness. For a synthesis of theoretical perspectives on family photo albums, see Sandbye (2014).

Prosser (1998) provided a very useful edited volume on images as data in anthropology, sociology, and psychology research. Particularly relevant were a chapter by Cronin (1998) on psychology and photographic theory, and a chapter by Chalfen (1998b) which proposed a framework for analyzing the communication characteristics of family photos.

The advent of consumer-level digital photography in the 1990s and social media in the early 2000s (boyd & Ellison, 2007) have changed how people use photography

as external memory. People are taking many more photos and sharing more (Duggan, 2013). There is less emphasis on portrayal of the ideal family. Lux, Kogler, and del Fabro (2010) suggested two dimensions for people's motivations in taking digital photos: functional versus affective, and social versus individual. Lux, Xhura, and Kopper (2014) have provided an open data set of photos along with the reasons why people took them.² Van House (2011) argued that with the shift to digital, personal photography is becoming more public and transitory and more for communication than memory. Reasons for taking photos that van House documented include memory, relationships, self-representation, and expressiveness.

The combination of cameras and messaging apps in smartphones has enabled many new ways of using photos, especially socially (e.g., Instagram, Snapchat), with self-portraits (selfies) becoming widespread. For a helpful review of such uses, and people's self-reported reasons for them, see Dharap (2016). For research on photo storage, organization, and retrieval practices in the twenty-first century, see Whittaker, Bergman, and Clough (2010) and Keightley and Pickering (2014). Fries (2018) reviewed several modern reasons for taking photos and interviewed several researchers on photos and memory.

Photos can also serve as *mementos*: objects kept as reminders of a person or event (related terms: keepsakes, memorabilia, souvenirs, objets d'art, objets trouvés). Petrelli, Whittaker, and Brockmeier (2008) investigated the types, placements, and meanings of mementos that people kept in their homes. Types of mementos included artwork, photos, everyday objects, and idiosyncratic objects. Functions of mementos included events, relationships, and personal reminiscing (e.g., for achievement or identity). Importantly, mementos are often symbolic, in that their full meaning relies on the internal memory of their owners (e.g., the story of the object's origin) and is not apparent to others. Petrelli, Bowen, and Whittaker (2014) considered the quality of physical versus digital mementos. External memory (photos in particular) can mediate remembering and reflecting, with possible influence on well-being (Konrad, Issacs, & Whittaker, 2016; Konrad, Tucker, Crane, & Whittaker, 2016). However, when taken to extremes, the keeping of physical possessions for memory and emotional purposes can cause distress and impair everyday living (compulsive hoarding; Steketee, Frost, & Kyrios, 2003).³

One use of photos in the service of memory is *scrapbooking*: making albums that combine photos with annotation, decoration, and other materials (e.g., ticket stubs, postcards, locks of hair). Phillips (2016) discussed scrapbooks as tools for autobiographical memory. Good (2013) drew parallels between social media and the archival and social functions of traditional physical scrapbooking. Whether digital or

²As the link to the data set was accidentally excluded from the Lux et al. (2014) article, we provide it here: <http://www.itec.uni-klu.ac.at/~mlux/index.php?id=photointentionsdata>

³Steketee et al. (2003) provided a useful 24-item scale, the Saving Cognitions Inventory (SCI-R), which includes the subscales emotional attachment, memory, control, and responsibility. Some questions are similar to ones used in our survey. For example, compare SCI-R question 10 ("I see my belongings as extensions of myself; they are part of who I am") to our Q91 ("I consider my external memories to be part of me").

physical, for many people photos heavily influence their internal episodic memories. Why do photos seem to *become* internal memories? Perhaps because they introduce a new internal memory trace every time we view them, whereas the original experience left only one trace. Or perhaps viewing a photo alters the original trace. More research is needed into this particular interplay of internal and external memory.

Earlier, in the Chapter 3 section on Cameras and Photos, we reviewed psychology research on the effects of taking photos (Barasch, Diehl, Silverman, & Zauberman, 2017; Diehl, Zauberman, & Barasch, 2016; Henkel, 2014; Henkel, Nash, & Paton, *in press*; Henkel, Parisi, & Weber, 2016), viewing photos (Finley & Brewer, 2018; Finley, Brewer, & Benjamin, 2011; Niforatos, Cinel, Mack, Langheinrich, & Ward, 2017) and using photos to help people with memory impairments (Allé et al., 2017; Silva, Pinho, Macedo, & Moulin, 2016). Although much of the theory and data we have reviewed about photos as external memory is also relevant for video, we think that video as external memory is worthy of further specific investigation.

Collective Memory

In this book we have been mostly concerned with the memory of individuals, which is the traditional unit of analysis in psychology. Collective memory⁴ concerns a higher and more emergent level of analysis: memory distributed across people, particularly shared memories of a group's history that are important to the group's identity. Note that these memories can extend to events that the individuals did not personally experience, such as the founding moments of a country (cf. postmemory, Hirsch, 1997, p. 22). Collective memory is an umbrella term with varying definitions, especially across disciplines. Research on collective memory has taken place more in sociology, history, philosophy, and anthropology than in psychology, though this is changing (see Barnier & Sutton's 2008 introduction to the special issue of *Memory*). Danziger (2008, pp. 264–274) attributed psychology's tardiness to the topic to its intellectual heritage of individualism. Frameworks from the study of collective memory can be useful because they identify dimensions that are relevant to the study of external memory.

For help in disentangling the various meanings of collective memory from a psychological perspective, see Abel, Umanath, Wertsch, and Roediger (2017), Hirst and Manier (2008), Roediger and Abel (2015), and Wertsch and Roediger (2008). Dudai (2002) argued for three components to collective memory: a shared body of knowledge, an attribute (a schematic narrative of a group of people), and a process (e.g., disputing and reshaping interpretations of the past). Abel et al. (2017) reviewed theory and data for each of those three components, including collaborative remembering, which can be thought of as a process of collective memory. Collaborative remembering is when people in a small group work to remember something together,

⁴Synonyms for collective memory include public memory, cultural memory, social memory, and popular memory.

often by discussion. For additional reviews, see Harris, Paterson, and Kemp (2008), Rajaram and Maswood (2017), and Weldon (2000). Harris et al. also reviewed different perspectives on the relationship between individual and collective memory.

From a sociological point of view, Olick (1999) articulated two competing concepts of collective memory: individualist versus collectivist. He wrote, “two radically different concepts of culture are involved here, one that sees culture as a subjective category of meanings contained in people’s minds versus one that sees culture as patterns of publicly available symbols objectified in society.” Hirst and Manier (2008) argued for reconciling these two approaches, which they saw as ends of a continuum. They also gave advice on relevant research methods: surveys, systems approach, laboratory, and ecologically valid studies. Finally, they noted that collective memory can be studied from an epidemiological approach too, as “the transmission of a memory across a network of community members and social resources” (cf. memes, memetics; Blackmore, 1999; Dawkins, 2016; Distin, 2005; Lake, 1998; Shifman, 2013). Reese and Fivush (2008) provided a helpful review of the influential view of philosopher and sociologist Halbwachs (1925/1992), who held that an individual’s memories are necessarily reconstructed in a social context.

From a historian’s point of view, Confino (1997) provided a review of collective memory, and Kansteiner (2002) critiqued methodologies. Wertsch and Roediger (2008) distinguished between history and collective remembering, with Wertsch (2009) giving even more details (pp. 124–127). Le Goff (1992, p. xi) wrote that “memory is the raw material of history.” Historiography can be seen as the study of external memory that has been used to record history.

How else is collective memory related to external memory? By some definitions, collective memory spans both the internal memory of individuals (which can also be considered social external memory to the extent that multiple people’s memories inform each other) and technological external memory in the form of monuments, memorials, media, cultural symbols, and cultural practices such as holidays and festivals. For example, Zelizer (1995) discussed the materiality of collective memory: “visual records stabilize the transient nature of memory itself, which, not unlike reality, is subject to continued reconstruction.” Le Goff (1992) traced the history of memory practices as new technologies such as writing arose, as did Danziger (2008), who also wove in the conceptual and cultural history of psychology. Klein (2000) traced the emergence of memory as a theme of study outside of psychology, with an emphasis on collective memory.

The collective memory umbrella is useful because beneath it, scholars from various fields have already begun exploring the interplay of external and internal memory across many aspects of human society. Anthropologists have studied how different forms of external memory serve collective memory, such as narrative text versus ritual bodily performances (Connerton, 1989). For a consideration of how recorded law (external memory) can serve as collective memory, see Havel (2005). For the issue of institutional memory in corporations, see Linde (2008), Bowker (1997), and Walsh and Ungson (1991). An edited volume, *Memory in Mind and Culture* (Boyer & Wertsch, 2009), provided an excellent set of perspectives on

collective memory. Pickering and Keightley (2016) discussed the dialectical between individual and collective memory and the implications that has for methodologies of studying memory at different spatial and temporal scales.

Remembering is often a social process. Weldon (2000), writing from a cognitive psychology perspective, helpfully analyzed the different ways that remembering can be conceptualized as a social process, reviewing the ideas of Durkheim, Halbwachs, Bartlett, Vygotsky, and Hutchins. She also described different approaches to conducting research on memory as a social process: social cognition; sociocultural influences; small groups as information-processing systems; the individual, group, and society as an information-processing system; activities as units of analysis (à la Vygotsky); group-level behaviors and knowledge (collective memory); and social network analysis. Weldon went into detail on social network analysis as a way of characterizing collective memory. It should be possible to extend this method of analysis to include non-social components of external memory.

Barnier, Sutton, Harris, and Wilson (2008) provided a conceptual and empirical framework based on distributed cognition that encompasses many, but not all, of the social memory phenomena included under the collective memory umbrella. Their framework included six dimensions: encoding versus retrieval, shared versus unshared experiences, intentionally versus accidentally shared experiences, distinct versus similar unshared experiences across people, retrieval done by an individual versus a group, and the degree of collaboration in group retrieval.

Our data show that people, to varying extents, rely on other people (Q24) and on technology (Q22, 23) for memory purposes. The use of Facebook, Twitter, and other social networks fits in the frameworks of collective memory. A majority of our participants agreed that social media helps them remember experiences (Q89) and that technology helps them collaboratively remember (Q90). Thus, technological external memory plays a role in the construction of collective memory; furthermore it also plays a role in the contestation of collective memory, as evidenced by a majority of our participants reporting having used it to settle a disagreement (Q64). Another technological arena for collective memory is Wikipedia, where page views and edits can illuminate the retrieval and contestation of historical events (Ferron & Massa, 2014; García-Gavilanes, Mollgaard, Tsvetkova, & Yasseri, 2017; Luyt, 2016). For a review of research on Wikipedia as the “sum of all human knowledge,” see Mesgari, Okoli, Mehdi, Nielsen, and Lanamäki (2015). Collective memory can also be seen in social (or crowdsourced) classification of data, such as descriptive collaborative tagging of images (e.g., [flickr.com](https://www.flickr.com)), scholarly articles (e.g., citeulike.org), or books (e.g., librarything.com or [goodreads.com](https://www.goodreads.com)). See also folksonomies (Mathes, 2004; Vander Wal, 2007). Technology can play a role in shaping collective memory, as in systems that combine automation with social tagging (Raimond, Ferne, Smethurst, & Adams, 2014), or when social media algorithms determine what content to show people (Sauter, 2017; Talusan, 2017).

Finally, we note that the journal, *Memory Studies*, has become a home for much of the work that falls under the umbrella of collective memory. Its first issue in 2008 gives a good view of an interdisciplinary approach to studying memory.

Anthropology and Archaeology

External memory has been part of the human experience since before recorded history. Anthropology and archaeology reveal the widespread and long-standing use of both social and technological external memory, in cultures living and vanished.

Although our ancestors' capacity for language and for tool use may have coevolved (Greenfield, 1991; Gibson & Ingold, 1993), social external memory might still predate technological external memory. Donald (1991, 1993, 2001) argued for the possibility of social external memory predating even language, in the form of mimetics (the ability to mime or reenact complex gestures for representational purposes), which could have arisen with *Homo erectus* as early as 1.9 million years ago. Even if we suppose that social external memory requires language, estimates of the time period when spoken language emerged range from 1.9 million years ago (*Homo erectus*) to 200,000 years ago (appearance of *Homo sapiens* and our version of the FOXP2 gene) to 50,000 years ago (cultural explosion and migration out of Africa; for reviews, see Davidson, 2003; Kenneally, 2007). With spoken language came oral tradition, the passing on of knowledge across generations (Ong, 1982; Rubin, 1995). Some such orally transmitted knowledge has endured accurately for over 7,000 years. Australian Aboriginal people have passed down stories about the shape of a coastline before it was altered by an ancient rise in sea level. These stories have been empirically corroborated using modern geographical data (Nunn & Reid, 2016). Social external memory has been with us for a very long time.

When did technological external memory emerge? Although simple stone tools appeared as early as 3.3 million years ago (Harmand et al., 2015), clear cases of technological external memory have so far only been dated to about 30,000 years ago (d'Errico, 2001), with less clear cases of symbolic markings going back to 70,000 years ago (d'Errico, Henshilwood, & Nilsson, 2001). D'Errico (1995, 1998) described a theoretical framework and methodology for identifying marked objects that served as artificial memory systems, which he defined as "devices specifically conceived to record, store, and recover information outside the physical body" (2001). The earliest of these were simply lines engraved on fragments of bone, antler, or ivory. What information did these artifacts carry? Likely, counts of something. Beyond that, we cannot know. Their meaning died with their users and has been lost to time.

Remnants of the earliest external memory artifacts are very rare. That may be because they were indeed scarce and/or because few have survived to be discovered. Bednarik (1994) notes: "The symbolic productions of human beings are almost without exception extremely ephemeral." This holds true to an even greater degree today in the information age (Anbu & Chibambo, 2009; Borgman, 2000, pp. 202–205; Kuny, 1998; Oliver & Harvey, 2016). For example, the BBC Domesday Project in 1986 compiled cultural information to be preserved for posterity on laserdiscs, but this record was nearly unrecoverable a mere 16 years later due to obsolescence of software and hardware, not to mention copyright issues (Darlington, Finney, & Pearce, 2003). Meanwhile, the original paper Domesday Book, a census of England

completed in the year 1086 C.E., has been carefully preserved for over 900 years and requires no special equipment to read.

In addition to the earliest marked artifacts of bone, ivory, and antler, we have clear records of a wide variety of technological external memory used throughout the ages. Cave paintings depicting animals date back at least 35,000 years (Aubert et al., 2014), as do carved figurines of humanlike forms (Conard, 2009). There were tally sticks, shell beads, oracle bones, and stone calendars. Ancient Peruvians developed a system of knots tied in cords, *quipus* (or *kipus*), to provide an external memory aid for their history and bureaucracy (Tylor, 1870, pp. 156–160; Locke, 1912). A single quipu consisted of knots tied on a series of small cords attached to one large cord. Different types of knots could represent numerical values, and the order and color of the small cords could represent different categories of objects (e.g., types of livestock in a herd or types of soldiers in an army). However, only specially trained officers could decode these cues to retrieve the information.

Prayer beads have been a widespread form of external memory used for centuries by many religions to guide adherents in the recitation of prayer cycles. Evidence of religious use of beads dates back at least as far as Hindu sculptures from 185 B.C.E. (Dubin, 2009, pp. 79–92). The beads do not encode the actual contents of the prayers, but rather form a scaffold of reminders to guide internal memory. Beads are held in one or two hands, and the fingers are passed over the beads as the prayer cycle progresses. Many prayer cycles include repetitions of certain segments. The feel of a particular bead cues adherents to move on to the next part of the prayer cycle. Thus the beads alleviate the need to keep internal track of the number of repetitions, freeing adherents to either clear their mind or focus on the content of the prayers.

