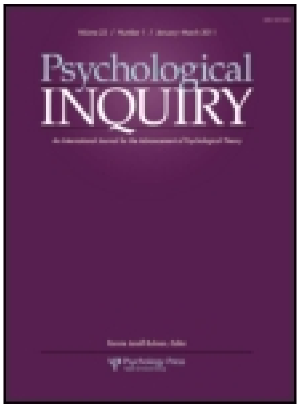

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Extending Cognition to External Agents

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Extending Cognition to External Agents

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Sparrow and Chatman ask if extending social cognition in the Internet age is "the same as it ever was" or whether, due to Google and other search engines on the Internet, something fundamentally different has occurred in the past 20 years. They make many interesting points, but the bottom line is that it is probably too soon to answer the question. The Internet is relatively new, and not much research has been done to address the questions they cogently raise. These are still early days. Their article provides a useful summary of some of what is known on the topic.

Humans have tried to offload memory tasks for as long as we have recorded history; in fact, such offloading is why we have the records of history. The ancient Greeks developed and perfected mnemonic systems, techniques for individuals to encode, store, and retrieve large amounts of information (Yates, 1966). Of course, some people were better at this than others. The institution of the *mnemon* arose, a person whose job it was to remember vast amounts of information concerning religious or legal information and who could be called upon to recite relevant laws or rules when decisions needed to be made (Le Goff, 1949/1992). In ancient Rome, slaves 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 (Schönpflug & Esser, 1995). This kind of externalization in both cases relies on having a few individuals charged with remembering the rules and history of a people (Danziger, 2008).

On a different front, ancient Peruvians developed a system of knots tied in cords, *quipus* (or khipus), to provide an external memory aid for their history and bureaucracy (Tylor, 1870, pp. 156–160). 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). This kind of mnemonic technique is partly independent of the group of rememberers, but as in the Greek and Roman traditions of the *mnemon* and *graeculi*, a person with extraordinary knowledge was needed to interpret the quipus. The quipus could not function as a book of history would, but rather they provided a set of retrieval cues from which a trained individual could reconstruct the recorded information (Rowlands, 1999).

The point of these tales is that the externalization of memory is not new—humans strove for that long before the printing press, much less the Internet. The issue is how the Internet has accelerated and changed the process. That is the critical issue that Sparrow and Chatman address. Of the myriad issues considered in their target article, we focus on two in the remainder of our commentary.

In the first section, we discuss the need for research on memory to expand its methods, frameworks, and theories to include external memory storage as a fundamental element of human memory systems. We expand on Sparrow and Chatman's discussion of the Internet as a transactive memory agent by highlighting several approaches, from psychology and other disciplines, to the study of external memory storage as an extension of the human mind.

In the second section, we focus on the role of retrieval in problem solving to highlight the need for continued use of internal memory as a core element of successful higher order cognitive function. We argue that although external memory can and should be a complement to internal memory processes, it is not always a viable alternative to internal memory. Rather, internally stored knowledge is often a prerequisite for optimal cognitive functioning. For a simple example, in order to successfully use Google, one must remember how to operate a computer, locate Google, and determine the key words that will lead to the best search for the missing information.

The Shifting Interplay Between Internal and External Memory

Sparrow and Chatman do well in highlighting the shifting role of human memory in the context of the global information infrastructure. Humans are and always have been situated beings; we adapt our cognitive practices to the current environment even as we alter that environment to expand our abilities, particularly for information storage. As noted in the introduction of this commentary, the Internet is a continuance of an ancient trajectory. Among philosophers of mind, the extended mind hypothesis (Clark & Chalmers, 1998) holds that cognitive operations should be understood as hybrid processes, taking place both within and beyond the human central nervous system. This view, reviewed and expanded in a recent volume edited by Menary (2010), implies that the unit of analysis should extend beyond individual humans, to include the information and processes that we offload onto the environment, and the dynamic interplay between internal and external memory storage (cf. Rowlands, 1999). The notion of the extended mind is consistent with Wegner's (1986) idea of transactive memory, in which members of collectives share responsibilities for what to remember. Of course, others have also argued for an embodied, situated, and/or distributed approach to understanding cognition (cf. Hutchins, 1995; Norman, 1993; Wilson, 2002). The thoroughness with which information and communication technology have saturated everyday human life (at least in highly developed societies) makes these views impossible to ignore, especially with respect to long-term memory. What researchers interested in human memory need now are frameworks with which to study the shifting interplay between internal and external memory resources.

