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Commentary

The Human-Machine Extended Organism: New Roles and Responsibilities of Human Cognition in a Digital Ecology

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> Automation does not necessarily supplant human activity but rather changes it, often in ways unintended and unanticipated by the designers of automation, and as a result poses new coordination demands on the human operator. (Parasuraman, Sheridan, & Wickens, 2000, p. 286)

Tool use is a fundamental aspect of the human condition. Tally sticks, clay tablets, abaci, punch cards, typewriters, and digital computers represent external media that humans have relied upon to more simply, or more efficiently, meet their intellectual and behavioral objectives. It is only recently, however, that technology has become a coequal partner in service of those cognitive goals. The partnership between physiology and technology warrants a reconsideration of what it means to be a successful agent in this environment. One perspective on this problem is provided by an analysis of the qualities of the internet: examining the various ways that technological affordances enable, constrain, and alter memory behavior. Marsh and Rajaram (2019) discuss properties of the internet that have consequences for cognition, such as its relative omniscience, widespread access, and fast information retrieval. Another perspective emphasizes the transactive nature of the relationship between human and technology: the presence of high-tech external memory devices such as the internet shapes the manner in which we can achieve our intellectual goals and, simultaneously, our queries and contributions shape the nature of the information it possesses and provides to others. How do we conceptualize the cognition of the human-machine *extended organism* to best understand the inherent qualities or liabilities of human memory and cognition in a digital ecology?

A New Cognitive Context

We start from the position that part of using memory effectively involves knowing how to increase access to useful information, while decreasing the cost of doing so (Anderson & Milson, 1989; Benjamin, 2007; Oaksford & Chater, 2007; Simon, 1996). This rational perspective is helpful regardless of whether we are referring to the information contained in our internal memory, or to information that resides in the many external memory devices we interact with, including the internet. Many technology-enabled offloading strategies, like storing contacts, finding directions, and searching the internet, are regularly employed in service of more efficient memory. Much of what we think of as human memory, or more broadly of mind, in a digital ecology is in fact the product of an integrative system of internal and external cognitive processes that are selected to meet the demands of a particular cognitive task. In such a theoretical perspective, the ability to effectively integrate internal and external processes to guide decisions is the critical feature of a successful cognitive agent.

High-tech external memory devices (e.g., computers, smartphones, internet) are able to perform some cognitive tasks that once could only be accomplished by humans. Certain features of these external devices, like their vastness, depth, and longevity, unequivocally outperform human memory, which is fallible in many ways (Schacter, 2001). As a consequence, the use of technology has become a habit of daily life. In a recent survey study, Finley, Naaz, and Goh (2018) summarized the ways in which external memory is seen as augmenting human capability in the early twenty-first century. Notably, 74% of participants indicated that external memory

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works better for semantic purposes, such as storing passwords, phone numbers, dates, appointments, email addresses, physical addresses, directions, “stone-cold facts,” quotes, names, recipes, financial information, numbers, formulas, and lists. This is especially the case for information that is infrequently used, complex, boring, or vast. For such information, technology plays a large and increasing role in supporting human cognition.

The ecological strengths of human cognition, on the other hand, are related to the ability to effortlessly draw inferences from data. This includes the development of categories: humans easily and spontaneously learn natural categories like “dogs” and social categories like “friends” from experience. In contrast, only recently have advances in machine learning progressed to the point where machines can classify complex stimuli that humans do routinely (in tasks like speech perception and object recognition; LeCun, Bengio, & Hinton, 2015). Humans also communicate, manipulate, and conceptualize problems with symbols—a strength that underlies our ability to solve complex problems (Anderson & Bower, 1973; Marcus, 2001). Unlike machines, people are able to apply abstract rules in novel but appropriate situations (e.g., Smith, Langston, & Nisbett, 1992), understand and learn complex language (e.g., Kim, Pinker, Prince, & Prasada, 1991), and express and use metacognitive knowledge in service of identifying individuals suited to solving those problems (Bennett, Benjamin, Mistry, & Steyvers, 2018). The uniquely human capability to go beyond the information presented to *infer* what is “true” of the world is our strength in a digital ecology.

