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# The Digital Expansion of the Mind: Implications of Internet Usage for Memory and Cognition

Elizabeth J. Marsh[a,*], Suparna Rajaram[b]

[a] Duke University, United States
[b] Stony Brook University, United States

The internet is rapidly changing what information is available as well as how we find it and share it with others. Here we examine how this "digital expansion of the mind" changes cognition. We begin by identifying ten properties of the internet that likely affect cognition, roughly organized around internet content (e.g., the sheer amount of information available), internet usage (e.g., the requirement to search for information), and the people and communities who create and propagate content (e.g., people are connected in an unprecedented fashion). We use these properties to explain (or ask questions about) internet-related phenomena, such as habitual reliance on the internet, the propagation of misinformation, and consequences for autobiographical memory, among others. Our goal is to consider the impact of internet usage on many aspects of cognition, as people increasingly rely on the internet to seek, post, and share information.

*Keywords:* Memory, Cognition, Internet, External memory, Metacognition, Social memory

***General Audience Summary***

The internet is rapidly changing what information is available to us as well as how we find that information and share it with others. Here we ask how this "digital expansion of the mind" may change cognition. We begin by identifying ten properties of the internet that we know influence cognition, based on decades of cognitive science research as well as work examining other ways that people externalize memory and cognition (such as relying on other people to help one remember information or printing out information rather than trying to remember it). These properties can be roughly organized around (a) internet content (e.g., the sheer amount of information available, its relative accuracy, the frequency with which it changes, and the number of options offered at any one point in time); (b) internet usage (e.g., access is easy, equires searching, and returns results almost instantaneously); and (c) the community involved in the creation and propagation of content (e.g., anyone can participate, although authorship may often be obscured; perhaps most importantly, the internet connects people in an unprecedented fashion). We then identify questions arising from the combination of these properties; for example, we ask whether internet usage can become habitual, given its ease of access, the scope of information available, and the speed with which results are returned. In this fashion, we consider whether the internet encourages superficial processing of information, is a powerful source of misinformation, inflates people's beliefs about what they believe they know, and changes how people remember their personal lives, among other questions. In so doing, we aim to redirect the field from questions about the internet as a place to store information to a broader consideration of how internet usage may affect many aspects of cognition, as people increasingly rely on the internet to seek, post, and share information.

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* Correspondence concerning this article should be addressed to Elizabeth J. Marsh, Department of Psychology and Neuroscience, Duke University, Durham, NC 27708-0086, United States. Contact: emarsh@psych.duke.edu or Suparna Rajaram, Department of Psychology, Stony Brook University, Stony Brook, NY 11794-2500, United States. Contact: suparna.rajaram@stonybrook.edu

The internet makes it easy to take a virtual tour of a house across the country (e.g., via Zillow or Trulia), to read Abraham Lincoln's papers (in the U.S. Library of Congress digital archives), to take a course on machine learning (through Coursera), to learn the proper way to fold a fitted sheet (as demonstrated in YouTube videos), to weigh political polls (as synthesized on fivethirtyeight.com), to communicate one's views and positions (e.g., via blogs or Twitter), and to connect with one's high school classmates (via Facebook), among many other things. The internet is rapidly changing what information is available to people across the world as well as the way we find that information and share it with others. The result is a "digital expansion of the mind" that is almost always available, easy to access, and covers a wide swath of topics (albeit not necessarily accurately).

The question discussed here is, does our reliance on the internet change cognition, given that our cognitive system developed in a very different world, for different goals and in response to different pressures (Nairne & Pandeirada, 2008)—and if so, how does relying on the internet change cognition? Many have weighed in on this topic, including but not limited to members of the media, the tech industry, and academics from a variety of disciplines including Psychology, Philosophy, Computer Science, Information Science, and Education. Of course, there is likely no single answer to such a broad question, and instead the field will move forward by asking more specific questions. When doing so, we propose that researchers build on past research in two ways. First, one would be remiss not to examine past work on the use of less technologically sophisticated memory stores (e.g., Hertel, 1993). Second, many of the properties of the internet are familiar ones, albeit oftentimes on a different scale than normally experienced. For example, we know how people interpret the speed with which they retrieve information from memory; this finding can be leveraged to make predictions about how people will interpret the speed with which internet searches return information (see Property 7 below). That is, we encourage the identification of important properties of the internet to identify and build upon basic laboratory studies focused on the same properties. This recommendation is made in the spirit of Tulving's (1983, p. 146) claim that "Rememberers do not leave their brains and minds behind, or switch them off, when they enter the memory laboratory."

To preview, the first section of the paper describes ten properties of the internet and draws on research on other external stores or basic laboratory findings to show why each property matters, in terms of consequences for cognition. In the second section of the paper we describe a number of phenomena observed (or predicted) in the digital age, such as changes in people's strategies for information searching and their metacognitive awareness of doing so, and discuss them in the context of the properties laid out in the first section. In the discussion we take a step back, speculating about whether internet behavior affects *offline* cognition and discussing whether a speed—accuracy tradeoff is at the heart of the internet's effects on cognition.

**Table 1**
*Ten Properties of the Internet That Have Consequences for Memory and Cognition*

| Property | Definition |
|---|---|
| 1. Unlimited scope | Any topic may be addressed |
| 2. Inaccurate content | There is no guarantee information is accurate |
| 3. Rapidly changing content | Content can be added, deleted, or changed quickly |
| 4. Many distractions and choices | Many pictures, ads, hyperlinks pepper content |
| 5. Very accessible | Does not require tech-savviness; available to many |
| 6. Requires search | Search terms must be input to find information |
| 7. Fast results | Hits are almost instantaneous |
| 8. The ability to author | Anyone can be an author |
| 9. Source information is obscured | Authorship may be hidden |
| 10. Many connections to others | Easy to share and receive information with others |

*Note.* This list is not meant to be exhaustive; our goal is to draw attention to properties beyond the internet's unlimited capacity that are expected to influence cognition.