Several useful approaches are suggested in work by Wolfgang Schönpflug, an early proponent of psychological research on the trade-off between internal and external long-term memory storage. He began study of this topic well before the Internet came into widespread use (Schönpflug, 1986a, 1986b, 1988; Schönpflug & Esser, 1995). Schönpflug 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). First, he argued that researchers should seek to identify and understand the variables that influence people's use of internal versus external memory. What types of information, and under what circumstances, do people choose to memorize versus offload? What are the strengths and weaknesses of engrams (memory traces; Semon, 1921) versus *exograms* (external records; Donald, 2001), and how do those characteristics complement each other?

Second, Schönpflug noted that retrieval of information from external memory stores requires the individual human to maintain an internal representation of the external store. Perhaps it is the case—as suggested by Sparrow and Chatman and others—that the role of human memory is partly shifting toward that of a concierge; we store procedural and source knowledge about how and where to find certain information when it is needed. This outlook suggests a new frontier for metamemory research: How accurate are people's mental models of the arsenal of external memory stores available to them? The critical question is, How well do people understand the relative strengths and weakness of internal and external memory, and how judiciously do they employ them (cf. Finley, Tullis, & Benjamin, 2010; Intons-Peterson & Fournier, 1986)?

Several other general approaches for considering external memory as integral to the study of human memory exist. Van House and Churchill (2008) outlined the "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. Hertel (1993) sketched a problem space of external memory, defined by dimensions such as the completeness of a record and the source of its generation. In addition, possibly useful research frameworks may be found in other disciplines. For example, in the field of library and information science, Borgman (2000) and others have discussed how information technology and communication technology have converged, and how such technology is coevolving with human behavior and human organizations. Relevant work from that field may be found under terms such as "information-seeking behavior" (Borgman, 2000, pp. 108–115); similar research approaches have also been adopted by some cognitive scientists (cf. "information foraging": Fu, 2012; Fu & Pirolli, 2007). In the field of human factors, optimizing the coordination of human and machine performance has been studied under the term "automation" (Parasuraman, Sheridan, & Wickens, 2000). In the field of personal information management, researchers have considered challenges such as information fragmentation, where people's personal data are distributed across multiple file formats and devices, often with inconsistent organizational schemes (Jones & Teevan, 2007).

The discussion here has focused on external *semantic* memory, that is, external storage of general knowledge (Tulving, 1972). Donald (2001) argued that development of semantic memory was a major and unique transition in human culture and cognition, so its emphasis is natural. But many of the same questions about the internal/external relationship are increasingly applicable to *episodic* and autobiographical memory (Rubin, 1996; Tulving, 1972). Not only are more of our actual experiences taking place online (e.g., e-mail and texting, web browsing, gaming), but also lifelogging technologies such as wearable digital cameras (e.g., SenseCam/Revue, Google Glass) are enabling ubiquitous and unobtrusive recording of our experiences, as well as providing new tools for memory researchers (Finley, Brewer, & Benjamin, 2011). External encoding is becoming trivial, and the overabundant wealth of episodic and semantic information available in external memory necessitates more emphasis on organization, maintenance, and facilitating retrieval (Bell & Gemmell, 2009). In many ways, the Internet age may also be the age of retrieval, which Tulving (1991) referred to as “the key process in memory” (p. 91; see also Roediger, 2000).

Problem Solving via Retrieval-Enhanced Internal Memory

Sparrow and Chatman argue that offloading memory details onto the Internet aids in creative problem solving, and they describe recent research (Sparrow, 2013) to support their claim. Their argument is that creative problem solving can be hindered by excessive accessibility of memorized informational details that are irrelevant to solving a problem; thus, offloading those details onto an external transactive memory agent (e.g., the Internet) reduces interference from those details and can enhance problem solving.

Intrusiveness of irrelevant details or otherwise misleading cues has long been known to hinder problem-solving ability (e.g., Gick & Holyoak, 1980; Smith & Blankenship, 1991). Problem-solving success can be enhanced, under certain conditions, by reducing access to those obtrusive details (Sio & Ormerod, 2009; Storm, Angello, & Bjork, 2011). On the other hand, several other studies have shown that retrieval of the *relevant* informational details is an important aspect of problem solving (e.g., Gick & Holyoak, 1980; Simon & Newell, 1971). Without relevant knowledge that can be brought to bear on the problem, the problem will remain unsolved. Thus, relative to utilizing one’s own internal memory, relying too heavily on the Internet (or any other external agent) to store information can reduce access to the knowledge needed to solve problems. In this sense, externally stored knowledge cannot always provide a viable alternative to internally stored knowledge.