Understanding the individual constituents of human-machine partnerships is insufficient to understand fully the processes and behaviors of the cognizer in a digital ecology. Treating human and technology as independent systems denies two important facts about the partnership. First is the fact that the ready availability of technology changes, and should change, exactly what humans feel they need to know in order to reach their goals effectively. For example, if we have reliable access to the internet, why *should* we try to remember birthdays or directions? Certainly it can do better than we can, and what is gained by keeping that information in our own heads? Second, it denies the fact that *many* qualities of present-day humans and technologies are shaped by the other. Outsourcing rote knowledge to the internet does not, despite popular opinion, make humans stupid. And the internet is not in any sense “omniscient.” Certainly, it is a record of known facts, queries, objects, and writings. But it is also a collection of our misgivings, biases, secrets, and attempts to distort. The internet does not seek to establish coherence across its knowledge base, making it vulnerable to gaps and biases in our knowledge (e.g., Vanian, 2018) and to attempts to weaponize the appearance of fact in service of political, social, or personal goals (e.g., Boffey, 2018). In contrast, because human cognition prioritizes inference over information, it seeks coherence and suffers from poor memory for rote knowledge as a consequence. Both of these two examples are considered in somewhat greater detail below.

The Extended Organism Metaphor

To understand how humans achieve intellectual goals in a digital world, one has to understand the process and abilities of the human-machine *extended organism* within its broader environment. A good working analogy is swarm cognition in termites. It can be helpful in understanding the termite’s adaptiveness and success in a variety of environments to consider the structure and geometry of the termite mound—tunnels made of varying materials and food caches—as part of the extended termite, rather than an external environment on which the termite acts (Turner, 2011). The termite mound is a dynamic body of knowledge that reacts and self-regulates in a changing environment and with changing goals. The complex behaviors of this extended organism emerge from its simple constituents, yet understanding these constituents alone does not suffice to understand the swarm’s cognitive abilities. The extended organism metaphor is reminiscent of studies on transactive memory systems in human dyads. In a problem-solving task, Wegner, Giuliano, and Hertel (1985) showed that close dyads tend to adopt an integrated strategy for resolving discrepancies between individual responses. These results support the notion that transactive communication processes tend to develop among close dyads, which form a unique “group-mind.” Although the transactive approach is often referred to in research on technology and cognition, researchers often use the transactive memory system metaphor to highlight the additive effects of the internet as a transactive memory partner, rather than to discuss the *unique mind* that manifests from the sum of two parts. To understand the full cognitive consequences of living in today’s digitally-mediated environment, we should understand the human and the internet together as an *extended organism that has capacities and risks beyond the reach of either alone*.

Novel Considerations from an Extended Organism Perspective

Research on the impact of technology on cognition has now developed into an extensive literature. In the next section, we introduce two novel considerations about human-digital cognition that arise from the extended organism perspective.

Human Memory and Digital Memory Shape One Another

In August 2016, three months before the US presidential election, an article in *The Political Insider* made the, shall we say, provocative claim that Democratic candidate Hillary Clinton sold weapons to the militant group ISIS (Roberts, 2016). Although the election story was quickly verified as false, the “fake news” story generated 789,500 shares, reactions, and comments on Facebook before the news outlet removed the story from its site (Silverman, 2016). According to an article published by BuzzFeed Founding Editor Craig Silverman (2016), the 20 top-performing fake election stories accumulated over 8.7 million Facebook engagements in the final three months of the

US presidential campaign. These points illustrate two important elements to consider about the human-machine extended organism. The first is that the internet is shaped by the people who use it. The vast and deep nature of the internet misleads many to treat the internet as an "omniscient" source of external memory. Indeed, several features of the internet, such as the diverse scope of information it covers, the speed at which it is able to access information, and its capacity to be continuously updated with new knowledge, distinguish the internet as a valuable knowledge source with expert information in an unfathomable number of domains.