Written language was a major breakthrough of external memory. Approximately 5,000 years ago, papyrus hieroglyphics appeared in Egypt, and clay cuneiform tablets appeared in Mesopotamia. Cuneiform tablets served as inventories of goods for trade, and these visual lists alleviated internal memory burdens from those overseeing trade. The tablets also eventually forced their creators to grapple with information infrastructure in order to house and organize the tablets to facilitate retrieval of their information (Rumsey, 2016, pp. 21ff). Cuneiform script evolved from pictorial to ideographic to phonetic forms. In another watershed development, the Phoenician alphabet developed around 3,000 years ago. An alphabet was key in allowing external memory to express limitless ideas using a small number of symbols. Furthermore, a phonemic alphabet exploits the cognitive processes used for spoken language.

Socrates, who lived some 2,400 years ago, was famously concerned that writing would erode internal memory. Oral tradition notwithstanding, we who exist several thousand years later would never have known Socrates's teachings if his student, Plato, had not written them down. By Plato's account, Socrates said of writing:

it will introduce forgetfulness into the soul of those who learn it: they will not practice using their memory because they will put their trust in writing, which is external and depends on signs that belong to others, instead of trying to remember from the inside, completely on their own. (Plato 370 B.C.E./1995, pp. 274c–d)

Socrates also pointed out that you cannot interact with written words like you can with a speaker, because written words have no intelligence or agency of their own; this mirrors our criticism of the overextension of the transactive memory framework. Socrates was right about people memorizing less and that does to some extent come with a cost (e.g., less information in internal memory to use for making efficient and creative connections). But what he failed to appreciate was how much more internal memory can do when acting in concert with external memory, how much more total information we can access, especially semantic.

Albert Einstein was once asked the speed of sound. He replied that “he did not carry such information in his mind but it was readily available in text books” (“Einstein sees Boston,” 1921). Vygotsky and Luria (1930/1993) recognized the long-term importance of “auxiliary tools of memory” such as the quipus and the notched feathers used by the Dakota tribe, as well as the written word. “All that enculturated mankind remembers and knows now, his entire experience accumulated in books, relics, monuments, and manuscripts, all of this immense expansion of the human memory ... is indebted to external memory based on signs.” (p. 108). Distin (2010) reviewed the development of what she called artefactual language (e.g., written language, musical notation) and how that has enabled cultural evolution. For a stimulating edited volume on evolutionary perspectives on technological change, see Ziman (2003). Issues include the possibilities of punctuated equilibrium (i.e., long periods of stability interspersed with short periods of rapid change) and of technological evolution being Lamarckian (i.e., inheritance of acquired traits) rather than Darwinian.

All of this tells us that the use of external memory, both social and technological, is nothing new for human beings. The dazzling technology of the early twenty-first century is a continuation of an ancient trajectory (Rumsey, 2016; Staley, 2014). Danziger (2008) and Draaisma (2000) traced the history of ideas and metaphors about memory, which have always been tied to changing societal values and practices, as well as changing technology (e.g., wax tablets, books, phonographs, photographs, computers, holograms).

We also see that internal and external memory have always been interdependent. This is evidenced by the fact that we can no longer decipher many ancient forms of external memory (e.g., the marked bones of the Upper Paleolithic, quipus, Zapotec calendars, Linear A). Deciphering requires special knowledge, which may be localized to a few well-trained individuals, and can easily be lost to time. The forms of external memory have also been shaped by the needs of internal memory. Danziger (2008, pp. 72–78) described innovations in written language that appeared during the period when cultural values shifted from auditory recitation in Roman times to silent visual memorization in medieval times. These medieval innovations included spaces between words, colored and embellished first letters of paragraphs, titles for chapters, and even bizarre creatures drawn in the margins (drolleries), all in order to help make the text more memorable. Kuchler and Melion (1991) provided an edited volume by anthropologists and art historians on the reciprocal relationship between internal memory and external representations throughout history, including dance,

engravings, paintings, stained glass, stone calendars, and funerary sculptures (see also the helpful review by Toren, 1992).

The most ancient external memory, to the extent that we can interpret it, was apparently used for only certain specific purposes (e.g., trade, agriculture, law) and was used by only a few people with specially trained skills. Thus, although it has been in use by some humans for many thousands of years, it has become a much larger and more widespread part of everyday life in more recent times. For example, the role of external memory expanded with the printing press around 1440 C.E. and the growth in literacy in subsequent centuries. McLuhan (1964, p. 174) remarked that “print provided a vast new memory for past writings that made a personal memory inadequate.” One result was the rise of “commonplace books” during the European Renaissance (Harvard University Library, n.d.). These were small handwritten notebooks in which people compiled collections of significant or useful passages that they heard or read elsewhere. The commonplace books helped people organize and retrieve external memory for later contemplation or for use in composing their own writing. This new form of external memory arose as an early form of personal information management to help people deal with the burgeoning amount of knowledge available to them. The commonplace book was also part of a fascinating long history of note-taking, detailed by Blair (2010). The everyday role of external memory has only continued to increase, with technology like cameras and computers becoming widely available in the late twentieth century, to the point that the participants in our study reported taking several photographs and sending/receiving numerous emails or text messages every day.

Anthropology is important to the study of external memory because the use of external memory is embedded in culture. One relevant concept is *material culture*: the physical objects and architecture of a culture. Only a subset of material culture is designed for cognitive affordances such as memory. Donald (2001, p. 305) stated that technological external memory, or symbolic technology, can be considered an extension of material culture “designed specifically to help us think, remember, and represent reality.” In the introduction to a book on material memories, Kwint (1999) proposed that objects of material culture may serve memory in three ways: they can be represented in internal memory, they can cue internal memory, and they can form records of information beyond what is contained in internal memory. The second and third ways are most consistent with the responses of the participants in our study (Q122, 127). Reaffirming the dynamic interplay view from media and cultural studies, Kwint states that “evocation implies an open dialogue between the object, the maker and the consumer in constructing meaning.” In a similar vein, Wertsch (1998a, 1998b) advocated for *mediated action* as a unit of analysis, by which he meant the interaction between humans and cultural tools such as external memory.

For an introduction to cognitive archaeology, which forms linked inferences about prehistoric cognition based on material traces of past activity, see Coolidge and Wynn (2016). For other anthropological and archaeological views on the role of material artifacts in the evolution of the human mind, see Donald (1991), Knappett (2011), Malafouris (2013), and Renfrew (2008). For a review of the place of anthropology in cognitive science, see Bender, Hutchins, and Medin (2010). For an

excellent edited volume combining anthropology, archaeology, and philosophy of mind (extended mind and distributed cognition), see Malafouris and Renfrew (2010). Science and technology studies (STS) is a relevant field covering how new technology is integrated into society (e.g., van House, 2011).

Finally, the methods of anthropology are well situated for tracking the changes in human thought and culture as we adopt new technologies of external memory. Some adaptation of methods may be necessary, especially as we become more and more integrated with our technology. For an introduction to Thad Starner and Steve Mann, pioneers of wearable computing to augment human cognition, see P. Miller (2012). There are movements underway to establish studies under banners such as digital anthropology (Horst & Miller, 2012; Wesch, 2008), digital ethnography (Pink et al., 2016), cyber-anthropology (Budka & Kremser, 2004; Libin & Libin, 2005), and cyborg anthropology (Case, 2014; Haraway, 2006). For cyber-psychology, specifically how human behavior changes online, see Aiken (2016).

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Part III
Discussion and Guide for Research
(The Future)

Chapter 7

A Framework and Methods for Researching the Interplay of Internal and External Memory



In this chapter we will first summarize the results from our current study that we reported in detail in Chapters 1, 2, 3 and 4. Then we will present a framework that ties together these results and can guide future research. We will also discuss limitations of the current study, and finally we will review the most relevant research methods for the study of external memory.

Summary of Results from the Current Study

External memory plays an integral and growing role in people's everyday lives (Tables 3.2 and 3.4). High-tech external memory (e.g., phone, computer, the Internet, camera) is used more than low-tech external memory (e.g., paper), which is used more than social external memory (i.e., other people). Low-tech and high-tech external memory use are uncorrelated (Table 4.5). People expect high-tech external memory in particular to be used more in the future. Most people still make strategic use of the physical environment to help them keep track of important objects (Table 3.3). Computers and paper are both used for taking notes, and people mostly believe that taking notes improves their internal memory (Table 3.5).

People use external memory for both personal experiences (episodic) and factual knowledge (semantic), the latter to a greater extent (Table 3.7). Phone numbers have been largely offloaded from internal to external memory (Tables 3.10 and 3.11). People regularly take photos for memory purposes and for sharing (Q119). Failures of external memory are widespread but infrequent (Table 3.6) and can happen for a variety of reasons (Q131).

External memory influences emotional and social aspects of everyday life. Most people report feeling strong emotions from viewing videos, pictures, and even texts from their past (Table 3.8). People report similar levels of online and offline social interaction (Table 3.14). Social media promotes both individual and collaborative remembering (Q89, Q90). External memory is also used to settle disagreements

with others (Q64, Q132). For some people there is an emotional tension between making external memory records of meaningful experiences (e.g., taking pictures) and being fully present and aware (Table 2.5). Despite the importance of external memory, and the potential emotional impacts of losing it (Table 2.4), people do not appear to back it up as much as they should (Table 3.13).

Although attitudes are mixed about whether it is more important to find information than remember it (Q66), most people have indeed done so at least sometimes (Q65). People generally recognize that internal memory is necessary for effective use of external memory (Q131, Table 4.2) and that internal and external memory are good at different things (Q49, Fig. 4.1).

People put considerable value in their external memories, and many consider their external memories to be part of them (Table 2.4). Most people think external memory helps them function, but they would also do fine without it, and they do not feel uneasy about relying on it. External memory is generally seen as augmenting human capability, not supplanting it.

People with higher self-reported internal memory ability tend to make less use of external memory (low-tech, high-tech, and social), rely less on it, and put less personal value in it (Table 4.5). Older people make greater use of low-tech external memory. Nostalgic people have more emotional responses to external memory and put greater value in it. Unease about reliance on high-tech external memory is associated with several variables (Table 4.6).

The overall picture is of a growing symbiosis between internal and external memory. The two complement and depend on each other. Although some people are concerned about relying on external memory too much, or losing internal memory abilities, many others see it as an enhancement, allowing them to strategically distribute their memory efforts between their brains and their environments, and enabling them to do more both intellectually and socially. *To put it broadly, external memory is augmenting internal memory for episodic purposes, and supplanting internal memory for semantic and prospective purposes.*

Framework for Interplay of Internal and External Memory

Figure 7.1 summarizes the interplay between internal and external memory elucidated by our results (see in particular Chapter 4). Examples of the directional relationships depicted in Fig. 7.1 can be found in Table 4.2. The main purposes for which internal memory is used more than external memory are episodic (i.e., personal experiences) and procedural (i.e., how to do things). The main strengths of internal memory are rapid convenient access especially to frequently used information, rich vivid representations that include sensations and emotions, personally meaningful experiences/information, creativity, and security of private experiences/information.

The main purposes for which external memory is used more than internal memory are semantic (i.e., general knowledge) and prospective (i.e., remembering to do

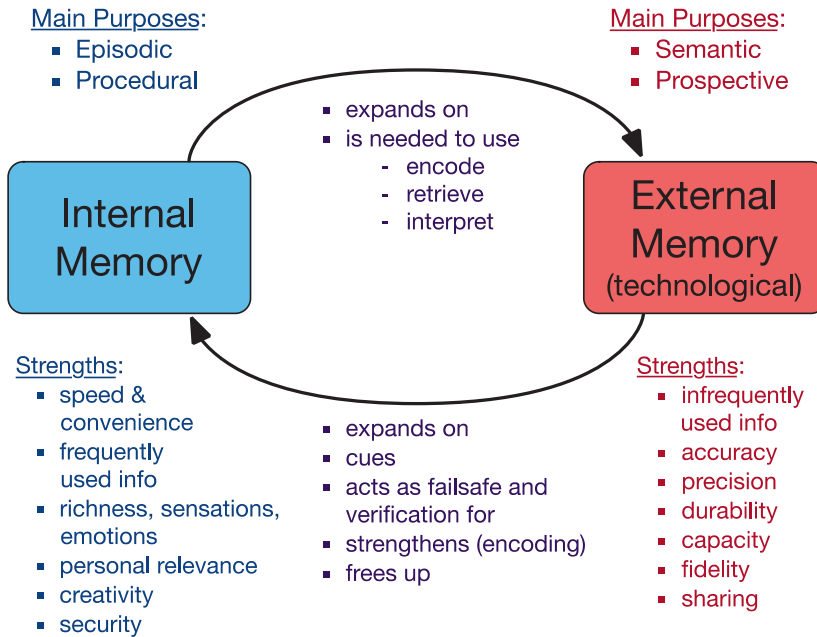


Fig. 7.1 Diagram of the interplay of internal and external memory, based on synthesis of participants' responses to the survey. (Note: external memory here includes both low-tech and high-tech, but not social)

future tasks). The main strengths of external memory are access to infrequently used information, accuracy (true representation of reality, where applicable), precision (exactness of details), longevity (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).

Internal memory is related to external memory in several ways. Internal memory can expand on external memory by providing rich recollections of original experience. Internal memory is also necessary to make use of external memory, to encode information to external memory in the first place, to remember that the information exists in external memory, to attempt to retrieve it when it is needed, to remember the location and procedure for retrieval, and to make sense of the information once retrieved. Without an accurate internal mental model of the location, structure, contents, and operational features of external memory, it may be inaccessible (Schönpflug, 1986b). However, the increasing power and flexibility of software search functions may be easing this burden on internal memory (Cutrell, Dumais, & Teevan, 2006; Russell & Lawrence, 2007). Of course, the organization of the external memory store itself facilitates its use and is a topic considered by the personal information management perspective which we discussed in Chapter 6.

Note that there is an asymmetry here: although internal memory is needed to use external memory, the reverse is not true (Intons-Peterson & Newsome, 1992, p. 113;

Schönplflug, 1986a, p. 373; but see also discussion in Clark, 2008, p. 162). External memory is not needed to use internal memory. However, it is related to internal memory in several ways. External memory can expand on internal memory by providing more detailed information than the gists provided by internal memory. It can cue (trigger) internal memory that would have otherwise laid dormant. It can serve as a fail-safe for when internal memory falters, and it can verify information retrieved from internal memory. The very act of encoding to external memory (e.g., taking notes) can strengthen internal memory. Finally, external memory can free up internal memory to be used for other tasks. Our framework is not meant to be a detailed process model, but rather is meant to broadly characterize the properties of internal and external memory, and the symbiosis between them, in order to organize our results and guide further research.

It should be clear by this point that external memory is not just an auxiliary to internal memory, a passive container of content; but rather it can guide and shape how we use internal memory. Not pictured in Fig. 7.1 are the changes in the interplay over time, as reported by our participants. Most participants reported a shift to more external memory use and less internal memory use, particularly for semantic information. Table 4.3 shows examples of how internal memory use has changed, including less semantic information, more episodic information, more higher-order cognition, and a focus on finding information in external memory.