## Properties of the Internet

The internet connects computers and networks—and in that sense there is seemingly no limit to the amount of information the internet can contain, as another computer or more cloud space can always be added (for some numbers on the growing size of the internet, see this 2016 article: https://www.livescience.com/54094-how-big-is-the-internet.html). In contrast, human memory is limited, with no one person able to remember everything, meaning that humans have long looked for shortcuts to ease the burdens of remembering and thinking (oral traditions and the abacus are early examples). However, the limitless capacity of the internet is orders of magnitude greater than those of traditional external memory sources such as books, photo albums, and newspapers. As will be discussed in the section on offloading, perhaps because of this unlimited capacity, research has focused on understanding the internet's role as an external memory store.

The internet is much more than an unlimited storage device, however; in this section we enumerate some of the other properties of the internet that likely have implications for cognition. These properties (see Table 1) can be roughly categorized into those involving internet content (*What* information is available and used), internet usage (*How* people access that information), and the larger community creating and propagating content (*Who* drives the content). Many of the properties are also true for other external memory sources (e.g., that they are not perfectly accurate), so for each we briefly situate it within the internet context (e.g., describing the speed with which the internet returns information). We then ground the general implications of each property in basic cognitive science research, where possible; in some cases, we also describe relevant work with other external memory aids.

## Property 1: Unlimited Scope

As far as anyone knows, there is no limit to the type of information that can be found on the internet (although the accuracy of that information is not guaranteed, as discussed in the next section). The sheer amount and breadth of information available on the internet makes it an attractive place, and we know that people defer to others who have more expertise—and the internet is the ultimate expert. These claims are based on classic research on *transactive memory systems*, whereby people work together to remember information (e.g., Wegner, Erber, & Raymond, 1991; Wegner, Guiliano, & Hertel, 1985). For example, pairs of office workers were instructed to memorize lists of words related to different job responsibilities (e.g., *ordering desk copies: publisher*); critically, one half of the worker pairs had the same job responsibilities in real life whereas the others did not. When both workers in the pair had the same expertise, they both remembered slightly more words related to their job responsibilities (as opposed to words not related to their jobs). However, when the pair had different job responsibilities in real life, expertise effects were much larger: people overwhelmingly remembered words related to their job duties rather than to other jobs (Hollingshead, 2000). In other words, they assumed their co-workers would remember words particular to their (different) jobs. This suggests that one should be more likely to offload the burden of remembering or otherwise defer to the internet when one believes that the internet "knows" more about a topic than oneself.

## Property 2: Inaccurate Content

Unlike traditional media, where editors and "fact-checkers" strive for accuracy, there are relatively few gatekeepers on the internet. Almost anyone can create a webpage or post information to social media; no credential is required to do so, nor is much required in the way of technical skills. The internet is the "wild west" of media, where authors create their own rules and have little ability to police the content of others—with the result that much content is inaccurate, sometimes accidentally and other times deliberately. Erroneous content is concerning given that we know that people easily pick up misinformation about the world from many sources, including but not limited to stories and movies (see Marsh, Butler, & Umanath, 2012, for a review), newspapers (e.g., Lewandowsky, Stritzke, Oberauer, & Morales, 2005), multiple-choice exams (e.g., Marsh, Agarwal, & Roediger, 2009), and social media (e.g., Del Vicario et al., 2016).

To date, much research on misinformation and false memories has focused on *episodic memories* that are localized to a specific time and place (Tulving, 1983), such as when an eyewitness is misled about what she saw (for a recent review, see Frenda, Nichols, & Loftus, 2011).) Such errors often involve *source misattributions*: memories from one source (e.g., another witness, a photograph) are misattributed to past experience. In contrast, our focus is on the internet as a source of false beliefs about the world—incorrect beliefs about politics, religion, and science, for example. In such cases, people have a bias to assume information is true (Gilbert, Krull, & Malone, 1990) and furthermore tend to judge belief in a statement heuristically rather than based on how vividly an event is remembered. That is, belief is inferred in part based on how easy it is to read statements such as "illegal immigration is increasing," meaning that simply repeating a statement increases belief in it (*illusory truth*; for a meta-analysis, see Dechêne, Stahl, Hansen, & Wänke, 2010). Unfortunately, this effect occurs even when people know better, with repetition similarly affecting belief in contradictions of well-known facts (e.g., *the sari is the short pleated skirt worn by Scotsmen*; Fazio, Brashier, Payne, & Marsh, 2015), with downstream consequences: people repeat misinformation even when they have the correct information stored in memory (Fazio, Barber, Rajaram, Ornstein, & Marsh, 2013).

## Property 3: Rapidly Changing Content

The Internet is constantly changing: websites appear and disappear, links break, and pages are edited. Books also change (i.e., new editions are published), but such changes typically take place over years—a snail's pace in comparison to changes on the internet where the average webpage lasts only 100 days (*The Atlantic*, 2015).[1] WikiData's 50+ million pages, for example, have been edited an average of 13.57 times apiece, totaling over 600 million edits since wikidata began (downloaded from https://www.wikidata.org/wiki/Special:Statistics on 6/7/18). And even if content is stable, consumers may not find it the next time they search if they use slightly different search terms. Furthermore, even the identical search term used on different days may yield different results or a different ordering of hits, as what one sees is in part driven by other people (what is trending over a much larger group), webpage keywords (which can be edited), and paid placements (which come and go based on payments). We are not optimistic that people will notice such changes, given that people often miss large changes to visual scenes (Simons & Ambinder, 2005) and errors in memory persist following multiple chances to align one's representation of information with the original to-be-learned content (Fritz, Morris, Bjork, Gelman, & Wickens, 2000). In the absence of a retraction or other explicit tagging of change, noticing a change depends upon people spontaneously being reminded of the original event (Wahlheim & Jacoby, 2013).

The very ease of content changes on the internet likely increases their frequency: one can quickly edit the content or keywords of a webpage at a speed that is not possible for print materials. And the sheer speed with which information can appear on the internet may boost the need for changes, as speedy posting may beget errors or the need to update as more information is known or a situation changes. In short, the pace of change is orders of magnitude greater than for traditional media such as books, journals, and newspapers.

[1] These and other statistics are based on information available at the time of writing; the exact numbers will certainly change with time, given expected technological advances.