What learners truly need for problem solving is flexible access to their internal knowledge stores. Retrieval practice of critical facts and concepts may be the tool for the job, as it has been argued to induce flexible access to information that can be used to solve new problems (Roediger, Putnam, & Smith, 2011). Unfortunately, research on the benefits of retrieval practice has not examined problem solving of the type discussed by Chatman and Sparrow. It is clear, however, that retrieval practice of critical facts and concepts enhances transfer to novel questions (Carpenter, 2012), demonstrating flexibility of knowledge.

Retrieval practice has been found to enhance various levels of transfer of learning, demonstrating a range of flexible use of knowledge. For starters, retrieval practice via one type of test has been shown to enhance performance on different test formats. For example, Kang, McDermott, and Roediger (2007) showed that, relative to rereading, short-answer questions following initial reading of a passage enhanced performance on both short-answer (same test format as initial learning) and multiple-choice final tests (a different test format). Karpicke and Blunt (2011) compared free recall retrieval practice to restudy of material and to concept mapping, a well-known method of elaborative study that (as the name implies) involves creating a graphic representation of the material. The results of a test 1 week after learning revealed that retrieval practice during learning produced the best performance among the three conditions on test items asking about concepts directly stated in the passage. Retrieval practice also exceeded concept mapping and rereading on inference questions requiring students to connect multiple concepts from the original text passage. In other transfer tasks, retrieval practice also promotes categorizing novel category members in concept learning (Jacoby, Wahlheim, & Coane, 2010), extrapolating new values of math functions (Kang, McDaniel, & Pashler, 2011), and finding object locations from novel vantage points in a spatial orientation task (Carpenter & Kelly, 2012).

To further illustrate the flexibility of knowledge promoted by retrieval practice, consider research by Butler (2010). In a series of experiments, subjects initially studied a set of prose passages on a variety of topics (e.g., bats) followed by three tests (repeated retrieval practice) on some of the passages and three restudy opportunities (repeated restudy) on the other passages. In all experiments, a final test was administered 1 week after the learning session. Not surprisingly, relative to repeated restudy, repeated retrieval practice enhanced final test performance for the facts and concepts that were initially tested (Experiment 1a), demonstrating the canonical testing effect (e.g., Roediger & Karpicke, 2006). More importantly, repeated retrieval also promoted successful performance on novel inference questions about facts and concepts from the same knowledge domain (Experiments 1b & 2), demonstrating near transfer. Perhaps most intriguing are the results of Butler’s Experiment 3, in which repeated retrieval practice enhanced final test performance on novel inference questions requiring transfer of knowledge from one initially studied passage to a new knowledge domain not initially studied (e.g., from echolocation in bats to SONAR in submarines), demonstrating far transfer. These experiments exemplify the power of retrieval practice in promoting the flexible use of internally stored knowledge to solve novel problems.

To be clear, we are not arguing that retrieval practice is a magic bullet solution for how to best solve problems. For one thing, people fail to utilize accessible knowledge when they fail to recognize that previously learned knowledge is relevant to a new problem (e.g., Gick & Holyoak, 1980), and this error is not necessarily corrected by retrieval practice. Also, the difficulty remains that intrusive access to the wrong information can disrupt problem solving, and retrieval practice of the wrong information has the potential to enhance accessibility of task-irrelevant information (e.g., Bishara & Jacoby, 2008). Finally, the Internet provides far more information on most topics than we could possibly attempt to learn and retain in the long run, so it follows that we must offload most of the memory duties onto outside sources, such as the Internet itself. The issue then becomes how to best select what information is most important to learn for some purpose, how to best implement retrieval practice to enhance that selective learning, and how to train people in this process. Future research should focus on how to best combine retrieval practice with transactive memory agents to meet the dual goals of building flexible internal knowledge stores while maintaining useful contact with the valuable resource of the Internet for additional memory storage. Perhaps using internal and external memory storage processes in tandem will prove an optimal strategy for certain types of cognitive operations.

In concluding this section, we reiterate our argument that externally stored information is not always a viable replacement for internally stored knowledge, particularly in the realm of transfer of knowledge. Although offloading memory onto the Internet as a transactive memory agent is certainly appealing, useful, and at times necessary, internally stored knowledge is crucial for cognition (including how to use the Internet). As people inevitably lean more heavily on the Internet as an information storage and retrieval device, it is important to consider that no device is currently better suited to problem solving—indeed, to thinking, reasoning, and decision making—than the human mind. To some extent, each of these higher order cognitive processes all draw on memory—knowledge stored in the human mind—and cannot be fueled solely by external memory sources. We suggest retrieval practice as the way to harvest the grains of memory needed to feed these processes.