Limitations of the Current Study

We acknowledge several limitations with the current study, which we will now discuss. First, the participants in our sample were necessarily technologically literate, as they were experienced workers on Amazon's Mechanical Turk, an Internet marketplace for recruiting people to complete tasks via computer. Computer and smartphone ownership rates for our sample were higher than in a national phone-based survey conducted by Pew in the same year (Anderson, 2015). Thus, we cannot assume our findings are representative of people with all levels of technological experience. For example, reliance on high-tech external memory in our sample may be higher than in the population at large. Furthermore, although our sample included a wide range of ages (18–75), we did not gather data from those under 18, who are likely to be on the forefront of new technology use (e.g., Snapchat). Also, the age distribution was positively skewed (Fig. 1.2), with more participants in young and middle adulthood than older adulthood.

Another limitation of the current study is that it relied on self-report and thus is susceptible to the same potential problems faced by all survey research, such as demand characteristics or reactivity. One criticism of the use of self-report in cognitive psychology is that participants are unlikely to have direct introspective access to their cognitive processes (Nisbett & Wilson, 1977). Fortunately, our main interest was not in explicating cognitive processes; rather, our aim was to measure attitudes, beliefs, behaviors, and experiences. Self-report is the most direct way to measure

attitudes and beliefs. But it is more problematic for behaviors and experiences. Recall of past experiences is imperfect and may be influenced by implicit theories (Ross, 1989), and self-reports of internal memory ability have been shown to be only weakly related to actual memory performance on laboratory tasks (Beaudoin & Desrichard, 2011). Herrmann (1982) gave an excellent review of memory questionnaires and their validity, providing a framework for the relationship between beliefs and performance (Herrmann, 1982, Fig. 1) and concluding that self-report can be useful for measuring beliefs about memory and for calling attention to everyday memory phenomena. Future work should combine self-report measures with objective internal memory tasks, including performance measures of working memory, prospective memory, and long-term memory (both episodic and semantic). The validity of self-report measures of external memory behaviors and experiences remains an open question (Schryer & Ross, 2013). Laboratory tasks involving external memory are still in their infancy and should continue to be developed. Self-report and laboratory tasks should also be combined with ethnographic research on people's use of external memory in their actual everyday settings. Overall, we think that self-report was appropriate for the purposes of this exploratory descriptive study.

Our use of some open-ended (qualitative) questions had advantages and disadvantages. On the one hand, participants' responses gave us broad and rich insights into their use of external memory and their attitudes about it. Participants were allowed to mention things that we the researchers may not have considered. On the other hand, the responses likely gave an underestimate of specific behaviors (e.g., Table 3.4; use of Wikipedia, Q132), as the percentages only reflect the number of participants who thought to mention each form of external memory. Future work should build closed-ended questions that list specific forms of external memory mentioned by our participants, for example. However, we think it will always be important to include some open-ended questions, as the interplay between internal and external memory will undoubtedly continue to shift with the development of new technology.

Some changes in that interplay that we are interested in may have largely already happened and gone undocumented, such as the shift to external memory for phone numbers. While there is no reason to doubt people's self-report that they remember far fewer phone numbers now that they have cell phones, it is still unfortunate that contemporaneous data were not gathered on this over the past 20 years. If any such archival data exist, we are unaware of them. As a field, we should do our best to gather what data we can as the world continues to change. This is a prime example of the underappreciated value of descriptive studies and induction in psychology, which as a field has emphasized hypothesis testing and deduction above all else.

Finally, there are a handful of topics that we did not ask about in our study that should be addressed in future work. For example, such topics include reliance on electronic spell-check and dictionaries, reliance on calculators instead of mental arithmetic, or even using parts of one's own body to help in counting. We only had one question (Q75) about videos as external memory; this should be further investigated. Another major type of everyday external memory that we did not specifically

address is a diary, blog, or journal (see also, scrapbooking). These can form intimate episodic records of one's experiences, thoughts, feelings, and relationships. Writing is a way to externalize our stories. Traditional diaries may to some extent have been superseded by blogs or social media, though this is an empirical question. Psychology researchers have employed special purpose diaries as a methodological tool (a type of experience sampling) in the study of a variety of topics (Bolger, Davis, & Rafaeli, 2003; Bolger & Laurenceau, 2013; Iida, Shrout, Laurenceau, & Bolger, 2012). For example, researchers studying everyday internal memory have had participants create diaries for the purpose of later testing their internal memory (Thompson, Skowronski, Larsen, & Betz, 1996). But there has been little if any psychological study of people's naturalistic use of diaries as external memory. This is a topic ripe for further research. For guidance on analysis of diaries and other self-writings, we recommend Zittoun and Gillespie (2012) and Brinkmann (2012). For a thoughtful consideration of diaries and blogs from a media and cultural studies perspective, see van Dijck (2007, pp. 53–76), who emphasized their formative, directive, and communicative properties. For studies on people's motivations for blogging, see Guadagno, Okdie, and Eno (2008), Okdie, Guadagno, Rempala, and Eno (2011), and Kjellberg (2010).

Methods for Studying External Memory

Several methods are available for studying external memory and its interplay with internal memory. All have their advantages, and a mixed method approach is best. *Modeling* methods should become appropriate at some point, but we believe there is a great deal of empirical work still needed before that time.

Surveys

Survey methods (e.g., interviews, self-report questionnaires) are useful for gathering large-scale data, both quantitative and qualitative, especially when a field of study is still in the early stages of identifying variables, associations, and phenomena of interest. Surveys can be conducted using a variety of mediums (e.g., email, phone, in-person, paper mail, or Internet recruitment services such as Mechanical Turk or Prolific Academic). Some examples of survey use in the study of external memory include Hamilton, McIntyre, and Hertel (2016), Harris (1980), Intons-Peterson and Fournier (1986), Kaspersky Lab (2015), Schryer and Ross (2013), and the current study.

Experiments

Experiments, in which one or more independent variables are manipulated and one or more dependent variables are measured, are vital for determining causal relationships between variables and for testing hypotheses generated by theories. Experimental methods are best used when important variables or phenomena have already been identified, though they can be useful for exploratory purposes too. Experiments may be done in laboratory or field settings. Although the use of external memory in everyday life is abundant, there is still a need for the development of laboratory task analogues. Some examples of experiments used in the study of external memory include Henkel (2014), Schönpflug (1986b), Sparrow, Liu, and Wegner (2011), Storm, Stone, and Benjamin (2016), and Ward (2013). Many variables are readily manipulated, such as cost of using external memory, nature of the task, and load on internal memory. One potential approach is to manipulate whether or not participants are allowed to use external memory and then measure their internal memory performance (see Kobayashi, 2005, for a review of research on note-taking).

Developmental Methods

In any attempt to research psychological changes over time (i.e., development), there are three broad types of effects to be disentangled: age, birth cohort (generation), and time period of measurement (Schaie, 1965, 1986). The study of the interplay of internal and external memory presents a rare situation in which all three effects are of interest. Age is of interest because an individual's internal memory abilities change across the life span, with performance on new episodic tasks declining while semantic knowledge increases to asymptote (Salthouse, 2004), and this may influence how a person uses external memory. Cohort is of interest because the year in which someone was born should heavily influence the amount of experience they have had with different types of technology. We may see generational differences in external memory use between digital natives who have grown up using computers and the Internet (Teo, 2013) as compared to digital settlers who have seen computers and the Internet come of age partway through their lifetime. Time period is of interest because the inexorable emergence of new technology and cultural practices affords new ways of using external memory.

Disentangling the effects of age, cohort, and time period is notoriously difficult. There are three common research methods that hold one of the three effects constant, leaving only the other two to vary, but confounded with each other. A *cross-sectional study* (e.g., the current study) samples participants of various ages at a single point in time; this holds time period constant but leaves age and cohort confounded. For example, if older adults in 2015 made more use of low-tech external memory than younger adults, as we found, we do not know if that was because of

their age or because of their generation's experience with and relationship to technology. A *longitudinal study* repeatedly samples participants from a single cohort as they age across multiple time periods; this holds cohort constant but leaves age and time period confounded. A *time-lag study* samples people of a single age at different time periods (e.g., 18-year-olds in 2014, 18-year-olds in 2015, 18-year-olds in 2016); this holds age constant but leaves cohort and time period confounded.

Schaie (1965, 1986) proposed a general developmental model encompassing all three variables (age, cohort, and time period) and from which could be derived all three of the aforementioned study designs (cross-sectional, longitudinal, and time-lag). Furthermore, Schaie proposed a “most efficient” sampling design (1965, p. 107) and three specialized sequential designs: a cohort-sequential design to disentangle age and cohort, a time-sequential design to disentangle age and time period, and a cross-sequential design to disentangle cohort and time period.

It is already too late to run prospective studies that would capture memory effects of important events such as the advent of mobile phones or widespread Internet access. But there are still large cohorts of people alive who were born before those events, so at the very least we may gather oral history from them regarding past changes in the interplay of internal and external memory. Furthermore, although to our knowledge there are no ongoing longitudinal data sets that measure external memory attitudes or behaviors, there are data sets that have been measuring internal memory abilities since the 1950s (e.g., the Seattle Longitudinal Study or the Wisconsin Longitudinal Study; the National Institute on Aging maintains lists of such studies). So it should be possible to do retrospective analyses to look for cohort and time period effects on internal memory that could be associated with changes in technological external memory. Finally, there will likely continue to be dramatic technological changes in the future to come, so it would be prudent to begin prospective longitudinal studies with multiple cohorts (as per Schaie, 1965) that include measurements concerned with external memory and its interplay with internal memory. Without large-scale research efforts, many changes in memory practices will continue to occur with little to no rigorous documentation.

Content Analysis

The use of external memory often results in physical or electronic traces or artifacts that may themselves be studied (e.g., notes, calendars, social media posts, emails, photos). Internet platforms such as Twitter (text) and Flickr (photos) provide publicly available archival data (Guadagno, Okdie, & Muscanell, 2013, pp. 305–307). Content analysis can involve qualitative or quantitative analysis methods. For a brief review, see Case and Given (2016, pp. 262–264). For guidance on conducting qualitative research on a variety of everyday external memory materials (e.g., diaries), see Brinkmann (2012) and Zittoun and Gillespie (2012). For text analysis specifically, see Chung and Pennebaker (2014). For photos, see Prosser (1998).

Ethnography

Ethnography is less a specific research method and more a perspective or approach to research. The aim with ethnography is to document and understand experience and practice in a naturally occurring cultural context, often by way of naturalistic observation or even participant observation. Ethnography is an approach more often used in sociology and anthropology than in psychology (despite Gibson's early emphasis on ecological psychology, 1979; see also Lave, 1988). However, ethnography is particularly appropriate for exploratory studies to document everyday memory practices involving external memory.

There is a great need for ethnographic studies in order to inform theory development (e.g., identifying the components of a distributed cognitive system) and to fuel experimental research; but these studies can be time intensive. For example, Forsblad (2016; see also Dahlbäck & Kristiansson, 2016), using a cognitive ethnography approach (Williams, 2006) and a distributed cognition theoretical framework (Hollan, Hutchins, & Kirsh, 2000), created an excellent in-depth study of how older adults make use of their physical environment at home to support prospective memory tasks. Forsblad gathered data over 2 years in the form of interviews, videotaped observations, field notes, and photographs.

Hutchins (1995) used cognitive ethnography methods in his study of how a navy crew interacted with each other and their technological tools to perform navigation. One of his points was that cultural knowledge can play key roles in the interplay of internal and external memory, and such knowledge would be overlooked without studying practice in context. Other examples of ethnographic approaches to cognition in practice include the computational practices of milk-processing plant workers (Scribner, 1984) and the working memory practices of bartenders (Beach, 1988) and restaurant servers (Stevens, 1993). A review of nuclear power plant control rooms found a case in which operators had placed beer tap handles over identical knobs in order to better distinguish them from each other (Seminara, Gonzalez, & Parsons, 1976). Such studies can reveal a *bricolage*, a flexible use of tools and materials at hand to extend memory and other cognitive functions in pursuit of a goal (Dawson, 2013, p. 229). Some relevant ethnographic research can be found published in journals such as *Memory Studies* and *Mind, Culture, and Activity*.

Kingstone, Smilek, and Eastwood (2008) described an approach they call cognitive ethology. Pink et al. (2016) provided a handbook on methods of digital ethnography, which considers digital media and technologies as part of people's everyday experiences. Naumer and Fisher (2007) provided an overview of naturalistic approaches to studying personal information management.

Finally, *task analysis* is a relevant method in human factors that can be used to identify the steps of a process by observing ordinary use (Sharit, 2012); this can help us understand exactly how people are using different types of external memory, what cognitive processes are required of them, and where errors may arise.

Experience Sampling

Experience sampling, or ecological momentary assessment, is a way of gathering data from participants as they go about their daily lives (Csikszentmihalyi & Larson, 2014). It may involve diaries and/or wearable technology (e.g., cameras, audio recorders). For example, participants may be prompted by a phone alert at random intervals throughout the day to make a record of their thoughts, feelings, and behaviors. Or they may make records at scheduled times or after a particular experience. Records may be made on paper or an electronic device such as a smartphone (Miller, 2012). Experience sampling provides a way to measure experiences in their natural contexts close to the moment in which they actually occur, rather than relying on retrospective reports, which are subject to distortions and biases of internal memory. This research method directly exploits external memory to avoid the weaknesses of internal memory, so it is only appropriate that we may use this method to study external memory itself; for example, we could prompt participants to report the number of times within a given interval that they looked up a fact on the Internet instead of trying to recall it. A useful handbook on experience sampling and other methods can be found in Mehl and Conner (2012). For a briefer introduction and primer, see Conner, Barrett, Tugade, and Tennen (2007). Additional practical advice can be found in Bolger et al. (2003), Harari et al. (2016; focus on smartphones), and Stone and Shiffman (2002). Although not focused on the study of external memory, some examples that illustrate different experience sampling methods include Thompson (1982; daily diaries of events), Brewer (1988; beeper-prompted handwritten records), Mehl and Pennebaker (2003; wearable audio recorder), Finley, Brewer, and Benjamin (2011; photos from SenseCam automated wearable camera), and Paxton, Rodriguez, and Dale (2015; Google Glass wearable camera and display).

Data from Beyond Academic Research

Many academic researchers do not bother to look outside of scholarly journals and books. That is a mistake. For several topics relevant to external memory (e.g., smartphone apps, camera usage, computer and Internet usage), data likely exist outside of the academic literature. Many organizations in private industry commission or conduct research on trends in consumer behavior, for example. But the results of such research may be restricted to internal reports that are not publicly available. These data, of indeterminant quantity, may exist in the “grey literature” or “deep web.” Such data may potentially be found through paid portals such as Statista or the ProQuest Statistical Insight Collection. Occasionally, one can find relevant “white papers” (non-peer-reviewed technical reports) on the websites of companies or analysts, or by requesting them from public relations representatives or the researchers themselves, if they can be found. As the data get older, they presumably become less

strategically valuable to the industry organizations that paid for the research and thus are more likely to be shared in response to a scholarly request; however, as time goes on, the data also become more difficult for industry representatives to dig up, even if they are willing to share. We encourage academic researchers to reach out to industry researchers and vice versa. For this book, we were grateful to discover relevant data from industry sources such as Backblaze (Klein, 2016), BullGuard (2012), Kaspersky Lab (2015), Suite 48 Analytics (Hartman, 2014), and Microsoft (Marshall, 2007). Phone companies, search engine companies, and Internet service providers are other likely sources of relevant data, as are industry research labs that focus on user experience (UX) and user interface design. Any company making technology to serve memory may have data on the topic.