### Property 4: Many Distractions and Choices

At the same time content on the internet is ephemeral (due to its rapidly changing nature), the standard web page also provides more "extras" to the user. That is, most webpages are not like pages in a book or a conversation; instead, the desired content is combined with pictures (sometimes relevant, other times not), advertisements, videos, and links to other articles (which may be unrelated in content but appear because algorithms predict they will be of interest to the reader). In other words, the internet offers many extras that have the potential to distract the user. Such distractions are not unique to the internet, of course—newspapers and magazines have ads, friends digress during conversations, and television shows have commercials—but the internet is likely unique in the sheer number of distractions present at any one time. Of course, some of the options have the potential to support the reader, such as hyperlinks to definitions of foundational concepts. On the other hand, people are not necessarily good at discriminating which of the many options they should take advantage of, and classic research on the "lure of the seductive detail" makes it clear that learners can be easily distracted by content such as photos and videos (Fries, DeCaro, & Ramirez, 2018; Garner, Gillingham, & White, 1989). People (especially older adults) struggle to ignore irrelevant information, even when they know how to identify it (e.g., Connelly, Hasher, & Zacks, 1991).

Beyond competing content, the internet also allows more active participation than is typical when reading a book or listening to a radio program. For example, the internet user can comment on an article, share it on social media, or bookmark it to read later. In general, people are not as good at multi-tasking as they believe, as illustrated in people's relative over-confidence in their driving while talking to another person or using a cellphone (for a discussion of these issues see Finley, Benjamin, & McCarley, 2014). Of course, some contemporaneous activities boost retention, such as answering relevant questions about a text while reading it (*embedded questions*; Dunlosky, Rawson, Marsh, Nathan, & Willingham, 2013), but the point here is that such activities also have the potential to distract the reader or reinforce pre-existing learning biases (e.g., confirmation bias; Nickerson, 1998), with downstream consequences for what is later remembered.

**Interim summary.** Compared to traditional media, the internet changes more rapidly and offers more information at once (including more irrelevant information); it likely also contains more misinformation than many traditional sources. The internet may not contain any more information than an excellent physical library, but the ease with which the information is accessed likely makes it a more preferred choice for content, as detailed in the next few properties describing *how* people use the internet.

### Property 5: Widespread Access

The internet is accessible in many ways: many people have access, technological sophistication is not required for access, and many times one does not have to go anywhere for access (instead relying on the phone in one's pocket). Worldwide, over 4 billion people use the internet (United Nations; https://www.internetworldstats.com/stats.htm) and 93% of Americans had access to the internet in 2016 (The Federal Communications Commission). Furthermore, modern smartphones mean that many people "carry the internet in their pockets," likely increasing the frequency of usage. Within the United States, for example, about a quarter of adults are online almost constantly, according to a 2018 report by the Pew Research center (http://www.pewresearch.org/fact-tank/2018/03/14/about-a-quarter-of-americans-report-going-online-almost-constantly/.)

Today's internet is also easy to use: modern search engines like Google and Bing are much more intuitive to use than older applications such as gopher. This matters, given that past work shows that ease of usage determines the frequencies with which people rely on their own memories versus external memory supports. For example, when given the choice of printing or memorizing texts, people were more likely to choose printing when it required a simple command (pressing the *p* key) as opposed to a series of commands that took over a minute to complete (Schonpflug, 1986).

### Property 6. The Requirement to Search

Most information on the internet must be actively sought out, resulting in some 3.5 billion google searches per day in late 2018 (http://www.internetlivestats.com/google-search-statistics/). That is, the internet is not a passive presenter of information; the user enters search terms and clicks on links to track down the information he or she needs. One could argue that other external memory stores also require search—we must ask our friend to share information and we use book indices to track down information, for example. Using search terms is also an option when searching one's local computer or one's personal files in the cloud, of course, but people using personal files can also click through their folders and directories to find their targets—a method unlikely to be used when looking for information on the internet (as people must discover how information is organized on the internet). Intriguingly, people's ratings of their own job knowledge differed as a function of whether they reported using automatic search functions to find information versus searching manually (Hamilton, McIntyre, & Hertel, 2016). For people who reported having more organized files, manual search was associated with higher ratings of knowledge than if they searched with automated functions. The way in which one searches information may draw more or less attention to what one does and does not know.

### Property 7: Fast Results

In its most recent report (2016), the Federal Communications Commission (FCC) estimated the median speed of internet in the U.S. to be 39 megabits per second (Mbps), up 22% from its prior report—and internet speeds will almost assuredly be faster by the time you are reading this article. Simple searches return hits almost instantaneously (although of course the search may or may not be deemed successful, depending on the skill of the searcher, the search terms input, etc.) and are clearly faster than the old-fashioned method of going to the library, using the card catalog, finding a book in the stacks, and using the book's index to locate the desired information in the book.

A fast response to one's google search provides instant cognitive satisfaction. But the speed of that response may also imply something about the quality or truth of the result. Cognitive research shows that people are more confident in their answers when they answer questions quickly and with ease, even when that speed of retrieval is driven by something other than one's own knowledge (Kelley & Lindsay, 1993). That is, people asked "What was Buffalo Bill's last name" are more confident in their answer if it popped to mind quickly—even if the reason it popped to mind was that they just read it on a list explicitly labeled as containing wrong answers! Thus one question is whether fast results from internet searches "feel truer" than results of other more time-consuming searches for information; it takes more time to call a friend than to quickly google a piece of information, for example, and even longer to find experts (e.g., professors) or to search the library stacks.

**Interim summary.** One must search for information on the internet, but modern browsers mean that most searches are easy to conduct, with results returned quickly. In many cases, one does not have to go anywhere to access the internet, but rather may simply look at a smartwatch or pull out a smartphone. In the final set of properties we focus on the people creating and sharing content on the internet, creating authors and publishers at unprecedented rates.