Yet other features of the internet, such as its indifference toward accuracy and relative permanence, reflect important exceptions to this generality. This second point leads us into the next section: the proliferation of misleading, oversimplified, or incomplete information leaves the extended organism vulnerable to unprecedented dangers that threaten the successful use of memory. Under these circumstances, the growing symbiosis between internal and external memory poses a new coordination demand on the user to monitor and verify the accuracy of information accessed on the internet. As we become increasingly reliant on the internet for outsourced knowledge, we become more deeply involved in a cognitive system that favors information that is immediate over comprehensive, provocative over substantiated, and affirmative over contravening.

A technology user can take advantage of the knowledge accessible on the internet to the extent that she can exercise effective quality-control assessments on that knowledge. If we remember, for example, that the source of some "fact" (e.g., Clinton sold weapons to ISIS) came from an untrustworthy news outlet (e.g., The Political Insider), we have the necessary information for assessing the veridicality of this information in the future. The ability to monitor the source of our knowledge underlies the ability to exert control over our own opinions and beliefs (Johnson, Hashtroudi, & Lindsay, 1993). Sources that are similar to one another can be difficult to discern (e.g., Ferguson, Hashtroudi, & Johnson, 1992; Johnson et al., 1993), and sources of unreliable information on the internet have increasingly taken on the appearance of legitimate news sources. The source-monitoring framework of Johnson et al. (1993) also proposes that reflective cognitive operations produce memories that are easier to distinguish than externally sourced memories. Because having unfettered access to the internet increases future use of the internet to access other information (Storm, Stone, & Benjamin, 2017) and can even decrease our willingness to rely on internal memory (Ferguson, McLean, & Risko, 2015), we are increasingly facing source assessments that lack the types of reflective cognitive operations that make it possible to distinguish between fact and fiction.

Identifying the source of information is even more difficult when time has passed between access to information and our need to evaluate its veracity. The *sleeper effect* refers to the increase over time in the persuasive effect of a message that is accompanied by a discounting cue (Hovland & Weiss, 1951). The idea is that, as time goes by, a person may have difficulty remembering a discounting cue, such as a noncredible source, but may still remember the content of the message. This finding is compatible with evidence that source information is forgotten more quickly than message content (Benjamin, 2010). When a user engages with misinformation online, flagging the content as a hoax does not guarantee that it will not affect downstream attitudes related to the message. This is particularly true when the message had a strong initial impact, like attention-grabbing news stories; when people have a higher ability or motivation to think about the message, like when information supports existing views of the world; and when people receive the discounting cue after the message, which is often the case when encountering misleading information online (Kumkale & Albarracín, 2004).

When confronted with the need to update information, humans have the counterintuitive but adaptive capacity to selectively forget outdated, irrelevant, or discredited information (e.g., Bjork, 2011). Indeed, the ability to forget prevents out-of-date information from interfering with the recall of relevant information (Bjork & Bjork, 1988). But how does the internet compare? One benefit of the internet as an enormous repository of rote information is its long-lasting accuracy and precision. When human memory fails us, the internet makes it easy to find the information we need. However, the long-lasting nature of digital memory makes it hard to efficiently retrieve *current, relevant* information. Say, for example, that you remember reading a news story that Clinton sold weapons to ISIS, but cannot recall whether the story is true. By searching the message, "Clinton sold weapons to ISIS" (December 2018) Google returns the following articles: *WikiLeaks Confirms Hillary Clinton Sold Weapons to ISIS? – Snopes.com*, *Wikileaks Confirms Clinton Sold Weapons to ISIS – 247Sports.com*, *Read all about it: The biggest fake news stories of 2016 – CNBC.com*. On the first page of results, seven out of 10 headlines suggest that the claim is true, whereas only two headlines directly state that the message is fictitious. In this capacity, the infrastructure of the internet is not at all similar to human memory—the internet does not "forget" information, even when the information becomes irrelevant or worse.

Using the internet as a repository of our memories prevents us from using adaptive qualities of our memory that innocolate us against misinformation. First, it prevents the easy application of source monitoring heuristics that have developed in order to enable us to distinguish between memory and confabulation (Johnson & Raye, 1981). In its place, we must develop skills for determining credible from untrustworthy digital sources. This is a difficult task, especially when considering the vast incentives that are in place for content purveyors to make that discrimination more, not less, difficult. The second quality of memory that cannot be easily brought to bear in an environment in which knowledge is digital is adaptive forgetting. The information on the internet is not a self-organizing structure like the human mind. What is most accessible is what has been most often accessed (and what search engines idiosyncratically determine is relevant, given their knowledge of you), but not necessarily what is most up-to-date or accurate.