Of course, as good scientists we need to be critical of the methods used to collect any set of data. Who were the participants in the sample, how were they contacted, how were the questions worded, what were the response options, and so on? Even if the methods and the reporting of results are not at the same level of fastidiousness as in academic research, the data can still be informative, especially when no other such data exist. The world of industry research is far less transparent than the world of academic research. Discovering and gaining access to data may require a different set of searching and public relation skills (see Fradkin, 2014, for a guide to using corporate data for academic research). But the potential contribution to our general knowledge is worth it.

This is all in addition to publicly available nonacademic sources of data. There are nonprofit organizations such as the National Opinion Research Center (NORC) at the University of Chicago and the Pew Research Center from which we found several data reports that we cite in this book (e.g., Purcell & Rainie, 2014). Pew in particular has been gathering more and more data on technology in everyday life. A number of such organizations, along with private research companies and academic sources of data, are aggregated by larger organizations such as the Roper Center for Public Opinion Research, the American Association for Public Opinion Research (AAPOR), and the Inter-university Consortium for Political and Social Research (ICPSR). Websites for these organizations are easily found by web search.

Additionally, there are publicly available government sources of data. In the United States, a good first stop is the Federal Committee on Statistical Methodology (nces.ed.gov/FCSM) or the data.gov webpage. A few of the specific government agencies likely to have relevant data are the Bureau of Labor Statistics (e.g., the American Time Use Survey), the Federal Communications Commission, and the National Institutes of Health.

Finally, we would be remiss not to mention the Open Science Framework (osf.io), an open-source project by the Center for Open Science to facilitate sharing of the process and products of scientific research. The only reason the complete data set from the current project is not shared in such an open repository is that we did not have the foresight to include the appropriate permission language in our informed consent forms that would allow us to ethically share the data. The ICPSR gives recommendations on informed consent language for data sharing: <https://>

www.icpsr.umich.edu/icpsrweb/content/datamanagement/confidentiality/conf-language.html. We mention all of these sources of data, and places for sharing data, because we believe a collaborative effort is needed to piece together as much data as possible while technology continues to change the ways we use internal and external memory.

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Chapter 8

Important Dimensions and Unanswered Questions



Important Dimensions of External Memory

What is the problem space of external memory? That is, what are the most important dimensions (variables) of external memory for researchers to measure and/or manipulate in order to better understand the interplay of internal and external memory? First we will review dimensions proposed by others in previous publications, some of which take the form of taxonomies. Then we will list the dimensions we currently see as most important and fruitful based on our data and our review of the existing literature.

Dimensions Proposed by Others

Technological Dimensions

Hertel (1993, p. 667) proposed three dimensions for technological external memory: completeness of the record, source of record (generated by self vs. other), and type of knowledge (declarative vs. procedural). Schönplugg (1986) identified several important variables in his empirical work: the relevance of a text record to the current task, the complexity of the record, operational costs of external encoding and retrieval, whether a person is encoding for themselves or for someone else, and how easily the location (address) of a record can be memorized (e.g., addresses generated by oneself vs. others, cf. Mäntylä & Nilsson, 1983; Tullis & Benjamin, 2015).

In the field of library and information science, White (1992) proposed three dimensions for categorizing external memory records: published versus unpublished, personal versus communal, and archival versus current. In the field of personal information management, Bergman (2013, Table 1) identified 15 variables he grouped into 5 categories: organization-related variables (order, redundancy, and

name meaningfulness), structure variables (collection size, folder depth, folder breadth, and folder size), work process variables (attendance time and modularity), memory-related variables (memory reliance, dominant memory type [episodic, semantic, visual-spatial]), and retrieval variables (retrieval type [navigation, search, etc.], retrieval success, retrieval time, and ubiquity). Okdie et al. (2014) outlined variables of media for further study in psychology: fidelity, privacy, sensory channel, interactivity, and content.

Heersmink (2013) proposed a taxonomy of cognitive artifacts on the basis of their informational properties: three types of representational cognitive artifacts (iconic, indexical, and symbolic) and two types of non-representational or ecological cognitive artifacts (spatial and structural). Intons-Peterson and Fournier (1986) distinguished between past and future (i.e., retrospective and prospective memory purposes) and spatial versus verbal coding. They compared ratings of frequency, dependability, ease of use, accuracy, and preference for internal versus external aids in four types of situations (past vs. future and verbal vs. spatial).

Social Dimensions

Barnier, Sutton, Harris, and Wilson (2008) proposed six dimensions for social external memory: encoding versus retrieval, shared versus unshared experiences, intentionally versus accidentally shared experiences, distinct versus similar unshared experiences across people, retrieval done by an individual versus as a group, and the degree of collaboration in group retrieval. Harris, Barnier, Sutton, and Keil (2014, p. 293), in the context of couples as distributed memory systems, proposed the following dimensions: type of material resource (e.g., diary, calendar, phone), physical location of the resource, how often the resource is needed (based on regularity of routine), redundancy of resource across the two partners, which partner is responsible for encoding information in the resource, and which partner is responsible for retrieving information from the resource.

Both Technological and Social Dimensions

From a philosophy of mind perspective, Wilson and Clark (2009, see also Sutton, 2006) proposed two dimensions for the varieties of cognitive extension: type of external cognitive resource (natural vs. technological vs. sociocultural) and durability and reliability of the augmentation. Sterelny (2010), promoting the perspective of niche construction (whereby an organism alters its environment), proposed three dimensions: trust in the accuracy of the resource, how individualized the resource is to a particular user, and whether the resource is individual or collective. Menary (2010b) added two dimensions to the ones proposed by Sterelny: type of manipulation of the environment (biological coupling, epistemic actions, self-correcting actions, and cognitive practices) and extent to which use of a resource transforms thinking over time.

Environmental and Contextual Dimensions

Tversky (2011) reviewed many variables in the use of space and form to convey meaning in visualizations, and she also pointed out the dimension of purpose (e.g., aesthetic, behavioral, cognitive, communicative). Kirsh (1995) distinguished between long-term and short-term structuring and management of the physical environment to support cognition. Phillips, Henry, and Martin (2008, Table 8.1) identified important variables for ecological validity of future research on everyday prospective memory in older adults: setting (everyday life, complex real or virtual environment, laboratory), naturally versus artificially occurring tasks, and familiar versus novel tasks.

Dimensions We Propose for Further Research

In our current view, the most important 11 dimensions (variables) are as follows.

1. Internal Memory Versus External Memory

First, there is the very distinction between internal memory (information stored in an individual's brain) and external memory (information stored outside of an individual's brain), represented as the second level in our taxonomy shown in Fig. 1.1. If we view internal and external memory as complementary components of a cognitive system, it is important to understand the ways in which these components differ. We have described the major relative strengths and uses of the two as evident from our participants' responses (see Chapter 4 and Fig. 7.1). Note we are referring here to the differences between internal memory and *technological* (not social) external memory. Internal memory is used more than external for episodic and procedural purposes, while external memory is used more than internal for semantic and prospective purposes. The main strengths of internal memory are rapid convenient access especially to frequently used information, rich vivid representations that include sensations and emotions, 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), longevity (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). Rowlands (2010, p. 88) also noted the relative permanence and stability of external memory compared to internal memory.

In addition to those differences derived from our data, we will now note several other important differences between internal and external memory. Internal memory is fundamentally associative and reconstructive in nature, while external memory is not. As Vannevar Bush (1945) said of external memory: "One cannot hope thus to

equal the speed and flexibility with which the mind follows an associative trail, but it should be possible to beat the mind decisively in regard to the permanence and clarity of the items resurrected from storage.” The self-organizing associations of internal memory can span many dimensions (e.g., semantic, phonological, temporal), thus allowing for multiple potential retrieval routes (Finley, 2012) and for flexible creative connections. For external memory to afford a given retrieval route or association, organizational efforts must be made during or subsequent to encoding (e.g., metadata, folder structure). That said, making changes to the organizational structure of external memory should in many cases be easier than doing so with internal memory. For external memory, it may only be necessary to rename or move documents and folders on a computer; however, this process will not happen on its own. For internal memory, modifying learned categories and schemas requires slow laborious learning; however, this does tend to happen automatically as one encounters new information.

Both internal and external memory are susceptible to physical damage; but external memory can be duplicated (i.e., backed up) across multiple locations, a precaution not available for internal memory. Sterelny (2004) noted that external memory is vulnerable to active sabotage by other agents (e.g., your notes could be deleted or altered by others; photos could be doctored, Garry & Gerrie, 2005), and he claimed that internal memory is not vulnerable. However, we note that internal memory may also be sabotaged, though more subtly, by means of misinformation or gaslighting. That said, the question of whether some information was encoded by oneself or by other agents or even an automated process is generally much more of an issue for external memory than internal memory.

Internal memory retrieval involves only a query to internal memory; external memory retrieval involves an added decision to attempt to use the external source in the first place, often requiring retrieval of an internal memory about the external source being relevant in a given case. Importantly, external retrieval does not in itself change the information being retrieved (except for metadata such as “date last opened”). In contrast, internal retrieval is reconstructive and does change the information being retrieved (e.g., the well-established testing effect, also known as retrieval practice effect, Middleton, Schwartz, Rawson, & Garvey, 2015; Roediger & Karpicke, 2006). Rupert (2004) similarly pointed out that the generation effect (Slamecka & Graf, 1978) exists for internal memory but not external memory. Adams and Aizawa (2008, p. 137) pointed out that internal memory displays regularities such as the primacy and recency effects and that external memory does not. External memory also does not display different properties based on retention interval (as does internal working memory vs. long-term memory) and does not require time for consolidation.

Information can be more easily reinterpreted in external memory than in internal memory. Chambers and Reisberg (1985) found that discovering the second interpretation of an ambiguous figure (e.g., the duck/rabbit) is more readily done when perceptually inspecting one’s drawing of the figure versus mentally inspecting one’s mental image.

Two other noteworthy perspectives on differences between internal and external memory were provided by Norman (2013, p. 110, Table 3.1) and by Donald (1991, p. 315, Table 8.1). Norman wrote that external memory (knowledge in the world), as compared to internal memory (knowledge in the head), is less ephemeral (though it can be permanently lost), is more readily accessible (though less elegantly so), and requires less effort to use (if well designed). Donald wrote that external memory (exograms), as compared to internal memory (engrams), can accommodate larger entries of more varied format, has unlimited capacity and longevity, can be more easily refined, has less constrained retrieval paths, is transferable across media, and affords unlimited perceptual access.

Many of the above characterizations of differences rely on casual observation and inference. An important step forward would be to operationalize variables in order to actually measure them where possible. Having discussed the dimension of internal versus external memory, all subsequent dimensions we describe here will refer only to external memory.

2. Social External Memory Versus Technological External Memory

Second, there is the distinction between social external memory (information stored in other people) and technological external memory (information stored in the inanimate environment), the third level on the right side of Fig. 1.1. It is important not to overlook the major differences between social and technological external memory (e.g., social has agency and theory of mind, and technological is more fragmentary; see our earlier discussion of the transactive memory framework in Chapter 5).

3. Level of Technology

Third, we further distinguish between low-tech and high-tech external memory, the fourth level in Fig. 1.1. We have adopted the criterion of something needing a power source to qualify as high-tech, though other criteria could certainly be used. Different forms and media could be distinguished within low-tech and high-tech (e.g., Table 3.4). As for the differences between the two categories, high-tech external memory (especially at the level of computers, smartphones, and the Internet) has advantages such as full-text search and easier transferability across devices and users. But high-tech external memory is also more complicated to use, and in some ways it is more fragile. It is more vulnerable to hardware failure, to hacking and viruses, to file corruption, and to obsolescence of file format, software, or hardware (e.g., floppy disks). Low-tech external memory may be less flexible, but it is also less fragile and easier to use. Library and information scientists have written about the trade-offs in converting low-tech records to high-tech (digitizing; Borgman, 2000, pp. 65–66).

One way to refer to these first three dimensions combined would be the *locus of information*—that is, where the information resides with respect to an individual (internal, social external, low-tech external, or high-tech external).

4. Type/Purpose

Fourth, there is the type or purpose of an instance of external memory: episodic, semantic, procedural, or prospective. These categories, which arose in our participants' responses (e.g., Q126, 127; Fig. 4.1), are also often used in theories of internal memory (Roediger, Marsh, & Lee, 2002; though see Rubin & Umanath, 2015). However, we have grouped them together here in a way that they are not usually grouped in such theories. In a typical taxonomy representing theories of multiple internal memory systems (e.g., our Fig. 1.1; Schacter & Tulving, 1994; Squire, 2004), long-term retrospective memory is divided into a declarative (explicit, knowing that) system which includes episodic and semantic memory and a nondeclarative (implicit, knowing how) system which includes procedural memory and other systems. Prospective memory is not included as a system (although see Szpunar, Spreng, & Schacter, 2014). Whereas for internal memory, it is at least plausible to propose distinct memory systems based on data from functional neuroanatomy and dissociations in behavioral performance (Roediger, Rajaram, & Srinivas, 1990), no such distinctions are necessary for external memory. The same technology (e.g., a jpeg image file) can underlie external representations that are episodic (a picture of you and your spouse dancing at your wedding), semantic (a map of a solar eclipse's path), procedural (a picture of furniture assembly instructions), or prospective (a picture of a to-do list). Thus we are not proposing these are distinct systems in external memory but rather distinct purposes or distinct types of information. Our thinking here is in the spirit of Willingham and Goedert (2001): "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." The different patterns of correlations we observed between our composite variables and Q68 versus Q69 suggest that episodic and semantic use of external memory are different practices (see Chapter 4, Correlations: Other Variables). A good future direction would be to explicitly ask participants about their use of internal and external memory for these four categories (episodic, semantic, procedural, and prospective).

5. Encoding Versus Retrieval Processes

Encoding is the process of entering information into a memory system. Retrieval is the process of extracting information from a memory system. Encoding sends information into the future; retrieval receives information from the past. These two processes can be very different from each other for external memory. Encoding is generally much easier than retrieval. Think of jotting down a note, saving a file on your computer, or taking a picture. Now compare to the process of finding that note, file, or photo again 1 year later. Retrieval is dependent on encoding and organization to a greater extent for external than for internal memory. In part retrieval is difficult because it is so easy to accumulate a massive volume of information and we are unlikely to put much effort into organizing it.

Some of the theoretical frameworks we have reviewed (e.g., personal information management, library information science) can help in characterizing the processes of encoding and retrieval (e.g., filing vs. piling, navigation vs. search). It is important to continue studying the variety of encoding and retrieval strategies for external memory, and the metacognitive processes that guide them, just as researchers have done for internal memory (Finley & Benjamin, 2012; Finley, Tullis, & Benjamin, 2010; Fiechter, Benjamin, & Unsworth, 2016; Goldsmith, 2016). External encoding and retrieval strategies may vary across different types or purposes of external memory (episodic, semantic, procedural, prospective; Bergman, 2013, p. 476; Clowes, 2013). Additionally, failures of external memory can be informative about encoding and retrieval processes (Table 3.6, Q131).

Some of the distinctions used in typologies of internal memory terms (Roediger, Zaromb, & Lin, 2017) may be fruitfully applied to external memory, at least by analogy. For example, there is the distinction between intentional (voluntary) versus incidental (involuntary) encoding and/or retrieval. External encoding may happen occasionally without intent, for example, when someone does not realize that an audio or video recording is being made. Involuntary external retrieval is even more common. You have likely had the experience of stumbling unintentionally upon an old photograph that stimulates a powerful reminiscence of a past experience, good or bad. A majority of our participants reported that external memory had at least sometimes reminded them of things they did not want to remember (Q78). These were presumably involuntary reminders, for example, when an app like Facebook or Timehop presents automated “memories” of dead loved ones or abusive ex-partners (Sauter, 2017). The distinction between voluntary and involuntary may be more of a continuum than a dichotomy; sometimes we browse our personal or public archives without a specific intent to retrieve but knowing that we may serendipitously encounter something moving.