### Property 8: The Ability to Author

The internet is more interactive than many traditional sources of information, especially print media. We cannot edit a library's books, but we can change Wikipedia pages, comment on news articles, blog, and use social media, potentially blurring the line between knowledge that is internal versus "out there" (Hamilton et al., 2016). On the one hand, attempts to explain (Dunlosky et al., 2013) or retrieve information (Roediger & Butler, 2011) boost learning and remembering. Thus, we would predict (for example) a student who defined a term in Wikipedia would be better able to remember it than another who simply read the Wikipedia definition. But what would happen if a student simply edited a Wikipedia page, mostly reading (and leaving) the content as is, but making minor changes? To the extent that the changes involved meaning, such as refining explanations, we would predict a benefit in memory for the entry. What is even less clear is whether students could appropriately identify how much of an entry they produced.

Past work has examined the circumstances under which people claim credit for information from external sources, such as when they plagiarize a computer's responses (R. L. Marsh & Bower, 1993) or another person's ideas (Hollins, Lange, Berry, & Dennis, 2016). For example, people are more likely to plagiarize another's work after time has passed, presumably as they forget the source of information (R. Marsh & Bower, 1993). People are also more likely to plagiarize in a give-and-take scenario (like a conversation); subjects who took turns generating category exemplars (e.g., sports) were more likely to plagiarize their partner when the categories were intermingled (generating, for example, a sport followed by a musical instrument) than when all exemplars of a category were generated in a row (Brown & Murphy, 1989). Thus, we would predict that the student who edited sporadically throughout a single entry would over-claim credit for the final product.

### Property 9: Source Information is Obscured

People are less inclined to rely on low credibility sources (e.g., Underwood & Pezdek, 1998), and drawing people's attention to the sources of information can sometimes reduce acceptance of misinformation (e.g., Lindsay & Johnson, 1989). However, there are several reasons why interventions based on source-monitoring are unlikely to solve the problems of misinformation on the internet, in our opinions (see also Marsh & Yang, 2017).

First, people struggle to evaluate the quality of internet sources (see Braasch & BrA_ten, 2017, for a model of how people evaluate sources), in part because many of the traditional cues to source are disappearing on the internet. Bots posting on social media go unrecognized and *native advertisements* are paid advertisements disguised as magazine articles or other legitimate sources (Conill, 2016; Wojdynski & Evans, 2016). Entire websites are sponsored by political or other organizations with agendas, and yet the involvement of that organization is difficult to spot (see MinimumWage.com for an example, as of the writing of this article). One might try to teach consumers to look for labels such as "sponsored content" but such an approach simply leads to the development of better camouflage for ads, fake news sites, and other sources of misinformation on the internet.

One approach involves browser or social media plug-ins that explicitly warn consumers not to trust particular webpages (akin to a librarian labeling a book as fiction rather than nonfiction). However, we are not optimistic about this approach, given that source information tends to be forgotten over time and with repetitions (Barber, Rajaram, & Marsh, 2008; Conway, Gardiner, Perfect, Anderson, & Cohen, 1997; Watkins & Kerkar, 1985), resulting in one simply "knowing" the information (Tulving, 1985).

### Property 10: Many Connections to Others

As social beings, people like to share memories (Berger & Milkman, 2012; Luminet, Bouts, Delie, Manstead, & Rimé, 2000) and psychological research suggests that information sharing regulates emotion and improves social bonds (Rimé, 2009). The internet makes it possible to share information quickly and with far more people than do more traditional means of communication, making it a powerful platform for social remembering and spreading information. The number of users is constantly increasing, as are the number and varieties of platforms for connecting with others (e.g., Twitter, Facebook, Whatsapp, LinkedIn, Instagram, Pinterest, Reddit, Tumbler), exploding the number of connections with whom a user can share information. The nature of one's connections, the extent to which people communicate within or across community clusters, as well as the size of one's network will affect what common ground is reached within a community.

**Interim summary.** We described ten properties of the internet we believe to have consequences for cognition, as summarized in Table 1. This list is not meant to be exhaustive; we are sure there are other properties that matter, but we believe our list is a reasonable starting point. We use these properties to explain (or ask questions about) phenomena observed in the internet age, in the next section of the paper.

## Consequences for Cognition: Questions to Explore

### Are There Costs to Offloading Memories to the Internet?

Early research on the internet's effect on cognition focused on the possible consequences of offloading one's memories to the internet, perhaps because researchers have a long tradition of thinking about memories as things stored in a physical space (Roediger, 1980). And the properties described in the last section make it clear why it makes sense to rely on the internet as an information store—it is unlimited in its capacity, almost always available, fast, and relatively unlimited in scope. There is no point in memorizing an address when one can look it up quickly, from anywhere.

Experimental work is still in its infancy, although much popular press warns (prematurely, in our opinions) about the dangers of internet reliance and whether the internet is "serving as the external hard drives for our memories" (Wegner & Ward, 2013), or even "making us stupid" (as asked on the cover of the July/August 2008 issue of *The Atlantic Monthly* in 2008; Carr, 2008). Such warnings are based on a 2011 *Science* paper showing that people are more likely to forget information stored on a computer, as opposed to information that was entered but erased (Sparrow, Liu, & Wegner, 2011). Participants read and copied statements such as "An ostrich's eye is bigger than its brain"; critically, half of subjects were told that the computer would save what they typed, whereas the other half were told their typing would be deleted. On a later free recall test, participants were more likely to remember the statements if they thought they had been erased—in other words, people relied on their own memories when they thought they would not have access to an external source.

We think it is premature to rely on this single set of studies to draw conclusions about the costs of offloading, given that there is a larger literature on the topic. While it is beyond the scope of this paper to review all of those studies (see Risko & Gilbert, 2016 for a review), it is clear that the picture is more complex. Many studies do find a cost to offloading: people are less likely to remember museum objects after taking digital photos of the exhibits (Henkel, 2014; but see Soares & Storm, 2018), or to remember card locations in a memory matching game when allowed to take notes during the encoding phase (Eskritt & Ma, 2014). And yet sometimes offloading affords deeper processing of information, such as when a note-taker connects a lecture to other material from a class (Einstein, Morris, & Smith, 1985). Offloading can also free resources for other processing. For example, Storm and Stone (2015) required participants to learn a series of 10-word lists; critically, they manipulated whether list A was saved to (or erased from) the computer before participants learned list B. List B was better remembered when List A was saved to the computer and did not have to be remembered, akin to the classic directed forgetting effect (Bjork & Woodward, 1973).