Consequences for Outsourcing Retrieval Depend on Abilities of the Extended Cognitive System

One of the major advantages of high-tech external memory is the ability to offload responsibility for maintaining information to a dependable external source. However, it does appear as though this collective movement of knowledge to external stores has demonstrable consequences for what we store internally. When learners are told that to-be-learned information will be stored on a computer for later, they show lower rates of recall for that information—a phenomenon coined the *Google effect* (Sparrow, Liu, & Wegner, 2011). One might draw the conclusion that Google is changing the way we think—and not for the better. Yet, if we consider the cognitive context in which this memory behavior is situated and evaluate memory as an optimization to the information-retrieval task that the human-machine extended organism faces, we see that in fact the decision to outsource (some) memory is an adaptive one. If we trust that semantic information will be accessible in the future and unlikely to be needed under circumstances in which the internet is not available, there is no need to fully encode it into our internal memory, which is limited in capacity and precision. In experiments in which users have access to information saved in external memory devices, they outperform users who are forced to rely on their own memory (e.g., Storm & Stone, 2015).

Much less is known about the long-term downstream consequences of such outsourcing behavior. In a laboratory setting, users who strategically offload memory onto high-tech external memory do not need to consider whether these strategies are sufficient for later access. Choosing an encoding strategy that is appropriate for an intellectual goal places unique demands on the extended organism that require both an understanding of how various encoding schemes translate into long-term retention and also the cognitive skill required to render them accessible in the future. For example, storing information in a file structure is helpful only if the file can be recovered later. Successful recovery is not only a function of the storage medium, which is relatively permanent, but also the ability to recover a path to that file in a complicated file structure. That depends on having generated good filename cues (Tullis & Benjamin, 2015a, 2015b; Tullis & Finley, 2018) and on having a transparent file structure that reflects future organizational demands. Here we review a few examples of new problems that arise when considering the downstream consequences of outsourcing retrieval for the extended organism.

Access to digital memory is constrained by the cognizer's ability to organize to-be-retrieved information at encoding and develop efficient retrieval plans that will ensure proper access to relevant information. This task highlights a unique responsibility for the extended organism. Whereas the human memory system is remarkable in its capacity to spontaneously self-organize and reorganize facts and routines stored internally, the role of the cognizer in a digital ecology has more to do with *explicitly* developing an organized system and less to do with aggregating knowledge.

A second concern for the human-machine extended organism is the development of expertise. A central premise of this paper has been that the strength of human cognition is the ability to draw inferences from data and solve problems that are beyond the capabilities of digital memory. Ironically, the ability for cognizers to accomplish the uniquely human feat of developing expertise, exercising creativity, synthesizing information, and generating new ideas is dependent upon having available the facts and routines that underlie these enterprises. One cannot become an expert birder by having a hard drive full of bird photographs. Generalization comes from internalized knowledge. Again, we see how the consequences of outsourcing retrieval are beyond the understanding of simple constituents. Although organization is a key factor for effective memory in an extended cognitive system, knowing simply how to access external information does not support the generalization of knowledge and development of expertise in the same way. A critical role of the cognizer in a digital ecology is the ability to make careful decisions about when we are best served by storing information internally for future inference, even when that storage is error-prone or difficult.

Concluding Remarks

One cross-cutting theme across the examples we have outlined here is the critical importance of metacognitive skill in the new digital ecology. People need to decide how to share cognitive responsibilities with a machine partner that is very different from themselves. They need to do so in a way that maximizes the benefits of the partnership and minimizes the risks. Doing so requires a deep understanding of what humans are good at, what machines are good at, and how to ensure access to relevant information in the conditions in which it is likely to be needed. As external memory devices become more active in our day-to-day cognition, it is increasingly important to consider how humans make these metacognitive decisions. Several researchers have already begun to investigate the subtle effects of outsourcing retrieval on metacognition (e.g., Fisher, Goddu, & Keil, 2015; Hamilton, McIntyre, & Hertel, 2016; Hamilton & Yao, 2018; McKinley, 2018; Ward, 2013).