6. Timescale

Analogous to the distinction between working memory and long-term memory, the interplay of internal and external memory may vary across timescales (Kirsh 1995, pp. 35–36). On a short-term scale, external memory can function as a component of an ephemeral closely coupled cognitive system, as when we use paper and pencil to solve a math problem, or when an artist uses a sketchbook while creating art (van Leeuwen, Verstijnen, & Hekkert, 1999), or as in the Blocks World task (Ballard, Hayhoe, & Pelz, 1995). In these cases, external memory forms a workspace that Donald referred to as an external memory field (1991, p. 297) and that Clark described as exhibiting continuous reciprocal causation (2008, pp. 24–28). On a long-term scale, external memory can serve as a passively dormant repository of potential information to be retrieved when needed, while also serving active prospective purposes (e.g., reminding you of a dentist appointment in 6 months). We can also conceive of timescale as retention interval. A shopping list may be intended for use within a few days, while a birth or marriage certificate is intended for indefinite future use.

7. Format

The format of representations in external memory may refer to sensory channel (i.e., modality; e.g., auditory vs. visual) or code (e.g., verbal vs. spatial). Different formats can provide different affordances and thus can interact with internal memory and cognition in different ways (Wickens & Liu, 1988). For example, while driving a car, it is much safer to listen to an audio news broadcast than to read a visual news article. Human factors research has also shown that the compatibility of stimulus and response is important for performance. For example, Wickens, Sandry, and Vidulich (1983) found that performance was best in a simulated flight task when spatial information was displayed visually and responded to manually, and when verbal information was displayed auditorily and responded to vocally. The interplay of internal and external memory works best when the format of information maps easily between the two (Norman, 2013). The format of a visualization can also facilitate or impair its use for a given task (Bederson & Shneiderman, 2003; Collins & Ferguson, 1993; Kosslyn, 2006, 2007; Larkin & Simon, 1987; Latour, 1986; Novick, 2001; Reed, 2010; Tversky, 2011; Zacks & Taylor, 2017; Zhang, 1997). It would be fruitful to investigate differences in use among common external memory formats, such as text, photos, videos, and audio recordings.

8. Role Relative to Internal Memory (Complementarity)

Clark (2001, p. 154) remarked that “much of what matters about human-level intelligence is hidden not in the brain, nor in the technology, but in the complex and iterated interactions and collaborations between the two.” How are we to characterize such interactions? To what extent does a given instance of external memory supplant (replace) internal memory versus augment (extend) internal memory?

Our data summarized participants’ general attitudes about the relationship between internal and external memory (Table 2.5), and their behaviors and experiences. The relationship appears to vary across types/purposes of external memory (Fig. 4.1, Table 4.1). For episodic (and perhaps procedural) purposes, external memory augments internal memory; for semantic and prospective purposes, external memory supplants internal memory. These are current use patterns and may change in the future. Our data also detailed specific ways in which augmentation or supplantation occurs (Tables 4.2, 4.3; Fig. 7.1; see also Chapter 4: Symbiosis of Internal and External Memory). In terms of augmentation, external memory can cue and expand on internal memory, can act as a fail-safe or verification for internal memory, and can strengthen internal memory (e.g., when a student uses flash cards). It is worth further exploring how things like photos may alter or override internal episodic memories. When external memory supplants internal memory, the latter is freed up to do other things (Table 4.3). These roles may not be mutually exclusive. For example, taking lecture notes can both strengthen encoding in internal memory (augmenting) and provide a record for later retrieval that obviates the need for internal memory (supplanting).

Menary (2007, 2010a, p. 237) outlined different ways that internal and external components can interact (e.g., biological coupling, epistemic actions, self-correcting actions, cognitive practices). Heersmink (2015) also outlined possible dimensions of integration, including information flow, reliability, durability, trust, procedural transparency, informational transparency, individualization, and transformation. Casati (2017) proposed four modes of thinking: an automatic internal mode (M1), a deliberative internal mode (M2; cf. Kahneman, 2011), a hybrid mode using cognitive artifacts (M3), and a completely offloaded mode (M4). He proposed that M3 uses mechanics such as displacement (converting an M2 task into an M1 task), shunting (representing information so as to use the simplest type of M1 processing, such as edge detection), and bridging (e.g., between vision and hearing). M3 augments; M4 supplants. The distinction between augmenting and supplanting is also discussed in rehabilitation contexts (Best, O'Neill, & Gillespie, 2014; Charness, Best, & Souders, 2012). Van den Hoven and Eggen (2014) discussed different ways for devices to cue internal memory. Norman (1993, pp. 221ff) talked about hard versus soft technology, a distinction which roughly corresponds to supplanting versus augmenting. For other relevant discussions, see Clowes (2013), Rupert (2010), Sutton, Harris, Keil, and Barnier (2010), and Wilson and Clark (2009).

9. Authorship and Intended Audience

Here we group two dimensions together. First, was a given record in external memory encoded by oneself, by someone else, in collaboration with someone else, or by an automated process without agency? Records that one made oneself are likely to be more familiar than records made by another, and thus they should have the advantage of greater mental representation in one's internal memory, which helps in finding and interpreting the external records. For example, you should have an easier time locating and reading a shopping list that you made in your own handwriting versus one made by another person in your household. You may not even know about records made by someone else or by an automated process. Of course, it is also possible to completely forget about records you made yourself.

Second, what about intended audience? Was a given record in external memory intended for oneself, for a specific other(s), for a class of others, or for everyone? Perhaps it was encoded with no intention at all? Someone else may have trouble interpreting notes that you took for yourself, because of idiosyncratic shorthand or references that you used. There is a difference between sending information to someone else versus sending information to one's future self (Mäntylä & Nilsson, 1988; Schönplflug 1986; Tullis & Benjamin, 2015). But as time passes, we become different people from who we once were, and notes that we made for ourselves may become harder to interpret or may carry less resonance. Grice's maxims of cooperative conversation (1975) are relevant to the ways we may encode external memory differently depending on intended audience. Challenges are greatest when sending external information to potential recipients in the very distant future, such as warning future generations for the next 10,000 years about the dangers of a

radioactive waste disposal site (Trauth, Hora, & Guzowski, 1993; see also The Long Now Foundation: longnow.org), or sending a concise record of life on Earth into interstellar space aboard the two Voyager spacecraft, in the event that they are ever discovered by space-faring civilizations (Sagan et al., 1978; Popova, 2014).

Authorship and intended audience also tie in to issues of ownership, access, and privacy (Karat, Karat, & Brodie, 2007; Shamos, 2007). The distinction between personal and public external memory is worth considering. See also Jones's (2007) notion of a personal space of information and Frohlich's (2004) diamond framework which represents the interactions between a photographer, the photograph, the subject of the photograph, and the person viewing it.

10. Context of Use

Several of the theoretical frameworks we reviewed (e.g., in human factors, media studies, anthropology, and cognitive rehabilitation) emphasized that we cannot ignore the social, cultural, and task-specific contexts in which external memory is used. Lave (1988) emphasized person, activity, and setting. Case and Given (2016, Chapter 1.1.5) discussed the variety of different types of contexts in which external memory use can be studied. Responses from our participants (e.g., Q122) illustrate the variety of contexts in which external memory is particularly useful for everyday life, including work, hobbies, family, friends, health, and household maintenance (including shopping for and preparing food, and other necessities of daily living). The context of health information is a particularly important applied area. In addition to formal electronic medical records maintained by healthcare professionals, individuals may keep their own personal external records of diet, exercise, drug use, and sexual experiences.

11. Person Variables

Individual differences are sure to play a role in people's thoughts, feelings, and behaviors with external memory. For example, personality variables are worth exploring further. In the current study, we considered a small number of these (see Chapter 4, Correlations: Personal Characteristics): nostalgia, liking to collect things, distractibility, and general organization. Each of these was related in some way to some of our composite variables (e.g., regarding attitudes, emotions, and behaviors related to external memory; Table 4.6).

There are basic demographic variables such as age, gender, education level, and socioeconomic status. Skin tone may be relevant to the practice of writing on one's hand. Relationship status and length of time in a relationship may be relevant for social external memory, though we did not find any noteworthy results in our data. The role of emotions and identity should not be overlooked, as a majority of our participants considered their external memories to be part of them, and that they would feel devastated if they lost them. See also Zhang, Kim, Brooks, Gino, and Norton (2014) and Diehl, Zauberman, and Barasch (2016).

Internal memory ability (both as measured by researchers and as perceived by the person) is likely to be very important, as is the amount of previous experience with a particular form of external memory, or with technology in general. A person's amount of reliance on external memory is itself a critical variable and one worthy of further study, either as a quasi-experimental independent variable or perhaps as manipulated experimentally.

A person's professional role is likely to be related to their use of external memory. Harris (1980) found differences in patterns of external memory use for college students versus women who were mostly homemakers. Different professional roles make different demands on memory and benefit from different kinds of external memory aids. For example, consider students using lecture notes and flash cards, professors using PowerPoint presentations, police officers using body-worn cameras, artists using sketch pads, healthcare workers using electronic medical records, accountants using spreadsheets, pilots using cockpit instruments, journalists using audio recorders, musicians using sheet music, or lawyers using case law databases. See Case and Given (2016, Chapter 10) for a discussion of research on information-seeking behavior as it varies across professional and other roles.

Yoder and Herrmann (2003) investigated young adults' attitudes about memory aids and how those were related to demographic, personality, and experiential variables (e.g., predictability of schedule). Herrmann, Brubaker, Yoder, Sheets, and Tio (1999) reviewed reminding devices and also covered characteristics of people more or less likely to buy and use such devices.

Other Research Questions

In addition to the above dimensions for exploration, and the framework illustrated in Fig. 7.1, we note here several other specific outstanding research questions.

When and Why Do People Use External Memory?

This question has only begun to be investigated (e.g., the current study; Harris, 1980; Intons-Peterson & Fournier, 1986; Kalnikaitė & Whittaker, 2007; Lux, Kogler, & del Fabro, 2010; Walker & Andrews, 2001). The relative strengths of internal versus external memory that we summarize in Fig. 7.1 are relevant to this question, as is the "context of use" dimension we identified earlier. We need to understand the variety of motivations or goal orientations behind external encoding and retrieval (Q119, 122, 127, 132). Motivations for encoding can include communication, aesthetic appreciation, emotional preservation, anticipation of future forgetting and information need (i.e., sending information to our future selves), offloading to reduce burdens on internal working memory, desire to capture a fleeting experience (Koenig, 2017), alleviation of existential angst due to the transience

of human life (Foer, 2011, p. 19; Manguso, 2015), a bid for immortality (Fries, 2018), or no particular reason at all. Motivations for retrieval can include resolving anomalous states of knowledge (Belkin, 2005), resolving a disagreement, looking up information needed to complete a task, verification of internal memory, curiosity, entertainment, or reminiscence.

Helpful frameworks for the question of when and why people use external memory have been provided by Arango-Muñoz (2013), Esser (1996), and Risko and Gilbert (2016). Case and Given (2016, pp. 79–96) provided a helpful review of motivations for information seeking. Intons-Peterson and Fournier (1986) proposed that external memory is likely to be preferred over internal memory when retention intervals are long, when there is likely to be interference during the retention interval, when high precision and accuracy are needed, when the information is complicated, when there is not much time for encoding, and when internal memory load is to be avoided. In other words, we prefer external memory when we are likely to forget. Predicting forgetting is an inherently metacognitive judgment (cf. JOLs, Dunlosky & Metcalfe, 2008). People may choose to create external memory logs of experience when they judge that their internal memory will be impaired, for example, due to the effects of psychoactive drugs, fatigue, or distraction, or when an upcoming change in context or activity is likely to obscure an internal memory trace or intention, such as when you think of a new insight or important errand while in the shower or driving a car, only to forget it as soon as you finish that activity (see also the double capture error in prospective memory, Kirsh, 1995). A waterproof note slate or an audio recorder for dictation would provide external solutions to such memory failures. Another common scenario we would add to those proposed by Intons-Peterson and Fournier is when precise information is needed for a single use in the near future, and it could interfere with future tasks if retained past its use. For example, it is wise to make an external note for a temporary password, or where you parked your car. An additional question for research is to what extent are decisions to use external memory deliberative versus automatic? When decisions are deliberative, they may involve metacognitive judgments of benefits and costs (e.g., Risko & Dunn, 2015; Schönplflug, 1986).

How Can We Measure and/or Manipulate the Cost or Effort of Using External Memory?

Time delays are one primary method that has been used to experimentally manipulate the cost of using external memory (Gray, Sims, Fu, & Schoelles, 2006; Schönplflug, 1986). Parametric manipulation of time costs can reveal the shape of the function for people's use of external memory (i.e., how long of a delay people are willing to tolerate before switching to internal memory). Related research has been done in the field of human-computer interaction, investigating the effect of system response time length and variance on user behavior and satisfaction (e.g., Weber, Haering, & Thomaschke, 2013). Other approaches beside time

delays should also be explored. This is important for mapping the landscape of trade-offs between internal and external memory. The time and effort required to use external memory, whether at encoding or retrieval, is a likely factor in people's decisions between internal and external memory.

How Do People Metacognitively Monitor and Control Their Use of External Memory?

Dovetailing external memory research with metamemory research should be fruitful. Dunlosky, Serra, and Baker (2007) outlined a framework for research on metamemory monitoring (i.e., the assessment of ongoing cognitive processes) that can be adapted to study metamemory control (i.e., the regulation of ongoing cognitive processes), including control of external memory: how do people control memory use, how optimal is their control, and how can it be improved (e.g., Walker & Andrews, 2001)? For example, one idea would be to naturalistically observe the organization of people's information on their own computers, assess how effectively that organization facilitates their goals, assess their internal memory for that organization, and test more optimal balances of internal and external memory using principles from the study of automation in human factors research.

Broadly, we can conceive of everyday memory use as a strategic allocation or distribution of resources, including internal memory and all the various types of external memory. People cannot make judicious use of external memory resources without first having accurate mental models of those resources. This leads to many research questions. For example, do people tend to under- or over-estimate how easy it is to find certain information on the Internet or in their own personal files? Do people have accurate understandings of the relative strengths and weaknesses of biological memory versus machine memory? What about people's confidence in the accuracy of internal memory versus external memory? Would we see the same levels of calibration, resolution, and the hard-easy effect for external memory as we do in internal memory (Lichtenstein, Fischhoff, & Phillips, 1982; Roediger, Wixted, & DeSoto, 2012; Tidwell, Buttaccio, Chrabaszcz, Dougherty, & Thomas, 2016)?

Is the Objective Accuracy of External Memory Perhaps Overstated?