We are also concerned with the focus on the *save/erase* paradigm, given that we need more studies to understand these effects at the time of this writing.[2] In our own studies, for example, we did not find a difference in memory as a function of whether participants were told that the computer would save versus erase what they typed (Marsh & Rajaram, 2018). We speculate that our different results may reflect a belief in today's world that things cannot ever be completely purged from the internet—for example, stolen images (published illegally, in violation of copyright or for blackmail purposes) often continue to pop up on new websites after having been removed from others. People are clearly sensitive to the idea that *individual* computers can be unreliable and lose information (see Storm & Stone, 2015), but it is unknown whether the erase manipulation is believable in the context of today's internet. We should also note one other major difference between our work and that of Sparrow et al.: we conducted our studies online, with MTurk participants. Our participants remembered at levels comparable to the original laboratory participants, so the switch in population might not necessarily explain this outcome (and it should be noted that many effects replicate with this population; Buhrmester, Kwang, & Gosling, 2011). However, it may be that the save/erase manipulation is not as powerful in an internet context as in the context of a desktop computer in the laboratory (which can more easily be perceived as unreliable).

Finally, the internet is much more than a place to put information. To be clear, offloading of memories happens and is interesting, but offloading is only one of the consequences of the internet. In the next few sections, we consider research questions about other possible consequences of the internet for cognition, with the goal of redirecting the field from questions about the internet as a place to store memories to broader questions about cognitive processing.

### Does Using the Internet Become Habitual?

It seems clear that people overrely on the internet as a source of information, in the same way that they sometimes overrely on other external memory aids (see Risko & Dunn, 2015). Consider a study in which people were asked to answer a series of trivia questions; only one half were allowed to use the internet to supplement their own knowledge (Ferguson, McLean, & Risko, 2015). The no-internet condition provided a baseline of how many questions people should have been able to answer without turning to Google, but people who had access to the internet were less willing to rely on their own memories,

[2] A recent paper attempted to replicate a series of psychology experiments published in *Science* and *Nature*, with mixed results. The Sparrow et al. paper described here was included, but the replication attempt (which failed) was aimed at a different experiment in the series (which examined performance on the Stroop task) not the memory experiment we focus on in this article.

outsourcing some of the questions they could have answered themselves.

In other words, reliance on the internet can become habitual (Storm, Stone, & Benjamin, 2017; see also Barr, Pennycook, Stolz, & Fugelsang, 2015; Wang, Wu, Luo, Zhang, & Dong, 2017). For example, in a study by Storm et al., a subset of participants used the internet to answer eight difficult trivia questions prior to being asked to answer eight easy questions such as "What does an "entomologist" study?" and "What is Big Ben?" A second group of participants answered the same hard questions first, but from memory; a third group of participants did not answer any questions prior to the set of easy questions. Critically, all participants had the option of answering the easy questions from memory or by googling the answers. People who relied on the internet to answer the hard questions were more likely to use the internet to answer the easy questions (on average, looking up 83% of answers) as compared to subjects who had not answered the difficult questions (65%) or who had relied on their own knowledge when answering them (63%). In other words, once people were in the habit of using the internet, they kept using it even when they should not have needed it. Intriguingly, a similar bias towards using the internet to answer easy questions was seen even when using the internet required participants to get up and walk across the room (Storm et al., 2017) a small roadblock was not enough to deter people from their habit of relying on the internet.

It is possible that habitual reliance on the internet will come at a cost, beyond issues of efficiency (as in the case of walking across the room). To the extent that searching for information is more akin to reading it than remembering it, searching will not boost later memory for that information. That is, there are known mnemonic benefits from retrieving information from one's own memory, as opposed to simply reading it (the testing effect; Congleton & Rajaram, 2012; Roediger & Karpicke, 2006a, 2006b). Even unsuccessful retrieval can benefit memory (Kornell, Hays, & Bjork, 2009), in part because it draws awareness to what one does versus does not know and guides later study (*test-potentiated learning*; Arnold & McDermott, 2013). In other words, routine searches unaccompanied by retrieval attempts may not yield as much learning of information as other more effortful activities (although we can envision an effortful search that might be more akin to retrieval practice).

## Does the Internet Encourage Superficial Processing and If So, When?

Does the internet encourage shallow processing, as compared to reading a book or listening to another person? The reader may be concerned that this question is reverting back to the "is the internet making us stupid?" question. But more generally, we know that the way people process information matters, with dozens if not hundreds of studies have shown that drawing people's attention to perceptual or phonological information has negative downstream consequences for memory for meaning (the classic *levels of processing effect*; Craik & Tulving, 1975; Hamilton & Rajaram, 2001; Roediger, Weldon, & Challis, 1989). Thus, it would be problematic if the internet drew attention to more superficial properties (e.g., aesthetic features of the web page) or did not involve the type of deep, elaborative processing known to yield comprehension and remembering benefits (see Carr, 2008, 2010 for a discussion). Here we describe two situations that cause such shallow processing; neither is unique to the internet, but both are commonly encountered by internet users.

One issue (Property 4) is that the typical webpage or social media platform offers many choices to people, and there is a cost to having to make choices (even if one doesn't choose the distraction). For example, deciding whether or not to share content on social media takes cognitive effort; it may be easier to share content on social media than to loan a book or photocopying an article but these decisions are much more common on social media. In a study using a laboratory analog of Weibo (the Chinese social media equivalent of Twitter), participants read 50 messages (many of which concerned the aging Chinese population); one group pressed "next" to go on to the next message whereas the experimental group decided whether to "repost" each message or to press "next" to simply advance to the next message (Jiang, Hou, & Wang, 2016). Critically, afterwards all participants were tested on their comprehension of the messages with a multiple-choice test; subjects who decided whether or not to repost messages performed worse than did readers who simply pressed "next" to read the next message. Deciding whether or not to post something took effort, meaning that less effort was directed towards understanding what one was reading. In this sense sharing was distracting and led to shallower processing (Craik & Lockhart, 1972). Furthermore, there may be an additional cost to having a large number of choices (although the literature is mixed on this point; see Scheibehenne, Greifeneder, & Todd, 2009).