Conclusion

We first argued that researchers must begin to include, as Sparrow and colleagues have done, external memory as an increasingly important element of how people use their own memory systems. We then used the case of transfer of learning to emphasize that internally stored knowledge is critical for higher order cognition and that retrieval practice is a powerful way to enhance flexible access to information and knowledge.

At first blush, our two main points may appear to contradict one another. On one hand, we argue that external memory is necessary and that understanding how humans use external memory devices is crucial to future research endeavors. On the other hand, we argue that excessive reliance on external memory sources may impair higher order cognition, particularly problem-solving abilities, by reducing flexible access to internally stored knowledge. Yet rather than contradicting one another, these two themes complement each other and highlight a point made earlier in this commentary: Research should focus on understanding the complex interplay between internal and external memory storage. Only research of this type can inform under what conditions internal memory processes are necessary versus conditions in which external memory records (and processes) can augment overall cognitive functioning. We must seek to understand how combining the two systems may optimize human performance.

Note

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References

Bell, G., & Gemmell, J. (2009). *Total recall: How the e-memory revolution will change everything*. Dutton, NY: Penguin.

Bishara, A. J., & Jacoby, L. L. (2008). Aging, spaced retrieval, and inflexible memory performance. *Psychonomic Bulletin & Review*, *15*, 52–57.

Borgman, C. L. (2000). *From Gutenberg to the global information infrastructure: Access to information in the networked world.* Cambridge, MA: MIT Press.

Butler, A. C. (2010). Repeated testing produces superior transfer of learning relative to repeated studying. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *36*, 1118–1133.

Carpenter, S. K. (2012). Testing enhances the transfer of learning. *Current Directions in Psychological Science*, *21*, 279–283.

Carpenter, S. K., & Kelly, J. W. (2012). Tests enhance retention and transfer of spatial learning. *Psychonomic Bulletin & Review*, *19*, 443–448.

Clark, A. & Chalmers, D. J. (1998). The extended mind. *Analysis*, *58*, 7–19.

Danziger, K. (2008). *Marking the mind*. Cambridge, UK: Cambridge University Press.

Donald, M. (2001). *A mind so rare: The evolution of human consciousness*. New York, NY: W. W. Norton.

Finley, J. R., Brewer, W. F., & Benjamin, A. S. (2011). The effects of end-of-day picture review and a sensor-based picture capture procedure on autobiographical memory using SenseCam. *Memory*, *19*, 796–807.

Finley, J. R., Tullis, J. G., & Benjamin, A. S. (2010). Metacognitive control of learning and remembering. In M. S. Khine & I. Saleh (Eds.), *New science of learning: cognition, computers and collaboration in education* (pp. 109–131). New York, NY: Springer.

Fu, W.-T. (2012). From Plato to the World Wide Web: Exploratory information foraging. In P. M. Todd, T. T. Hills, & T. W. Robbins (Eds.), *Cognitive search: Evolution, algorithms, and the brain* (pp. 283–300). Cambridge, MA: MIT Press.

Fu, W.-T., & Pirolli, P. (2007). SNIF-ACT: A cognitive model of user navigation on the World Wide Web. *Human–Computer Interaction*, *22*, 335–412.

Gick, M. L., & Holyoak, K. J. (1980). Analogical problem solving. *Cognitive Psychology*, *12*, 306–355.

Hertel, P. T. (1993). Implications of external memory for investigations of mind. *Applied Cognitive Psychology*, *7*, 665–674.

Hutchins, E. (1995). *Cognition in the wild*. Cambridge, MA: MIT Press.

Intons-Peterson, M. J., & Fournier, J. (1986). External and internal memory aids: When and how often do we use them? *Journal of Experimental Psychology: General*, *115*, 267–280.

Jacoby, L. L., Wahlheim, C. N., & Coane, J. H. (2010). Test-enhanced learning of natural concepts: Effects on recognition memory, classification, and metacognition. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *36*, 1441–1451.

Jones, W., & Teevan, J. (Eds.). (2007). *Personal information management*. Seattle: University of Washington Press.

Kang, S. H., McDaniel, M. A., & Pashler, H. (2011). Effects of testing on learning of functions. *Psychonomic Bulletin & Review*, *18*, 998–1005.

Kang, S. H., McDermott, K. B., & Roediger, H. L. (2007). Test format and corrective feedback modify the effect of testing on long-term retention. *European Journal of Cognitive Psychology*, *19*, 528–558.