External memory too may be subject to distortions, especially with the editing capabilities of current apps, which allow us to alter text of social media posts we have made and to alter photos (e.g., Instagram filters, Snapchat photo effects, Photoshop retouching). For example, if someone took a picture in the mountains on a sunny day but added a filter effect to make it look cloudy, will they remember the day as cloudy when they revisit the picture several years later? We are also free to delete

material from external memory. Researchers working with archival records have long confronted the problems of selective deposit and selective survival, which can distort an archive's representativeness of the past (see also historiography). These concerns now extend to everyone's personal external memory stores. What we choose to externally encode and retrieve can shape our narrative understanding of our lives and our sense of self, in a very long-term interplay of internal and external memory. For example, consider embarrassing pages from an old diary that we tear out, letters from an old romance that we hide away, reminders of a trauma that we discard, a treasured book that we reread, a song we replay, a movie we rewatch, and a wedding photo or diploma we display in our homes (see also our earlier discussion of family photograph albums in Chapter 6: Photography). With external memory, making sense of one's life and identity becomes a kind of personal historiography (for an exploration of how people use Gmail in their life narratives, see Zalinger, 2011). An important advance for researchers would be to integrate the construct of external memory into theories of memory and identity, such as Conway's self-memory system (Conway & Pleydell-Pearce, 2000).

Backup Practices

Backup and archiving behaviors are an important applied issue (Table 3.13). To the extent that people value their external memories as part of themselves, they should take the same precautions to protect those memories as they would to protect their own brain. But do they? What are people's practices (or lack thereof), what factors influence those practices, and how can those practices be improved? Marshall's work (2008a, 2008b, 2011) provides a fruitful springboard.

Prospective Memory

There are several unanswered questions with regard to prospective memory tasks. What different kinds of external memory aids do people choose to use for prospective tasks? When and why do they choose to use them? What metacognitive judgments are behind these choices? What problems do the aids solve, and what problems do they introduce?

Measurement and Operationalization

In our study we found that self-assessed internal memory ability was negatively correlated with use of external memory. An important next step is to add standard laboratory memory tasks to get objective measurements of internal memory ability,

and see how that relates with use of and attitudes about external memory. It would also be useful to operationalize some of the proposed advantages and disadvantages of internal versus external memory that we have identified with our survey data, so that they can be more formally measured. For example, speed, ease of use, and ability to make connections and see the big picture.

Developmental Questions

There are interesting long-term developmental questions. Are there cohort effects on people's interactions with external memory (e.g., for digital natives who have grown up with the Internet vs. digital settlers who have seen the Internet come of age in their lifetime)? What are the effects, if any, of exposure to information intensive environments from an early age? What role does external memory play in identity formation and maintenance (e.g., reflecting on videos or certificates of past milestones such as graduations), and does that role differ for experience with low-tech versus high-tech? Can external memory be particularly helpful for continuity of identity in people with impaired internal memory? Will we see long-term well-being effects from greater reliance on technology (e.g., sleep disturbance, altered attentional habits, eye strain, tendonitis)? See our earlier discussion of developmental methods for studying external memory in Chapter 7.

Classifying and Keeping Up with External Memory Technology

Efforts must be made to continue identifying and classifying specific strategies, tools, and tasks of external memory. Adams and Aizawa (2001) gave a pessimistic view of research into external memory:

Consider, then, the range of tools humans use as mnemonic aids. There are photo albums, Rolodexes, computer databases, strings around the finger, address books, sets of business cards, bulletin boards, date books, personal information managing software, palmtop computers, hand drawn maps, and lists of 'things to do.' What are the chances of there being interesting regularities that cover humans interacting with all these sorts of tools? Slim to none, we speculate. There just isn't going to be a science covering the motley collection of 'memory' processes found in human tool use. (Adams & Aizawa, 2001, p. 61)

We disagree with this bleak outlook, and we hope that the interesting regularities we found in our data will be followed by more. However, it is worth considering that there may be a need to develop more specific models for internal-external interactions on a task by task basis (cf. Intons-Peterson & Fournier, 1986). For example, Schönplugg and Esser (1995, Figure 14.2) analyzed a text reproduction task, though their model could apply to both low-tech and high-tech versions of such a task. There is still exploratory descriptive work to be done in order to fuel such theory-building. Researchers will need to keep up with evolving technologies like smart

watches, smart glasses (Bohn, 2018; Levy, 2017; Miller, 2012), augmented reality, virtual reality, artificial intelligence, brain-machine interfaces, implants, and whatever else is next. How will the interplay between internal and external memory change as technology and society continue to change? Is there a limit to how much external memory can augment internal memory? As the symbiosis between our biology and technology grows ever closer, perhaps the distinction between internal and external will evaporate in a *singularity*, beyond which memory and intelligence will be transhuman/posthuman or even postbiological (Dick, 2003; Gillings, Hilbert, & Kemp, 2016; Kurzweil, 2005; Masci, 2016; Smart, 2012; Vinge, 2008).

Is Technology Making Memory Worse?

We have saved this question for last. This is the question most asked in the popular press (e.g., Biegler, 2016; Carr, 2011, 2014; Naughton, 2010; Tan, 2016; Thompson, 2013; Turney, 2013; Wagner, 2015; Wegner & Ward, 2013). But it is too simplistic and vague to answer. What we can say is that technology is making memory different. We are offloading semantic and prospective information onto external memory, and we are using external memory to augment episodic internal memory. Most participants reported that they think external memory helps them function, but they would also do fine without it, and they do not feel uneasy about relying on it. Participants generally recognized that internal memory is necessary for effective use of external memory and that the two types of memory have strengths that complement each other.

People tend not to memorize semantic information if they expect to have access to it in external memory. This can be seen in the apparent decline in memorized phone numbers (Q110) and as experimentally demonstrated by Sparrow, Liu, and Wegner (2011, Experiment 2) and Macias, Yung, Hemmer, and Kidd (2015). The Kaspersky Lab (2015) coined the term *digital amnesia* for “the experience of forgetting information that you trust a digital device to store and remember for you.” While researchers can measure the amount of information that people choose to internally memorize in the presence or absence of external memory, a broader open question is whether our very *ability* to internally memorize new information is atrophying with disuse in the long term. This is a very challenging question to research, though perhaps not quite impossible. The developmental research methods we discussed in Chapter 7 could be used (e.g., a combination of longitudinal, cross-sectional, and time-lag studies), but they are time and resource intensive, and the evidence they yield is fundamentally correlational. Experimentally manipulating long-term access to external memory would be impractical and/or unethical (Thompson, 2013, p. 135); however, it may be possible to experimentally manipulate reliance on technology in a short-term laboratory situation or to ask participants to forego or increase use of certain types of external memory in everyday life for limited durations (e.g., Deters & Mehl, 2013; Tromholt, 2016).

Some authors have proposed reasons that technology may make internal memory worse. Hoskins (2016) warned that the increasing entanglement of human and digital memory leads to a potentially dangerous ceding of control over our memories to networks, with uncertain consequences such as loss of privacy and security, degradation of the spontaneity and schema formation of human memory, and alienation of memory from the self. Carr (2011, pp. 194–195) argued that using the Internet invites such distraction that it disrupts consolidation of short-term into long-term memory and that we are training ourselves to be distracted. He argued that not only are the rich interconnected stores of our internal memory diminishing but that our very ability to encode new information is also diminishing. Ward (2013) similarly argued that overreliance on the Internet may “impair future memory formation by preventing the construction of schema necessary for encoding new memories.” Ward furthermore argued that people may come to mistake knowledge in external memory for knowledge in internal memory, leading to the metacognitive effect of overconfidence in one’s internal knowledge. Greenfield (2014, p. 209) argued that if people only learn the external locations of answers, rather than the answers themselves, they will not build up the rich internal associative network of knowledge that allows for deep understanding.

Views that technological external memory is bad for internal memory tend to hinge on the assumptions that (a) we are foregoing internal memorization of things we would have otherwise memorized, and (b) it would have been beneficial to have those things in internal memory. With regard to (b), we argue that some things gain no added value from being in internal memory (e.g., phone numbers, which require accurate retrieval that is better performed by external memory), while other things do gain added value from being in internal memory (e.g., integrated knowledge of literature, history, and science, which may allow one to form new creative insights). With regard to (a), we have to ask: when people use external memory, to what extent are they really offloading things that they would have otherwise memorized versus things that they would have otherwise never known at all? Consider expertise. Throughout much of the history of human civilization, experts in a particular trade or domain of knowledge were relatively uncommon and highly valued, and this was part of the division of labor in society. Now, in the early twenty-first century, the Internet provides easy access to factual answers and a wealth of do-it-yourself instructional videos on procedural tasks from computer troubleshooting to home repair. With the use of external memory, it is easier for people to become jacks-of-all-trades across domains for which they may have otherwise relied on the expertise of others. Perhaps on a societal level, there is a trade-off between such widespread versatility and the prevalence of deep expertise. Perhaps such a trade-off occurs in individuals too, sacrificing mastery for versatility, though it is also possible that people are adding versatility on top of their area(s) of mastery. These are interesting possibilities that require more evidence to assess. But they illustrate that the question of “is technology making memory worse” can be addressed in multiple ways. Are we talking about the number of experts in a society and the depth of their expertise? Are we talking about changes within individuals (total amount of knowledge, breadth of knowledge, depth of knowledge)? Are we talking about the

average amount of knowledge and skills across people in a society? To what extent does it matter whether particular kinds of knowledge are internal or external?

With regard to the question of decline in memorization ability, for which we have already described the methodological difficulty in answering, we add one more thought. It is possible that external memory, at least in some cases, can act as a tireless and even adaptive tutor rather than a replacement for internal memory. This is the case in educational and formal training contexts (e.g., Aleven, McLaughlin, Glenn, & Koedinger, 2016; Mettler, Massey, & Kellman, 2016) as well as everyday life. Suppose, for example, that you need to build a bookshelf. You browse several tutorials (whether on the Internet or in books) and then proceed to the building process. If you only build a bookshelf once every 10 years, there is no need to remember the procedure for the rest of your life. However, if you end up making several bookshelves per year for the next 10 years, it is highly likely that you will eventually be able to recall all the key steps without consulting the tutorials anymore. You may even develop your own improvements on the process. So, external memory does not *necessarily* impair internal memory abilities; it depends on how, and how often, you use it. With frequent use, external memory information can still be internalized and can help us learn more than we otherwise would have. Furthermore, skilled use of external memory is crucial for functioning in the modern world.

Heersmink (2016) said: "...having the skills to efficiently navigate, evaluate, compare, and synthesize online information are (under most circumstances) more valuable than having a lot of facts stored in biological memory." Based on our data, and our review of the literature, we agree with Norman (2013, p. 286): "Reliance on technology is a benefit to humanity. With technology, the brain gets neither better nor worse. Instead, it is the task that changes. Human plus machine is more powerful than either human or machine alone." Development of technological external memory has generally uplifted humanity in the long run. Although a tremendous amount of research remains to be done, at this point we are cautiously unpessimistic about the future of human memory.

Conclusion

In this book we have presented new empirical evidence about the ways people use internal and external memory together in everyday life in the early twenty-first century (Chapters 1, 2, 3 and 4), and we have provided guidance for future research in the form of a thorough review of the disparate literature to date on external memory (Chapters 5 and 6), as well as providing a theoretical framework for the interplay of internal and external memory (Chapter 7), including important dimensions and specific questions (Chapter 8).

Using tools for memory is integral to human existence. We have a long history of doing so. It changes us. Internal and external memory have mutually shaped each other for tens of thousands of years and will continue to do so into the future. It is important to keep documenting and seeking to understand this interplay.

Are we reliant on technology? Yes, but we have always been, and it is one of our greatest strengths. Technology will continue to change. For example, smartphones have consolidated what were once multiple separate devices (phone, camera, GPS, music player, personal digital assistant, computer with web browser), though we still face problems of data fragmentation. It is hard to imagine technological changes more dramatic than those we have already witnessed in the late twentieth and early twenty-first century. But such changes may well come. Thus, the role of external memory in everyday life is a moving target. We have laid the groundwork for more empirical and theoretical work. We encourage you to conceive and undertake such work. It is long past time that psychology fully embrace this crucial aspect of human existence, with concerted and coordinated long-term programs of research. For, in the words of Proust (1919/2015, p. 240), “the greater part of our memory exists outside us.”

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Appendix A: Complete Text of Questionnaire

Note. Response options for closed-ended questions are listed in square brackets. Question 111 was not added until after the first nine participants.

1. What is your current age (in years)?
2. What is your sex? *[male, female, other]*
3. Which of the following best describes your highest achieved education level?
[Some high school; High school graduate; Some college, no degree; Associate degree; Bachelor degree; Graduate degree (Master, Doctorate, etc.)]
4. Are you currently a student or taking any classes? *[yes, no]*
5. In what country do you live?
6. What is the total yearly income of your household? *[Less than \$12,500; \$12,500–\$24,999; \$25,000–\$37,499; \$37,500–\$49,999; \$50,000–\$62,499; \$62,500–\$74,999; \$75,000–\$87,499; \$87,500–\$99,999; \$100,000 or More]*
7. How many languages are you fluent in?
8. Is English your primary language? *[yes, no]*
9. Have you ever had any neurological problems (e.g., traumatic brain injury, strokes, seizures)? *[yes, no]*
10. Are you currently in a relationship? *[yes, no]*
11. If you are currently in a relationship, how many years have you been in this relationship?
12. Do you think your memory is worse, the same as, or better than most people of your own age? *[much worse, somewhat worse, the same as, somewhat better, much better]*
13. Do you think your own memory has become better or worse during the last 5 years, or is it unchanged? *[much worse, somewhat worse, unchanged, somewhat better, much better]*
14. Do you think your own memory will become better or worse during the next 5 years, or will it be unchanged? *[much worse, somewhat worse, unchanged, somewhat better, or much better]*

15. Most people are exposed to large amounts of new information each day. Do you think there is a limit to the amount of information the brain is able to store? [*yes, no*]
16. Physical exercise makes the body stronger. Do you think it is possible to train memory in an analogous fashion? [*yes, no*]
17. How good are you at judging the reliability of your own memory? [*very bad, pretty bad, neither good nor bad, pretty good, very good*]
18. Rate the extent to which you disagree or agree with the following statement: Once someone has experienced an event and formed a memory of it, that memory does not change. [*strongly disagree, disagree, neutral, agree, strongly agree*]
19. Rate the extent to which you disagree or agree with the following statement: Human memory works like a video camera, accurately recording the events we see and hear so that we can review and inspect them later. [*strongly disagree, disagree, neutral, agree, strongly agree*]
20. Sometimes a memory about our past suddenly pops up in our mind with no preceding attempts at remembering. The memory may seem to arise from nothing or it may come as an association to, for example, a sound, or a smell, or a song on the radio, etc. Some sudden memories may deal with old experiences, others with things that have happened recently. How often does it happen to you that memories suddenly pop up by themselves? [*never, several times a year, several times a month, several times a week, several times a day*]
21. If you answered “several times a day” to the previous question, please type a number estimating the number of times per day:

“Internal memory” refers to information stored in your own brain. “External memory” refers to information stored in the world outside of your brain, and it could be low-tech (e.g., paper) or high-tech (e.g., computer). Information is also stored in other people’s brains, but for this survey we do not consider other people to be “external memory”.