Second, we can ask: Do people read differently when reading screens? It appears they do. Reading on a screen increases eye fatigue, perhaps explaining why people read more slowly when reading on screens as compared to hard copy (e.g., Ackerman & Lauterman, 2012; Daniel & Woody, 2013). People may also read in different orders; reading on paper is relatively linear, as opposed to the experience of reading a document peppered with hyperlinks. Such differences have consequences: across studies, the evidence suggests that comprehension suffers when people read on screens, as opposed to reading paper versions of the same information (e.g., Mangen, Walgermo, & BrA,nnick, 2013), although there are studies showing null or opposite effects (e.g., Porion, Aparicio, Megalakaki, Robert, & Baccino, 2016). This issue is not specific to the internet, of course, as one may also read e-books and other content on screens (and most of the just cited studies involved tablets). Reading on the internet, however, is not just reading on a screen. As noted earlier, the internet typically offers *more* information at once and requires more choices than other forms of communication. A single search offers us dozens of links to articles and blogs, and once we choose an article to read it will likely be littered with advertisements and "related" hyperlinks to other sources of information. As a result, no single link or article may be processed with enough depth to matter in the long run.

### Does Using the Internet Require a Different Kind of Metacognitive Awareness?

With respect to metacognitive awareness, cognitive scientists are typically interested in either *judgments of learning (JOLs)*, one's prediction that he or she will remember recently learning information, or *feelings of knowing (FOKs)*, which are good (albeit not perfect) estimates of one's ability to actually retrieve stored information from memory (Hart, 1967). Intriguingly, using the internet may require a different form of metacognitive awareness: a *feeling of findability* (Risko, Ferguson, & McClean, 2016). That is, what matters when searching the internet is one's sense of how easily one will *find* the desired information, not how imminent retrieval from one's own memory is. These ideas were tested empirically in a study where people predicted how long it would take them to find information on the internet before they search for it. People's actual search times (e.g., to find the author of *The Old Man and the Sea*) were moderately correlated with their estimated feelings of findability (trials where subjects knew the correct answers were excluded from the analysis, as they did not search in those cases). To show that *feelings of findability* (FOF) are not simply *feelings of knowing* (FOK) masquerading under another name, the researchers used a between-subjects design so that one group of subjects made FOK judgments, a second group rated FOF, and a third group was timed while they actually searched for the answer to each question (given a lack of knowledge). Both FOK and FOF predicted search times, and yet were uncorrelated ($r = .05$) with each other.

More generally, the very act of searching may change one's beliefs about what one knows. In one study, participants were asked questions such as "how does a zipper work?" In one condition, participants searched the internet for the answer whereas others were either not allowed to search the internet or were simply given the answers in text format (Fisher, Goddu, & Keil, 2015). Across several experiments, those who googled the answers were more confident in their ability to answer a new set of questions (as compared to those who did not search the internet). In other words, searching the internet inflated one's sense of knowing, even for unrelated topics. Finding the answers was not as important as searching for the answers—it was the act of searching that inflated confidence in one's own knowledge.

### How Do the Internet's Effects on Social Connections Affect Cognition?

To the extent that the internet changes people's connections to others, it will have consequences for cognition. Social media platforms afford us the opportunity to go beyond the core groups we know and with whom we interact on a frequent basis (e.g., our immediate family members or close friends in our Facebook or Whatsapp groups). We also disseminate information to those who are connected to our family or friends but not directly connected to us, and we read information that these distally connected people post. In fact, we also frequently view information posted by strangers (e.g., on Twitter). How might the indirect connections in our networks influence our memory representations and our cognitive structures?

The spread of social influence in large communities has long held the interest of social scientists (e.g., Cialdini, 2001; Christakis & Fowler, 2009; Schelling, 2006), and sociological and epidemiological work shows that behaviors such as smoking and psychological characteristics such as loneliness and happiness can be influenced by our social networks (for a review, see Christakis & Fowler, 2007; Christakis & Fowler, 2008). Recent experimental and computational modeling research in cognitive psychology provides a window into how information spreads in large networks that contain both direct and indirect connections. This work shows that our memories are influenced not only by those with whom we interact directly but also by those with whom we are connected indirectly (e.g., our friends' friends, their friends, and so on; Choi, Blumen, Congleton, & Rajaram, 2014; Luhmann & Rajaram, 2015). People develop shared memories with both directly and indirectly connected group members; memory similarity decreases as connections become more indirect but it can persist up to distances of six to seven separations (Choi et al., 2014; Coman, Momennejad, Drach, & Gean, 2016; Luhmann & Rajaram, 2015). As the social media platforms continue to expand internet users' circle rapidly and widely, these findings suggest that users acquire information from others far more than they might realize.

Depending on the types of social networks that users inhabit (e.g., relatively insular chat groups on Facebook versus much more distributed following on Twitter), information bubbles and echo chambers can coalesce the users' opinions, whereas large, diverse, and complex interconnections yield varied mental representations. By insular groups we should be clear we are not necessarily talking about small personal groups—we are referring to groups whose communications are limited to group members, yielding echo chambers that amplify memories for negative information (Choi, Kensinger, & Rajaram, 2017) and that develop similar frameworks or cognitive structures for interpreting new information (Congleton & Rajaram, 2014; Choi et al., 2014; Weldon & Bellinger, 1997). That is, in the same way that people's schemas direct their attention and change their interpretation of incoming information (e.g., Anderson & Pichert, 1978; Pichert & Anderson, 1977), alignment of memory structures in insular groups can become a cultural tool for members of a community to attend to the same information and interpret it similarly, as compared to groups where people share information with different partners across interactions (Choi et al., 2014). Evidence also suggests that a group member selectively remembering national and historic events can cause a listener to selectively forget other related events (Stone, Gkinopoulos, & Hirst, 2017), especially if the listener trusts the speaker or believes the speaker to have greater expertise (Koppel, Wohl, Meksin, & Hirst, 2014). Since the internet has become a popular platform for social interactions, these psychological mechanisms, observed in small groups, have wide-ranging implications for memory and belief formation resulting from conversations on social media platforms.