Karpicke, J. D., & Blunt, J. R. (2011). Retrieval practice produces more learning than elaborative studying with concept mapping. *Science*, *331*, 772–775.

Le Goff, J. (1992). *History and memory* (S. Randall & E. Claman, Trans.). Oxford, NY: Columbia University Press. (Original work published 1949).

Menary, R. (Ed.). (2010). *The extended mind*. Cambridge, MA: MIT Press.

Norman, D. A. (1993). Cognition in the head and in the world: An introduction to the special issue on situated action. *Cognitive Science*, *17*, 1–6.

Parasuraman, R., Sheridan, T., & Wickens, C. (2000). A model for types and levels of human interaction with automation. *IEEE Transactions on Systems, Man and Cybernetics. Part A. Systems and Humans*, *30*, 286–297.

Roediger, H. L. (2000). Why retrieval is the key process to understanding human memory. In E. Tulving (Ed.), *Memory, consciousness and the brain: The Tallinn conference* (pp. 52–75). Philadelphia, PA: Psychology Press.

Roediger, H. L., & Karpicke, J. D. (2006). The power of testing memory: Basic research and implications for educational practice. *Perspectives on Psychological Science*, *1*, 181–210.

Roediger, H. L., Putnam, A. L., & Smith, M. A. (2011). Ten benefits of testing and their applications to educational practice. *Psychology of Learning and Motivation-Advances in Research and Theory*, *55*, 1–36.

Rowlands, M. (1999). *The body in mind: Understanding cognitive processes*. Cambridge, UK: Cambridge University Press.

Rubin, D. C. (1996). *Remembering out past: Studies in autobiographical memory.* Cambridge, UK: Cambridge University Press.

Schönpflug, W. (1986a). External information storage: An issue for the psychology of memory and cognitive capabilities. In F. Klix & H. Hagendorf (Eds.), *Human memory and cognitive capabilities* (Vol. 1, pp. 369–375). Amsterdam, the Netherlands: Elsevier.

Schönpflug, W. (1986b). The trade-off between internal and external information storage. *Journal of Memory and Language*, *25*, 657–675.

Schönpflug, W. (1988). Retrieving texts from an external store: the effects of an explanatory context and of semantic fit between text and address. *Psychological Research*, *50*, 19–27.

Schönpflug, W., & Esser, K. B. (1995). Memory and its "Graeculi": Metamemory and control in extended memory systems. In C. A. Weaver, III, S. Mannes, & C. R. Fletcher (Eds.), *Discourse comprehension: Essays in honor of Walter Kintsch* (pp. 245–255). Hillsdale, NJ: Erlbaum.

Semon, R. (1921). *The mneme*. London: Allen & Unwin.

Simon, H. A., & Newell, A. (1971). Human problem solving: The state of the theory in 1970. *American Psychologist*, *26*, 145.

Sio, U. N., & Ormerod, T. C. (2009). Does incubation enhance problem solving? A meta-analytic review. *Psychological Bulletin*, *135*, 94.

Smith, S. M., & Blankenship, S. E. (1991). Incubation and the persistence of fixation in problem solving. *The American Journal of Psychology*, *104*, 61–87.

Sparrow, B. (2013). *The upside of information accessibility: Offloading details enhances creative problem solving*. Unpublished manuscript.

Storm, B. C., Angello, G., & Bjork, E. L. (2011). Thinking can cause forgetting: Memory dynamics in creative problem solving. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *37*, 1287.

Tulving, E. (1972). Episodic and semantic memory. In E. Tulving & W. Donaldson, (Eds.), (*Organization of memory* (pp. 381–403). New York, NY: Academic Press.

Tulving, E. (1991). Interview with Endel Tulving. *Journal of Cognitive Neuroscience*, *3*, 89–94.

Tylor, E. B. (1870). *Researches into the early history of mankind and the development of civilization* (2nd ed.). London, UK: John Murray.

Van House, N., & Churchill, E. F. (2008). Technologies of memory: Key issues and critical perspectives. *Memory Studies*, *1*, 295–310.

Wegner, D. M. (1986). Transactive memory: A contemporary analysis of the group mind. In B. Mullen & G. R. Goethals (Eds.), *Theories of group behavior* (pp. 185–205). New York, NY: Springer-Verlag.

Wilson, M. (2002). Six views of embodied cognition. *Psychonomic Bulletin & Review*, *9*, 625–636.

Yates, F. A. (1966). *The art of memory.* Chicago, IL: University of Chicago Press.