Our guiding questions must be framed with a consideration of the dynamic ways in which cognizers can strategically engage encoding processes to successfully accommodate intellectual goals. Theorizing about memory with partitions between internal and external memory processes restricts comprehension of several realities about memory in a digital ecology. First, it discredits observed memory behaviors that play to the ecological strengths of each constituent—digital memory as harborer of rote knowledge and human memory as inference machine. Second, it constrains the development of research that seeks to understand how to optimize the use of encoding strategies that play to the ecological strengths of the extended organism (e.g., strategic offloading), and how to prevent adaptations that lead to the detriment of effective memory (e.g., source memory failures, circulation of misinformation). We believe that understanding the inherent qualities or liabilities of human memory and cognition in a digital ecology will require a revised outlook on what it means to be a successful cognitive agent in a digital world. By understanding memory as an extended organism with a singular structure and system of rules, we become privy to the unique role that cognizers play to accomplish their intellectual goals, such as how to monitor the dynamic body of knowledge of the extended organism, how to make strategic decisions about memory in complex domains, and how to execute control processes that are appropriate to the demands of those complex domains.

Author contribution

KAH and ASB jointly planned the arguments for this paper. KAH drafted a preliminary version and both authors critically edited the manuscript.

Conflicts of interest

We have no conflicts of interest to disclose.

References

Anderson, J. R., & Bower, S. (1973). *G. H. Human associative memory*. Washington, DC: Winston & Sons.

Anderson, J. R., & Milson, R. (1989). Human memory: An adaptive perspective. *Psychological Review*, *96*(4), 703.

Benjamin, A. S. (2007). Memory is more than just remembering: Strategic control of encoding, accessing memory, and making decisions. *Psychology of Learning and Motivation*, *48*, 175–223.

Benjamin, A. S. (2010). Representational explanations of "process" dissociations in recognition: The DRYAD theory of aging and memory judgments. *Psychological Review*, *117*(4), 1055.

Bennett, S. T., Benjamin, A. S., Mistry, P. K., & Steyvers, M. (2018). Making a wiser crowd: Benefits of individual metacognitive control on crowd performance. *Computational Brain & Behavior*, *1*(1), 90–99.

Bjork, R. A. (2011). On the symbiosis of remembering, forgetting and learning. In A. S. Benjamin (Ed.), *Successful remembering and successful forgetting: A festschrift in honor of Robert A. Bjork* (pp. 1–22). London: Psychol. Press.

Bjork, E. L., & Bjork, R. A. (1988). On the adaptive aspects of retrieval failure in autobiographical memory. In M. M. Gruneberg, P. E. Morris, & R. N. Sykes (Eds.), *Practical aspects of memory: Current research and issues* (Vol. 1) (pp. 283–288). Oxford, England: John Wiley.

Boffey, D. (2018, December 10). *Russia 'paved way for Ukraine ship seizures with fake news drive'*. Retrieved from https://www.theguardian.com

Ferguson, S. A., Hashtroudi, S., & Johnson, M. K. (1992). Age differences in using source-relevant cues. *Psychology and Aging*, *7*(3), 443.

Ferguson, A. M., McLean, D., & Risko, E. F. (2015). Answers at your fingertips: Access to the Internet influences willingness to answer questions. *Consciousness and Cognition*, *37*, 91–102.

Finley, J. R., Naaz, F., & Goh, F. W. (2018). *Memory and technology*. Cham, Switzerland: Springer.

Fisher, M., Goddu, M. K., & Keil, F. C. (2015). Searching for explanations: How the Internet inflates estimates of internal knowledge. *Journal of Experimental Psychology: General*, *144*(3), 674.

Hamilton, K. A., McIntyre, K. P., & Hertel, P. T. (2016). Judging knowledge in the digital age: The role of external-memory organization. *Applied Cognitive Psychology*, *30*(6), 1080–1087.