## Is the Internet a More Potent Source of Misinformation?

There are many sources of misinformation about the world, and the same mechanisms likely drive acceptance of misinformation from the internet as from any other source. We have known for some time now that people are highly susceptible to misinformation, accepting and later remembering erroneous suggestions about past events (Loftus, 1979) or false statements that contradict the true state of the world. However, as alluded to earlier, it is arguably *easier* to disguise a low credibility source on the internet, and it is also *easier* to put misinformation on the internet, as opposed to publishing it in a book or broadcasting it via mainstream media. The real-time nature of the internet combined with most people's near-constant access likely increases the chances that people are exposed to erroneous reports in developing stories. This is problematic given that retractions of errors are no guarantee that people will end up believing the correct information (e.g., Lewandowsky et al., 2005).

Furthermore, the internet makes it easy to discreetly change content or change one's position. Multiple authors can make changes quickly, even simultaneously (e.g., on Wikipedia). We are not optimistic that viewers will notice such changes, given that people often miss large changes to visual scenes (Simons & Ambinder, 2005) and are biased towards remembering the overall meaning of a communication rather than the exact wording (Bransford & Franks, 1971). We suspect it is rare for people to compare a site's current content to cached versions, and even if they did we suspect they would not be good at noticing subtle differences across versions (Fritz et al., 2000). In the absence of a retraction or other explicit tagging of change, noticing a change depends upon people spontaneously being reminded of the original event (Wahlheim & Jacoby, 2013), which seems unlikely for most minor changes to a webpage. Furthermore, even when people notice changes (or catch errors), their later memory may still be affected (Marsh & Fazio, 2006).

The social nature of the internet likely increases the *spread* of misinformation (Gabbert, Memon, Allan, & Wright, 2004; Hoffman, Granhag, See, & Loftus, 2001; Meade & Roediger, 2002; Reysen & Adair, 2008). That is, dating back to Sir Francis Bartlett's classic (1932) work we know that people transmit information to others, and such transmissions shape not only our true memories but also lead to the transmission of errors to listeners (e.g., B.H. Basden, Reysen, & Basden, 2002; French, Garry, & Mori, 2008; Gabbert, Memon, & Wright, 2006; Maswood & Rajaram, 2018; Meade & Roediger, 2002; Reysen, 2003, 2005; Roediger, Meade, & Bergman, 2001). The result is that people in echo chambers are likely to share false representations (Choi et al., 2017). Furthermore, memory accuracy decreases and memory errors increase as information continues to move away from the original source (Roediger, Meade, Gallo, & Olson, 2014). Such findings do not bode well for the accuracy of transmission for information that goes viral on the internet.

Not only does communication with others propagate memory errors, these errors increase if the nature of communication is superficial. Conversely, memory errors reduce when the interactions are deeper and involve back and forth discussions about the memories (B.H. Basden, Basden, Bryner, & Thomas, 1997; Tan & Fay, 2011; Thorley & Dewhurst, 2007), or when people have the ability to edit another person's account of a past event (Ditta & Steyvers, 2013). These findings suggest that spread of misinformation on the internet may depend on the extent to which the varied and rapid social exchanges entail back and forth discussions or provide editing capabilities (e.g., for Wiki entries). False collective memory of a group can also increase when members repeatedly interact within their circle, reinforcing information as in echo chambers; further, following interactions within such insular groups, individuals show increased confidence for falsely recognized information they had never originally seen (Choi et al., 2017).

## Does Internet Usage have Consequences for Autobiographical Memory?

While our focus has been on knowledge (and the source of that knowledge) in this paper, we should note that the internet likely has implications for autobiographical memory as well. To the extent that people document and share their lives via social media, it will affect how they process and remember events.

First, documenting an event (e.g., by taking a photo or writing notes) may change how that event is experienced and processed. While documenting one's life is not a new behavior (see Burt, 1992, for a classic study with diarists), the advent of smartphones and the explosion of social media likely have increased the *frequency* of such actions. The research on the consequences of these behaviors is somewhat mixed, likely because documentation has multiple effects on cognition: it requires effort, focuses attention selectively, and encourages elaboration. Negative effects have typically been observed when students are assigned to photograph particular objects or when note-taking consists of rote copying. That is, taking digital photos of museum exhibits reduces memory for those exhibits, as compared to other items that were viewed but not photographed (Henkel, 2014; but see also Soares & Storm, 2018). Different results are observed when the documenter is able to choose what to photograph or take notes on. For example, students who chose which exhibits to photograph were better at remembering the visual details of them than the auditory details (Barasch, Diehl, Silverman, & Zauberman, 2017).

Second, curating one's social media profile may have downstream consequences for memory in the same way that tuning conversations for a specific audience or goal biases memory (Marsh & Tversky, 2004). That is, unlike daily journaling and other means of reflecting on one's life, posts on social media are made to an audience (oftentimes a very large one), meaning that one is likely more selective in the details posted and the photos shared. To the extent that one focuses on the good parts of an event or posts one's best photos, we predict that shared events will later be viewed more positively. Such a result would parallel the findings that narrating one's autobiographical memory to a listener or jointly recalling an event reduces the negative valence attached to the memory (Maswood, Rasmussen, & Rajaram, in press; Skowronski, Gibbons, Vogl, & Walker, 2004), and those who jointly reminisce about a shared autobiographical experience develop a closely aligned, collective narrative compared to those who recall the same experience alone (Maswood et al., in press). Social media also allows tailoring one's posts to smaller audiences, such as when one shares a photo with a specific group of people (e.g., work friends), which in turn should have implications for how events are later remembered (Dudukovic, Marsh, & Tversky, 2004; Tversky & Marsh, 2000).

