Memory in the Digital Age

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Abstract. Digital technologies have changed the everyday use of human memory. When information is saved or made readily available online, there is less need to encode or maintain access to that information within the biological structures of memory. People increasingly depend on the Internet and various digital devices to learn and remember, but the implications and consequences of this dependence remain largely unknown. The present chapter provides an overview of research to date on memory in the digital age. It focuses in particular on issues related to transactive memory, cognitive offloading, photo taking, social media use, and learning in the classroom.

Keywords. Autobiographical Memory; Cognitive Offloading; Digital Technology; Extended Cognition; Fake News; Google Effect; Metacognition; Photo-taking-impairment Effect; Social Media; Transactive Memory

Digital technologies have altered the everyday use of human memory. What used to be accomplished largely by individuals and their personal, organic memory systems, is now accomplished in concert with the Internet, computers, smartphones, GPS devices, cameras, digital assistants, and so forth. The use of external resources to extend and expand upon the abilities of internal memory is not new. People have sought to overcome the limitations of internal memory for as long as there have been records of human behavior (e.g., Rowlands, 1999; Yates, 1966). Human cognition evolved, at least in part, to help people take advantage of and interact with external resources. What is new is the sheer power of the external resources afforded by digital technologies, the way people use them, and the accelerated rate at which people have come to rely on them.

Arguably, no recent technology has had a more profound impact on the functioning of human memory than the Internet. The Internet is unlike anything seen before. The depth and breadth of the information potentially available is unparalleled, and the proliferation of smartphones and smart devices allow it to be virtually omnipresent. The degree to which the Internet has changed the nature and functioning of human memory has been the subject of considerable debate, with some contending that the Internet has had substantial and deleterious consequences for the way people think and remember (for various perspectives, see, e.g., Carr, 2010; Clowes, 2013; Marsh & Rajaram, 2019; Nestojko, Finley, & Roediger, 2013; Ward, 2013a; Wegner & Ward, 2013; Yamashiro & Roediger, 2019).

Of course, there is a long history of fears regarding the implications of new technologies for human cognition. Socrates famously argued that writing would “create forgetfulness in the learners’ souls, because they will not use their memories; they will trust to the external written characters and not remember of themselves. The specific which you have discovered is an aid not to memory, but to reminiscence, and you give your disciples not truth, but only the semblance of truth; they will be hearers of many things and will have learned nothing; they will appear to be omniscient and will generally know nothing; they will be tiresome company, having the show of wisdom without the reality." (Plato, 1980).

The parallels between concerns about writing in 370 BC and the Internet in 2019 AD are noteworthy. The comparison makes it seem like concerns about the Internet may be overblown, as few would argue that the advent and proliferation of the written word has been bad for human cognition. That said it is difficult to separate the advantages of the written word for the development of science and civilization from the memory and intellectual abilities of a typical individual, and it is certainly possible that people living thousands of years ago enjoyed a few select cognitive abilities superior to those enjoyed by people today. People tend not to remember and communicate stories the way they used to, for example, and it is difficult to know whether the advantages of having access to vast amounts of external information can completely compensate for the potential disadvantages of not having that information stored internally. Even if disadvantages do exist, however, they would seem to result from how technologies are designed and the way in which people use them, as opposed to anything intrinsic about the technologies. All factors considered, technologies like the Internet should have the potential to enhance human cognition and the types of things that people are capable of accomplishing (Marcos & Storm, 2018).

The more general problem when thinking about memory in the digital age, and the consequences of new technologies like the Internet on the way people learn and remember, is that there is often a mismatch between the way people study memory and the way memory functions in everyday life (Yamashiro & Roediger, 2019). On the one hand, researchers can study the costs and benefits of digital technology for the functioning of an individual's memory when separated from that technology. On the other hand, researchers can study the effects of digital technology on the functioning of an individual's memory when working in the context of the world and tasks with which that technology developed. Indeed, it is easy to suffer from what can be referred to as a sort of "Cartesian prejudice" (Menary, 2010). Going forward, memory will need to be studied not only at the level of individual participants in controlled laboratory environments but also in the context of the environments and technologies with which individuals typically interact. Indeed, the interaction of memory and technology could become so ubiquitous that it may, in many ways, become inappropriate or even misleading to consider the functioning of memory in the absence of technology.

When thinking about the effect of digital technologies like the Internet, it is useful to consider the properties of such technologies and how they differ from internal memory and other types of external memory systems (Marsh & Rajaram, 2019). Overly simplistic arguments about whether the Internet is good or bad for memory neglect the nuanced ways in which the Internet can affect memory, and to understand such effects requires researchers to more fully understand the nature of the Internet and how people interact with it. In a recent review, Marsh and Rajaram discuss ten properties of the Internet (i.e., unlimited scope, inaccurate content, rapidly changing content, many distractions and choices, very accessible, requires search, fast results, the ability to author, source information is obscured, many connections to others), all of which should be considered in any model of memory as it relates to the Internet. Making matters even more complicated, however, is the perpetual development of digital technologies. The digital world of tomorrow is likely to be very different from the digital world of today, pushing the study of human memory into a constant state of flux. The present chapter will provide a snapshot of the inchoate research to date.

Cognitive Offloading and Transactive Memory

Individuals do not remember alone. Rather, they remember in collaboration with others and with the external resources that are available to them. Such resources include not only digital technologies, but things like books, physical actions, and anything else with which to-be-remembered information can be stored either wholly or in partnership with an individual's internal memory (Kirsh & Maglio, 1994; Risko & Gilbert, 2016). In this way, memory is becoming extended increasingly to encompass information stored both within and beyond the head (Clark, 2010; Clark & Chalmers, 1998). From this perspective, information does not necessarily need to be stored within the neural structures of the human brain to be considered available in, or part of, that person's overall extended memory system (Storm, 2019).