22. I use low-tech external memory to help me remember things (e.g., writing on paper). [*never, seldom, sometimes, often, always*]
23. I use high-tech external memory to help me remember things (e.g., computers, phones, Internet). [*never, seldom, sometimes, often, always*]
24. I use other people to help me remember things. [*never, seldom, sometimes, often, always*]
25. Do you use low-tech external memory to help you remember things more or less often compared to 5 years ago? [*much less often, less often, no difference, more often, much more often*]
26. Do you use high-tech external memory to help you remember things more or less often compared to 5 years ago? [*much less often, less often, no difference, more often, much more often*]
27. Do you use other people to help you remember things more or less often compared to 5 years ago? [*much less often, less often, no difference, more often, much more often*]

28. In 5 years do you think you will use low-tech external memory to help you remember things more or less often compared to now? [*much less often, less often, no difference, more often, much more often*]
29. In 5 years do you think you will use high-tech external memory to help you remember things more or less often compared to now? [*much less often, less often, no difference, more often, much more often*]
30. In 5 years do you think you will use other people to help you remember things more or less often compared to now? [*much less often, less often, no difference, more often, much more often*]
31. Do you use shopping lists when you go shopping? [*never, seldom, sometimes, often, always*]
32. When you are reading a [physical] book, do you use a bookmark to indicate where you stopped reading last time? [*never, seldom, sometimes, often, always*]
33. When you want to remember an event such as a birthday, do you ask somebody else (e.g., partner or friend) to help you remember? [*never, seldom, sometimes, often, always*]
34. Do you post notes on a board or other prominent place to help you remember things for the future (e.g., meetings or dates)? [*never, seldom, sometimes, often, always*]
35. Do you put things (e.g., glasses or keys) in particular places to remember where they are for future purposes? [*never, seldom, sometimes, often, always*]
36. Do you put things in obvious places (e.g., in front of the door) in order to remember them when you're going out? [*never, seldom, sometimes, often, always*]

How often do the following happen to you?

Response options for questions 37–42: [not at all in the last three months, about once in the last three months, more than once in the last three months but less than once a month, about once a month, more than once a month but less than once a week, about once a week, more than once a week but less than once a day, about once a day, more than once a day]

37. Forgetting where you have put something. Losing things around the house.
38. Completely forgetting to take things with you, or leaving things behind and having to go back for them.
39. Finding that a word is “on the tip of your tongue”. You know what it is but cannot quite find it.
40. Completely forgetting to do things you said you would do, and things you planned to do.
41. Forgetting to tell somebody something important. Perhaps forgetting to pass on a message or remind someone of something.
42. Knowing that you have some piece of information stored in external memory somewhere, but being unable to find it.
43. I feel uneasy about how much I rely on technology for memory purposes. [*strongly disagree, disagree, neutral, agree, strongly agree*]

44. I feel that using technology for memory purposes enhances me as a person.
[strongly disagree, disagree, neutral, agree, strongly agree]
45. Using technology for memory purposes allows me to do things that I could not otherwise do. *[strongly disagree, disagree, neutral, agree, strongly agree]*
46. With the help of technology for memory purposes, are you less functional or more functional? *[much less functional, somewhat less functional, neither less nor more functional, somewhat more functional, much more functional]*
47. Without the help of technology for memory purposes, how well would you be able to function with just your human memory? *[very poorly, poorly, neither poorly nor well, well, very well]*
48. How well do you understand the technology you use for memory purposes? *[very poorly, poorly, neither poorly nor well, well, very well]*
49. Rate the extent to which you disagree or agree with the following statement: Human memory and machine memory (computers) are good at different things. *[strongly disagree, disagree, neutral, agree, strongly agree]*
50. Rate the extent to which you disagree or agree with the following statement: Human memory and machine memory (computers) work roughly in the same way. *[strongly disagree, disagree, neutral, agree, strongly agree]*
51. Overall, do you think human memory is getting better or worse? *[much worse, somewhat worse, neither worse nor better, somewhat better, much better]*
52. I have trouble remembering things without external aids. *[never, seldom, sometimes, often, always]*
53. I have trouble finding information that I have stored externally (e.g., on paper or in your computer). *[never, seldom, sometimes, often, always]*
54. I take notes, on paper. *[never, seldom, sometimes, often, always]*
55. I take notes, on a computer or other electronic device. *[never, seldom, sometimes, often, always]*
56. When I take notes, I take a lot of notes. *[strongly disagree, disagree, neutral, agree, strongly agree]*
57. Taking notes improves my memory. *[strongly disagree, disagree, neutral, agree, strongly agree]*
58. I write on my hand. *[never, seldom, sometimes, often, always]*
59. I keep information on my computer well-organized. *[strongly disagree, disagree, neutral, agree, strongly agree]*
60. I rely on search functions to find information on my computer. *[strongly disagree, disagree, neutral, agree, strongly agree]*
61. It is important to me to be present and aware for meaningful experiences. *[strongly disagree, disagree, neutral, agree, strongly agree]*
62. It is important to me to make external records of meaningful experiences. *[strongly disagree, disagree, neutral, agree, strongly agree]*
63. The act of recording an experience takes away from the experience. *[strongly disagree, disagree, neutral, agree, strongly agree]*
64. I have used external memory to settle a disagreement. *[never, seldom, sometimes, often, always]*

65. How often do you look something up instead of trying to remember it? [*never, seldom, sometimes, often, always*]
66. It is more important to remember how to find some piece of information again rather than remembering the information itself. [*strongly disagree, disagree, neutral, agree, strongly agree*]
67. If I can't remember something, I can remember how/where to find that same information in external memory. [*never, seldom, sometimes, often, always*].
68. I use external memory to store and retrieve personal experiences. [*never, seldom, sometimes, often, always*]
69. I use external memory to store and retrieve factual knowledge. [*never, seldom, sometimes, often, always*]
70. I am generally a well-organized person. [*strongly disagree, disagree, neutral, agree, strongly agree*]
71. I am a nostalgic person. [*strongly disagree, disagree, neutral, agree, strongly agree*]
72. I like to collect things. [*strongly disagree, disagree, neutral, agree, strongly agree*]
73. How often are you distracted by activity or noise around you? [*never, seldom, sometimes, often, always*]
74. I have experienced powerful emotional responses from looking at PICTURES from my past. [*strongly disagree, disagree, neutral, agree, strongly agree*]
75. I have experienced powerful emotional responses from looking at VIDEO from my past. [*strongly disagree, disagree, neutral, agree, strongly agree*]
76. I have experienced powerful emotional responses from looking at TEXT from my past. [*strongly disagree, disagree, neutral, agree, strongly agree*]
77. External memory has caused me to remember things that I DID want to remember. [*never, seldom, sometimes, often, always*]
78. External memory has caused me to remember things that I DID NOT want to remember. [*never, seldom, sometimes, often, always*]
79. About how many EMAILS do you RECEIVE per day?
80. About how many EMAILS do you SEND per day?
81. About how many TEXT MESSAGES do you RECEIVE per day?
82. About how many TEXT MESSAGES do you SEND per day?
83. Please rate your overall level of online social activity. [*very low, low, neither low nor high, high, very high*]
84. Please rate your overall level of offline social activity. [*very low, low, neither low nor high, high, very high*]
85. Please check any forms of social media that you use: [*Facebook, Twitter, YouTube, Instagram, Snapchat, Tumblr, Pinterest, Google Plus, Pandora, Spotify, Other*]
86. Do you use Facebook? [*yes, no*]
87. How many friends do you have on Facebook?
88. Approximately how many hours per week do you spend using Facebook? [*<1 hour/week, 1–2 hours/week, 3–6 hours/week, 7–14 hours/week, 14+ hours/week, not applicable*]

89. Social media has helped me remember experiences that I would not have otherwise. *[strongly disagree, disagree, neutral, agree, strongly agree]*
90. Technology helps me COLLABORATIVELY remember experiences with friends/family. *[strongly disagree, disagree, neutral, agree, strongly agree]*
91. I consider my external memories to be part of me. *[strongly disagree, disagree, neutral, agree, strongly agree]*
92. My external memories are valuable to me. *[strongly disagree, disagree, neutral, agree, strongly agree]*
93. If I lost all my external memories I would feel devastated. *[strongly disagree, disagree, neutral, agree, strongly agree]*
94. If I lost all my external memories I would feel relief or release. *[strongly disagree, disagree, neutral, agree, strongly agree]*
95. If I lost all my external memories I would be inconvenienced. *[strongly disagree, disagree, neutral, agree, strongly agree]*
96. About how often do you backup all the data on your computer? *[never, yearly, monthly, weekly, daily]*
97. When was the last time you backed up all the data on your computer? *[yesterday, last week, last month, last year, never]*
98. Please describe any backup practices you use. For example, backing up to local physical hard drives, using internet-based data storage services to keep copies of some or all of your files, etc.
99. About how many times have you attempted to restore files from a backup?
100. About how many times were you successful in restoring files from a backup?
101. About how many different passwords do you have?
102. Do you keep your passwords written down or saved someplace? *[yes, no]*
103. About how often do you forget a password and have to recover it over email? *[never, several times a year, several times a month, several times a week, several times a day]*
104. Approximately how many phone numbers do you currently have memorized (not including your own)?
105. Approximately how many phone numbers do you currently have stored (in a phone, computer, address book, on paper, etc.)?
106. For approximately how many years have you had a cellular/mobile phone?
107. What percentage of your FAMILYS'/RELATIVES' phone numbers do you have memorized?
108. What percentage of your FRIENDS' phone numbers do you have memorized?
109. What percentage of your BUSINESS/WORK CONTACTS' phone numbers do you have memorized?
110. How many phone numbers do you have memorized now as compared to 5 years ago? *[many fewer, fewer, the same, more, many more]*
111. How many phone numbers do you think you will have memorized in 5 years as compared to now? *[many fewer, fewer, the same, more, many more]*
112. Please describe any specific memory aids or memory devices that you use to help yourself remember.

113. Please check any of the following technology that you own: [*smartphone* (e.g., *iPhone*, *Android*, *Windows Phone*), *cellular/mobile phone* (not *smartphone*), *laptop computer*, *desktop computer*, *tablet*, *other*]
114. What forms of external memory do you carry with you regularly (e.g., computer, phone, pen & paper, notebook, calendar, address book)?
115. What forms of external memory do you have around your living space?
116. What forms of external memory do you have around your working space?
117. Do you regularly carry a device with you that can take photos (e.g., a camera or a phone with a camera)? [*yes*, *no*]
118. Approximately how many photos do you take per day?
119. What are the main reasons you take photos?
120. What do you do with photos you have taken?
121. In what circumstances do you use your human memory instead of external memory?
122. In what circumstances do you use external memory instead of your human memory?
123. In what ways do your human memory and external memory work TOGETHER in your life?
124. Does using external memory change the way that you use your human memory? Explain.
125. Have you noticed any changes in how you use your human memory versus external memory over the years? Explain.
126. Something that human memory works better for:
127. Something that external memory works better for:
128. Do you rely on some form of tool to remind you of events/appointments in your everyday life? If yes, please list the tools that you have used and how helpful they have been.
129. Do you find people in your life helpful in reminding you about important dates/events? If yes, please describe how?
130. If you are currently a student, please list strategies you have used recently to make sure you remember the course material.
131. Has external memory ever failed you on something important? Describe.
132. If you have ever used external memory to settle a disagreement (e.g., looking up information on the internet), please describe one such episode.
133. If you have used the environment to help you remember (e.g., putting things in certain places), please describe an example.
134. How much do you expect technology to change in the next 10 years? [*not at all*, *slightly*, *moderately*, *very much*, *extremely much*]
135. How much do you expect everyday human life to change in the next 10 years? [*not at all*, *slightly*, *moderately*, *very much*, *extremely much*]
136. (OPTIONAL) Any additional final comments:

Appendix B: Questions Adapted from Other Studies

Questions 12, 13, 15, 16, 17: adapted from Magnussen et al. (2006).

Questions 18–19: adapted from Simons and Chabris (2011).

Question 20: adapted from Berntsen and Rubin (2002).

Questions 31–36: from the Memory Compensation Questionnaire (de Frias & Dixon, 2005).

Questions 37–41: from the Everyday Memory Questionnaire (Sunderland, Harris, & Gleave, 1984).

Question 85: forms of social media adapted from <http://www.theatlantic.com/technology/archive/2014/06/facebook-texting-teens-instagram-snapchat-most-popular-social-network/373043/> and from <http://www.ebizmba.com/articles/social-networking-websites>

Question 88: adapted from Facebook Survey by Joel Purkiss, U Michigan <http://www-personal.umich.edu/~purkissj/FacebookSurvey.pdf>

Question 112: from Intons-Peterson & Fournier (1986, pilot study)

Appendix C: Coding of Qualitative Data from Open-Ended Questions

Coding for Inclusion in Composite Variables

Responses to some qualitative (open-ended) questions were coded numerically for inclusion in composite variables. For questions 112 and 114–116, for each participant we summed the occurrence of the relevant categories, as detailed in Table A1.

Table A1 Categories used for coding of qualitative responses for inclusion in composite variables

Item	Composite variable	Categories included
112	EM use: low tech	Physical notes
	EM use: high tech	Alarm, camera, cloud, computer, digital assistant, digital calendar, digital notes, email, external hard drive, internet, phone, photos, recordings, social media, tablet, texting
114	EM use: low tech	Calendar, pen and paper, physical notebook
	EM use: high tech	camera, computer, e-reader, external drive, flash drive, memory card, phone, smartphone, tablet, wearable tech
115	EM use: low tech	Board, calendar, other physical references, pen and paper, physical notebook
	EM use: high tech	Camera/recorder, CD, computer, digital assistant, DVR, e-reader, flash drive, hard drive, memory card, phone, photo/video, smartphone, tablet
116	EM use: low tech	board, calendar, other physical references, pen and paper, physical notebook
	EM use: high tech	camera/recorder, CD, computer, digital notes, e-reader, flash drive, hard drive, memory card, phone, photo/video, smartphone, tablet, wearable tech
128	EM use: low tech	Board, calendar, pen and paper, physical notebook
	EM use: high tech	Alarm/notification, app, computer, digital assistant, digital calendar, email, phone, smartphone, social media, tablet, wearable tech

For example, if a participant's response to Q115 mentioned phone, computer, and calendar, that would yield a sum of 2 for high tech and 1 for low tech. Those values would then be standardized before being averaged with the standardized quantitative questions included in the given composite variable (Table 4.4).

For question 129 (used in the EM Use: Social composite variable), a value of -1 was assigned for responses indicating that other people were not helpful for remembering, a value of 1 was assigned for responses indicating that other people were helpful for remembering, and a value of 0 was assigned for responses indicating both helpfulness and unhelpfulness. Blank or irrelevant responses were assigned no value.

For question 133 (used in the EM Use: Low Tech composite variable), a value of -1 was assigned for responses indicating that the participant did not use the environment for memory, and a value of 1 was assigned for responses indicating that the participant did use the environment for memory in any way. Blank or irrelevant responses were assigned no value.

Below we provide notes on the coding scheme used to code responses to the qualitative questions that were used in creation of the composite variables. We only include notes on the categories that were used for the composite variables. Numerical codes of 0 (no) or 1 (yes) were assigned to each participant's response for each category in each question. For example, if a participant's entire response to Q112 was "sticky notes," that would be coded as 1 for category 112_Physical Notes and 0 for all other categories for that question. If their response was "sticky notes and email," then that would be coded as 1 for category 112_Physical Notes, 1 for category 112_Email, and 0 for all other categories for that question.

Coding was performed by author FWG, working with author JRF through several iterations to develop categories of common themes of responses for each question and to resolve coding of ambiguous responses through discussion. We decided that one coder was adequate for the purposes of this initial exploratory study. It would be ideal for future studies to employ multiple coders and establish interrater reliability.