Social media also cues one's memories, allowing rehearsal of past events. Beyond seeing other people's posts (shared memories), Facebook, for example, has an "X years ago today" feature whereby one is surprised by some image or post from the past. Such reminders are likely to be surprisingly pleasing (Zhang, Kim, Brooks, Gino, & Norton, 2014) while at the same time increasing memory for the events (Koutstaal, Schacter, Johnson, Angell, & Gross, 1998). Photos can, of course, also mislead memory—such as when doctored photos lead people to believe they experienced events that never happened (Garry & Gerrie, 2005; Wade, Garry, Read, & Lindsay, 2002). One might doubt that posting completely fake photos is common, but at a minimum it is commonplace to use Snapchat or other filters to enhance one's photos, with unknown consequences for memory.

In short, social media allows selectivity in sharing, audience tuning, and rehearsals, at a rate that may be greater than traditional means of sharing one's memories. Platforms such as Facebook, Twitter, blogs, and Instagram (at the time of writing this article) make it possible to continuously build, broadcast, review, and update an autobiographical narrative with details big or small, or even inconsequential. These practices of sharing, audience tuning, and rehearsals are themselves not new nor unique to the internet. But social media platforms are increasing the scope, prevalence, and frequency of these practices by orders of magnitude, making the consequences for cognition potentially more far reaching.

## Does the Internet Increase Information Appropriation?

We predict that searching the internet will increase information appropriation, meaning that people will misinterpret the ideas and knowledge of others as their own, so long as the search is easy (see Hamilton et al., 2016 and Ward, 2013 for similar predictions). It should be noted that this position is inconsistent with early speculations that people using the internet would be better at remembering *where* they found information than the information itself (that is, people would remember the source but not the content). However, a closer look at the original work suggests that such speculations were unfounded. In Sparrow et al.'s seminal work participants copied trivia statements and were told that each typed statement was saved into one of six named computer folders (e.g., *data, facts, names*). When asked to recall the facts, participants remembered 23% of them; when asked to retrieve the folder of a given fact (e.g., the ostrich fact), participants correctly identified the folder for almost twice as many facts as they had recalled (Sparrow et al., 2011). The authors included a number of caveats about this comparison, but many still interpret this finding as evidence that the source of information on the internet is remembered better than the information itself—even though the two rates should not be directly compared. That is, it is not surprising that the free recall rate would be lower than performance on a six-alternative forced-choice test, where guessing would lead to 17% of items being sourced correctly. In other words, there is no evidence to our knowledge that strongly supports the claim that people remember "where" they found information rather than "what" information they found.

We go a step further here and predict that compared to information from a friend or a book, information found on the internet may be particularly vulnerable to hindsight bias (*I already knew that*; Fischhoff & Beyth, 1975), inflated judgments of learning (e.g., Koriat & Bjork, 2005), or inadvertent plagiarism (*cryptomnesia*; Gingerich & Sullivan, 2013). Of course, these problems are not specific to the internet. Rather, what is unique about the internet is perhaps the number of opportunities it provides for authorship, and the relative anonymity of the information sources, both of which likely increase information appropriation. Furthermore, searching the internet is not entirely passive; one must input search terms and select links—activities with the potential to be confused with the cognitive operations that typically mark self-generated information (Johnson & Raye, 1981). Finally, the near-constant access to the internet that many people now have (e.g., via the smartphone almost always at hand) may further blur the distinction between what one knows and what exists on the internet—yielding the digital expansion of the mind.

## Conclusions: The Digital Expansion of the Mind

The increasingly interactive use of the internet—whether to look up facts or to actively edit a blog, Wikipedia, or a social media entry—blurs the line between knowledge that is internal versus "out there." In the modern world, knowing how to quickly and accurately find information on the internet oftentimes is just as useful as learning the information oneself. There are benefits to relying on the internet: more information, social connections, and reduced processing load (in some cases). But, relying on the internet may convey a sense of ownership over external information and reduce the depth of processing that is necessary to make information stick, likely exacerbated by the very speed with which hits are returned in response to one's search terms. Relying on the internet can also increase the influence of misinformation because anyone can edit information and do so at a fast pace.

We began this piece asking "how does the internet change cognition" with the goal of broadening the question beyond those focusing on the internet as an outsourced storehouse of information. Critically, the internet's effects on cognition are not limited to the information searched for—internet usage can affect later behavior, even when people are offline. For example, there is concern that people will start reading paper texts differently if people are in fact reading more superficially when online (since online reading is increasing in frequency). People may develop cognitive representations (schemas) through exchanges on the internet or echo chambers, which will in turn affect how they interpret and remember information outside of the internet context. People make choices about how to document their life experiences on social media (e.g., Facebook, Instagram, or

Twitter), changing their autobiographical memories in ways that are unlikely to be internet-limited.

Finally, we speculate that there may be a speed–accuracy tradeoff involved in information consumption, with the wealth of information available on the internet pushing consumers towards speed over accuracy. That is, does the reader try to consume *more* information when faced with the many options the internet offers, making them likely to consume any one source more superficially? Does the internet searcher read many news stories quickly, whereas one holding a print newspaper might read fewer stories more carefully? Does the option of having many choices and the fear of missing out (FOMO) on chatting with social connections disrupt the quality of information processing and the satisfaction derived from the experience? Or is there a benefit of knowing a little bit about everything, as opposed to depth?

Of course, there are still many contexts where people are expected to rely on their own memories,perhaps most notably in formal educational settings, where students are often required to take closed-book exams. It is not polite to rely on google to remember the name of one's conversational partner, nor is it advisable to consult the internet on the rules of the road while driving. Conversation depends upon stored knowledge of vocabulary and grammar, as does learning to speak a foreign language. Yet, we can contrast all of this with the immense opportunities on the internet for learning (e.g., courses and demonstrations on YouTube, Coursera, TEDx talks) that are game-changers and enhance our educational options.

Our key aim has been to identify the ways in which specific properties of the internet and the specific characteristics of human information processing meld to shape human cognition. Understanding these interactions will transform our ability to exploit the wealth of information the internet provides us and curtail the cognitive costs that come with using it.

## Author Contributions

Elizabeth J. Marsh and Suparna Rajaram participated equally in the preparation of this manuscript.

## Conflict of Interest Statement

The authors declare that they have no conflict of interest.

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