Hamilton, K. A., & Yao, M. Z. (2018). Blurring boundaries: Effects of device features on metacognitive evaluations. *Computers in Human Behavior*, *89*, 213–220.

Hovland, C. I., & Weiss, W. (1951). The influence of source credibility on communication effectiveness. *Public Opinion Quarterly*, *15*(4), 635–650.

Johnson, M. K., Hashtroudi, S., & Lindsay, D. S. (1993). Source monitoring. *Psychological Bulletin*, *114*(1), 3.

Johnson, M. K., & Raye, C. L. (1981). Reality monitoring. *Psychological Review*, *88*(1), 67.

Kim, J. J., Pinker, S., Prince, A., & Prasada, S. (1991). Why no mere mortal has ever flown out to center field. *Cognitive Science*, *15*(2), 173–218.

Kumkale, G. T., & Albarracín, D. (2004). The sleeper effect in persuasion: A meta-analytic review. *Psychological Bulletin*, *130*(1), 143.

LeCun, Y., Bengio, Y., & Hinton, G. (2015). Deep learning. *Nature*, *521*(7553), 436.

Marcus, G. F. (2001). *The algebraic mind: Integrating connectionism and cognitive science*. MIT Press.

Marsh, E. J., & Rajaram, S. (2019). The digital expansion of the mind: Implications of internet usage for memory and cognition. *Journal of Applied Research in Memory and Cognition*, *8*(1), 1.

McKinley, G. L. (2018). Retrieval in the information age: How interface design can affect long-term memory. In *Poster presented at the 59th Annual Meeting of the Psychonomic Society*.

Oaksford, M., & Chater, N. (2007). *Bayesian rationality: The probabilistic approach to human reasoning*. Oxford University Press.

Parasuraman, R., Sheridan, T. B., & Wickens, C. D. (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*(3), 286–297.

Roberts, H. (2016, November 17). *This is what fake news actually looks like—We ranked 11 election stories that went viral on Facebook.*. Retrieved from https://www.businessinsider.com

Schacter, D. L. (2001). *The seven sins of memory: How the mind forgets and remembers*. Boston, MA: Houghton Mifflin.

Silverman, C. (2016, November 16). *This analysis shows how viral fake election news stories outperformed real news on Facebook.*. Retrieved from https://www.buzzfeednews.com

Simon, H. A. (1996). *The sciences of the artificial*. MIT Press.

Smith, E. E., Langston, C., & Nisbett, R. E. (1992). The case for rules in reasoning. *Cognitive Science*, *16*(1), 1–40.

Sparrow, B., Liu, J., & Wegner, D. M. (2011). Google effects on memory: Cognitive consequences of having information at our fingertips. *Science*, *333*(6043), 776–778.

Storm, B. C., & Stone, S. M. (2015). Saving-enhanced memory: The benefits of saving on the learning and remembering of new information. *Psychological Science*, *26*(2), 182–188.

Storm, B. C., Stone, S. M., & Benjamin, A. S. (2017). Using the Internet to access information inflates future use of the Internet to access other information. *Memory*, *25*(6), 717–723.

Tullis, J. G., & Benjamin, A. S. (2015a). Cue generation: How learners flexibly support future retrieval. *Memory & Cognition*, *43*(6), 922–938.

Tullis, J. G., & Benjamin, A. S. (2015b). Cueing others' memories. *Memory & Cognition*, *43*(4), 634–646.

Tullis, J. G., & Finley, J. R. (2018). Self-generated memory cues: Effective tools for learning, training, and remembering. *Policy Insights from the Behavioral and Brain Sciences*, *5*(2), 179–186.

Turner, J. S. (2011). Termites as models of swarm cognition. *Swarm Intelligence*, *5*(1), 19–43.

Vanian, J. (2018, June 25). *Unmasking A.I.'s bias problem*.. Retrieved from http://fortune.com

Ward, A. F. (2013). Supernormal: How the Internet is changing our memories and our minds. *Psychological Inquiry*, *24*(4), 341–348.

Wegner, D. M., Giuliano, T., & Hertel, P. T. (1985). Cognitive interdependence in close relationships. In *Compatible and incompatible relationships*. pp. 253–276. New York, NY: Springer.

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