- *Q112. Please describe any specific memory aids or memory devices that you use to help yourself remember.*
 - C3. EM Use: Low Tech
 - 112_Physical Notes: notes, journal, sticky notes/post-its, organizer, pen and paper to-do lists, shopping lists, "lists"/"checklist" (assume physical paper-pencil list), address books, writing things down, black/white board, flash cards, "notepad" (if not clearly stated that it's the digital program), writing notes on hand
 - C4. EM Use: High Tech
 - 112_Recordings: videos, voice recordings, voicemail
 - 112_Computer: laptop, files on computers, Notepad app, Notepad++ app, text files
 - 112_Phone: apps, to-do list on phone, cellphone, smartphone

- 112_External Hard Drive: flash drive, thumb drive, hard drive, cd-rs (CD-Rs)
- 112_Cloud: Dropbox, Google Drive, Google Platform
- 112_Digital Notes: to-do lists on devices, digital sticky notes, password manager apps (e.g., Memengo Wallet, mSecure, LastPass, 1Password), “.txt files”/text files (e.g., MS Excel, Word), apps that store info/lists (e.g., notepad/reminder/grocery list/memo apps), digital agendas, ColorNote, Evernote, Google Keep (or “Google notes”), Moleskine app, Multilist, My Effectiveness, Paper app, Trello, Wordpad, Wunderlist, “keywords stored on my computer,” saving phone numbers in phone, “contact list”
- 112_Social Media: Facebook
- 112_Internet: bookmarks in browsers, Google, “search functions,” online services (e.g., online banking)
- 112_Text (check “112_Phone” category as well whenever participants indicate use of texting): “SMS”
- 112_Email: send emails, starring important emails, email notifications, Gmail, Outlook
- 112_Digital Assistant: GPS, Google Now, Siri
- 112_Digital Calendar: Google calendar, calendar on email (e.g., MS Outlook), calendar apps, phone calendar, iCal
- 112_Alarm: timer, “notifications,” alerts and reminders in phones/computers, specified calendar alerts, Alarm++ (check “112_Computer” category as well), alarm clock
- *Q114. What forms of external memory do you carry with you regularly (e.g., computer, phone, pen & paper, notebook, calendar, address book)?*
 - C3. EM Use: Low Tech.
 - 114_Calendar: “Date book,” paper agenda, planner (code under “114_Physical Notebook” as well), “agenda book with calendar” because there’s a calendar with the agenda.
 - 114_Pen & Paper: grocery/shopping/to-do lists on paper, index cards, memo/notepad, notepaper, post-it notes, “appointment cards, prescription slips, pertinent flyers and/or business cards,” “notes”
 - 114_Physical Notebook: address book, binder, journal, memo book, organizer, planner, “notebook” (assume it’s not digital notebook), “little black book”
 - C4. EM Use: High Tech.
 - 114_Phone: cell phone, mobile phone, “phone,” smartphone (check “114_Smartphone” as well), “regular phone”
 - 114_Smartphone: participant must explicitly state “smartphone.” If response states “cell phone” but mentions apps, assume it’s a smartphone too
 - 114_Computer: Chromebook, laptop
 - 114_E-Reader: Kindle

- 114_Flash Drive: jump drive, thumb drive, “USB pens”
- 114_Memory Card: SD card, “Sandisk card”
- 114_External Drive: SSD (solid state drive), iPod
- 114_Wearable Tech: Apple watch, “smartwatch”
- *Q115. What forms of external memory do you have around your living space?*
 - C3. EM Use: Low Tech.
 - 115_Physical Notebook: address book, binder, composition book, date book, diary, filofax, journal, memo book, planner, “notebook” (assume it’s not digital notebook)
 - 115_Other Physical References: books (dictionary, atlas), documents, files, folders, paperwork, phone book, postcards, rolodex. “Cheat sheets,” “boxes with special items,” artwork
 - 115_Pen & Paper: grocery/shopping/to-do lists on paper, index cards, legal pad, memo/notepad, notepaper, post-it notes, “notes,” spiral-bound tablet, “stickies,” “pads”
 - 115_Calendar: agenda, date book (code under “115_Physical Notebook” as well), planner (code under “115_Physical Notebook” as well)
 - 115_Board: blackboard, bulletin board, chalkboard, cork board, dry erase board, whiteboard, “push board,” “magic erase board,” “hallway board”
 - C4. EM Use: High Tech
 - 115_Phone: cell phone, mobile phone, “phone,” smartphone (check “115_Smartphone” as well)
 - 115_Smartphone: participant must explicitly state “smartphone.” If response states “cell phone” but mentions apps, assume it’s a smartphone too. iPhone
 - 115_Computer: Chromebook, desktop PC, laptop. “internal hard drive” coded here because to use an internal hard drive, you need a computer to put it in.
 - 115_Tablet: iPad, Kindle Fire, writing tablet. One participant’s response of “Kindle” coded here because participant states it’s used for books and games, so the Kindle must serve more than just an e-reader function.
 - 115_E-Reader: Kindle
 - 115_Flash Drive: flash disk, jump drive, thumb drive, “memory sticks,” “USB drive,” “USB”
 - 115_Memory Card: SD card, “media cards”
 - 115_Hard Drive: external hard drive, internal hard drive, iPod, “backup hard drive”
 - 115_CD: CD, DVD, “mini DV cassettes”
 - 115_Digital Assistant: Amazon Echo
 - 115_Camera
 - 115_Digital Recorders: voice recorders
 - 115_DVR
 - 115_Photos: photos, photo albums, pictures
 - 115_Recordings: Videos

- 115_Digital Notes: bookmarks on computer, notepad on computer, sticky notes on computer, “computer files,” Evernote
- *Q116. What forms of external memory do you have around your working space?*
 - C3. EM Use: Low Tech
 - 116_Physical Notebook: address book, binder, composition book, date book, diary, filofax, journal, lab book, memo book, organizer, planner, “notebook” (assume it’s not digital notebook)
 - 116_Other Physical References: books, documents, files, folders, phone book, postcards, rolodex. “Print out of phone numbers,” “cheat sheets,” “sorted piles,” “work sheets,” “miscellaneous papers”
 - 116_Pen & Paper: legal/paper pads, lists, notepad, notepaper, notebook paper, post-it/sticky notes, scratch paper, “notes,” notes on boards, “stickies,” blotter
 - 116_Calendar: agenda, date book, organizer, planner (code all under “116_Physical Notebook” as well)
 - 116_Board: bulletin board, whiteboard
 - C4. EM Use: High Tech
 - 116_Phone: cell phone, mobile phone, smartphone (check “116_Smartphone” as well), “phone”
 - 116_Smartphone: participant must explicitly state “smartphone.” If response states “cell phone” but mentions apps, assume it’s a smartphone too. iPhone
 - 116_Computer: Chromebook, desktop pc, “desktop,” laptop
 - 116_Tablet: iPad
 - 116_E-Reader: Kindle, Pocketbook
 - 116_Flash Drive: thumb drive, “USB drive”
 - 116_Memory Card: SD card
 - 116_Hard Drive: external hard drive, internal hard drive, iPod, portable hard drive, “computer’s memory”
 - 116_CD: CD, DVD
 - 116_Cameras
 - 116_Digital Recorders: voice recorder
 - 116_Photos
 - 116_Recordings: videos, recordings
 - 116_Digital Notes: cloud, email notifications, emails (e.g., Microsoft Outlook), digital sticky notes, notes in computer, “computer files” (coded in “116_Computer” as well because you need a computer to access computer files), “online databases with work-related information”
 - 116_Wearable Tech: “Smart watch”
- *Q128. Do you rely on some form of tool to remind you of events/appointments in your everyday life? If yes, please list the tools that you have used and how helpful they have been.*

- C3. EM Use: Low Tech
 - 128_Boards: whiteboard
 - 128_Physical Notebook: address book, filofax, organizer, (day) planner, “notebook” (assume it’s not a digital notebook), “day timer”
 - 128_Pen & Paper: appointment cards, lists on paper, memo/note pads, note-paper, post-it notes, “notes,” “I make a calendar for the week with pen and paper” (also coded under “128_Calendar”), “I write them down,” “I sometimes write down appointments”
 - 128_Physical Calendar: appointment book, agenda, date book, organizer, (day) planner (code these under “128_Physical Notebook” as well unless it’s implied they’re digital). “Dry erase calendar”
- C4. EM Use: High Tech
 - 128_Phone: cell phone, mobile phone, “phone,” smartphone (check “114_Smartphone” as well), “regular phone”
 - 128_Smartphone: participant must explicitly state “smartphone.” If response states “cell phone” but mentions apps, assume it’s a smartphone too.
 - 128_Computer: laptop, PC reminders, spreadsheet, sticky notes, WordPad
 - 128_Tablet: iPad
 - 128_Apps: when participants state that they use downloaded notification/reminder apps to remind them of events/appointments. In-built apps that come with phones/computers (such as phone calendars, notes, Notepad on computer, OS X calendars) not included in this category. Alarm++, Cozi, Evernote, Google Calendar/Keep, Mint (participant #53), Multilist, My Effectiveness, Microsoft Outlook, Gmail, Windows Calendar, Wunderlist, when participants state “calendar app” only (because it could refer to a downloaded calendar app).
 - 128_Digital Assistant: Google Now, Siri.
 - 128_Email: when participants state that they send emails to themselves as reminders
 - 128_Social Media: Facebook
 - 128_Digital Calendar: do not check “128_Physical Calendar.” Calendars in email, Google Calendar, “computerized day planner,” “technical calendars”
 - 128_Wearable Tech: Apple watch, “smartwatch”
 - 128_Alarms_Notifications: when participants state that they use digital alarms, alerts, notifications, reminders to remind them of events/appointments. Includes in-built phone alarms and notifications. Alarm clocks, push notifications, text message reminders, timers

Coding for Purpose of Memory

Responses to questions 121–122 and 126–127 were coded for purpose of memory (Fig. 4.1, Table 4.1): episodic, semantic, procedural, and prospective. Below we provide notes on the coding scheme used for these four categories and these four

questions. Other categories were also coded for these questions, but we do not go into them here. Initial coding for these four categories was performed by author FWG, followed by a final round of coding by author JRF. The categories were not mutually exclusive. Numerical codes of 0 (no) or 1 (yes) were assigned to each participant's response for each category in each question.

Initial coding scheme for the four categories:

- *Episodic*: experiences, stories, events, happenings, occasions, childhood memories, reminiscing, etc.
- *Semantic*: facts, general knowledge, trivia, dates, names, numbers, passwords, recipes, ideas, information, locations, directions, etc.
- *Procedural*: remembering HOW TO, muscle memory, routine tasks, directions
- *Prospective*: remembering to do things in the future, upcoming events, appointments

FWG's coding notes, including the initial coding scheme and additional examples.

- *Q121. In what circumstances do you use your human memory instead of external memory?*
 - 121_Episodic: experiences, stories, events, happenings, occasions, childhood memories, reminiscing, emotions, sensations, “visual memory,” “when the impression of an experience is more important than a factual record,” “times when it really isn't appropriate to take photos, such as a funeral,” “for ant memory I don't need to be specific for—like spending time with family and friends,” “When I want to remember something the way I want to remember it,” “i use my human memory for experiential experiences”
 - 121_Semantic: facts, general knowledge, lyrics, trivia, dates, names, numbers, passwords, SSN, recipes, ideas, information, locations, directions, etc. Errands, faces, (grocery) lists, “I will memorize a few things that are key to my current activities,” “the big picture” (coded here because it's similar to knowledge/ideas), “when I am deliberately trying to see if I can recall something for the simple satisfaction of figuring it out myself”
 - 121_Procedural: remembering HOW TO, muscle memory, routine tasks, directions, recipes, “playing games” (coded here because there's usually a certain way to play a game), “day-to-day things,” “If it is something that I've done millions of times (like enter a certain password)” (also coded under “121_Semantic”), “it's a task that's easy to remember and that I might have done before,” “I use my human memory for video games where I have to remember buttons,” “when its a familiar task,” “Ordinary activities,” “doing household tasks”
 - 121_Prospective: remembering to do things in the future, upcoming events, appointments. “I basically only use my human memory to remember to write something down,” “remember less important messages to pass along to someone” (coded here because participant has to remember to pass message later on)

- *Q122. In what circumstances do you use external memory instead of your human memory?*
 - 122_Episodic: experiences, stories, events, happenings, occasions, childhood memories, reminiscing, emotions, sensations
 - 122_Semantic: facts, general knowledge, lyrics, trivia, dates, names, numbers, passwords, SSN, recipes, ideas, solutions, information, locations, directions, errands, faces, (grocery, to-do) lists, “When it a lot usually I could speak to Siri and it register every so I won’t have to write it myself” (coded here because response implies use of external memory to remember a large amount of info), “Certain medical issues,” “I use external memory for detailed or complex documentation that I don’t want to try and remember,” “If I am afraid I will not be able to memorize something,” “When it comes to finances”
 - 122_Procedural: remembering HOW TO, muscle memory, routine tasks, directions, instructions, recipes, “When I need to make sure I am doing something correct or if I do not remember clearly what to do” (also coded under “122_Semantic”), “saving little-used computer shortcuts,” “game walkthroughs”
 - 122_Pro prospective: remembering to do things in the future, to-do lists, upcoming events, appointments, meetings, schedules, times, reminders. “calendars,” “I almost always write dates down as I have a tendency to get busy and forget those” (“dates” coded here because response implies they’re appointments), “If I know that I’m distracted and will require a reminder,” “anything that needs to happen later on or a few days later,” “future info that I know I won’t be able to remember”
- *Q126. Something that human memory works better for:*
 - 126_Episodic: experiences, stories, events, happenings, occasions, childhood memories, reminiscing, emotions, sensations, “pretty much anything that involves your personal space,” “Life happenings like mistakes I have made or sensitive happenings, like secrets, for example” (coded here because context of response implies episodic memory)
 - 126_Semantic: facts, general knowledge, language, (grocery) lists, errands, lyrics, trivia, dates, names, faces, numbers, passwords, SSN, recipes, ideas, solutions, information, locations, directions, websites, etc. “Pictures,” “Quickly recalling something with ambiguous detail,” “small details,” “I think it works better for imagination,” “remembering what I need to do right away,” “Instant recall information is good for human memory,” “Making connections between things,” “Abstract thoughts,” “Private information”
 - 126_Procedural: remembering HOW TO, muscle memory, routine tasks, directions, recipes
 - 126_Pro prospective: remembering to do things in future, upcoming events, appointments, “Remembering to eat”

- *Q127. Something that external memory works better for:*
 - 127_Episodic: experiences, stories, events, happenings, occasions, childhood memories, reminiscing, emotions, sensations, “the details that fade from my human memory over time,” “remember some specific point,” “pictures and photos last forever and are always the same” (coded here because response implies that photos are from past events)
 - 127_Semantic: facts, general knowledge, lyrics, trivia, dates, names, numbers, passwords, SSN, recipes, ideas, solutions, information, locations, directions, errands, faces, (grocery, to-do) lists, “It is better for anything large that can be somewhat of a hassle for someone to remember,” “Things that are overly complicated,” “things that are very complicated,” “long segments that you can’t remember regularly,” “When you need to access accounts that you seldom use”
 - 127_Procedural: remembering HOW TO, muscle memory, routine tasks, directions, instructions, recipes, “Solving equations,” “They help me remember important daily tasks”
 - 127_Pro prospective: remembering to do things in the future, to-do lists, upcoming events, appointments, meetings, schedules, times, reminders, alarms, “making lists or notes to pass on to others”

Changes to coding scheme made for final coding performed by JRF:

- Faces were coded as both episodic and semantic, because recognizing someone’s face could involve memory for a specific episode (e.g., someone you only just met yesterday) and/or more generalized memory (e.g., a colleague you see nearly every day). We thank Hal Pashler, Roddy Roediger, Sharda Umanath, and Carolina Kuepper-Tetzel for their thoughtful comments on this point.
- Shopping/grocery/to-do lists were coded as both semantic and prospective. Unspecified lists were coded as semantic only.

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