Memory has been studied in this context with regard to the creation and use of transactive memory systems (e.g., Peltokorpi, 2008; Wegner, 1995; Wegner, Erbert, & Raymond, 1991; Wegner, Guiliano, & Hertel, 1985). Transactive memory systems are formed whenever two or more individuals share the responsibility of learning and remembering. By dividing the labor of remembering as a function of individual expertise, and then relying upon each other when such information is needed, each individual can potentially have access to more information than they would have had alone. In a transactive memory system, individuals do not need to know any particular piece of information—rather, they merely need to know who knows it or where to find it.

Owing to the properties of the Internet (e.g., its remarkable breadth and depth, and its ubiquitous and largely perpetual availability), the Internet can be thought of as a type of transactive memory partner, one that in many ways is far superior to that of any other individual or non-digital technology (Ward, 2013a). The amount of information available on the Internet is virtually limitless. When people want to know something, they conduct a Google search, ask Alexa, or look it up on Wikipedia. Moreover, unlike friends and partners, the Internet is almost always available through digital devices and even personal information is now saved and accessible via the cloud. In fact, there is an entire area of research (Personal Information Management, or PIM) focused on the study of how people maintain, organize, and retrieve their personal information—not surprisingly, a significant portion of people's personal information is now managed in concert with the Internet and other digital devices (e.g., Bergman & Whittaker, 2016; Jones, 2012).

The Google Effect: Costs and Benefits of Saving Information

Interest in the effect of the Internet and digital technology on memory grew substantially with the publication of a paper in *Science* by Sparrow, Liu, and Wegner (2011). In that paper, Sparrow et al. reported a series of experiments demonstrating that when participants believe that information is saved on a computer, they remember it less well than when they believe it is not saved on a computer. In one experiment, for example, participants were instructed to read 40 trivia statements, such as "An ostrich's eye is bigger than its brain" and "the space shuttle Columbia disintegrated during re-entry over Texas in Feb. 2003," and to type the statements into the computer. Critically, half of the participants were told that the computer would save the statements and that they would thus have access to them later in the experiment (Save Condition). The other half of the participants were told that the computer would erase the typed statements, and thus that they would not have access to them later in the experiment (Erase Condition). When the participants were subsequently asked to try to recall as many of the statements as they could remember, participants in the Erase condition outperformed participants in the Save condition.

The impaired performance observed by Sparrow et al. (2011) in the Save condition relative to the Erase condition has come to be known as the Google Effect. According to Sparrow et al., the effect was observed because participants came to rely upon the computer as their transactive memory partner, relieving them of the need to learn and remember the statements using their internal memory. Interestingly, the effect was observed even when participants received explicit instructions to remember all of the statements, suggesting that the mechanisms underlying the Google Effect might involve more than a person's conscious intent to remember.

In subsequent experiments, Sparrow et al. (2011) examined other consequences of saving, focusing in particular on how people remember information differently when they know that information is saved. According to the transactive memory framework, when information is stored externally, what becomes important to remember is where the information can be found when it is needed, not the details of the actual information itself. The results of Experiments 3 and 4 were generally consistent with this idea, showing that although people might not remember saved information as well as erased information, they do tend to remember the location of the saved information (i.e., the fact that the statements were saved, and the particular folders in which they were saved).

It is important to note that despite the impact of the paper by Sparrow et al. (2011), the empirical effects reported in that study have yet to be fully unpacked or reliably replicated. Marsh and Rajaram (2018), for example, failed to replicate the Google Effect in a series of experiments conducted using MTurk participants. It is unclear why the effect failed to replicate, but one possibility is that the participants did not fully believe the save versus erase manipulation. More generally, much remains to be known about exactly how, when, and why, people remember information less well when they think information is saved than when they think it is not, as well as how properties of the Internet, such as its dependability or the nature of the information, impact such effects. It remains to be seen, for example, whether the Google effect occurs with personally relevant information, or if the effect is confined to general-knowledge information as used by Sparrow et al. There may be certain types of information or experiences that individuals are less likely or willing to offload onto their digital transactive memory partners.

Finally, research has shown that relying on digital devices to remember can not only lead to costs (i.e., the Google Effect), but it can also lead to benefits. Believing that an initial set of information can be forgotten (i.e., that it no longer needs to be remembered), for example, has been shown to enhance the learning and remembering of a second set of information (E. L. Bjork & Bjork, 1996; Sahakyan & Kelley, 2002; see chapter by Sahakyan). To the extent that people treat the Internet and digital technologies as transactive memory partners, information that is saved does not need to be remembered. Thus, analogously to work on list-method directed forgetting, saving should not only make saved information less likely to be remembered than it would have been otherwise, it should make non-saved information more likely to be remembered than it would have been otherwise.

Storm and Stone (2015) reported just such a demonstration in a phenomenon they referred to as a saving-enhanced memory effect. In their study, participants studied lists of words contained in PDF files on a flash drive. On some trials, participants were instructed to save an initial file before learning a second file, ensuring that the initial file would be available for restudy prior to test. On other trials, participants were instructed to close the initial file before learning the second file, thus communicating that the initial file would not be available for restudy prior to test. Critically, when participants were tested on their memory for the second file, they remembered significantly more words when they had saved the initial file than when they had not. This finding suggests that offloading memory can free up attentional and memory resources for the encoding and processing of other information. Subsequent experiments by Storm and Stone replicated the saving-enhanced memory effect and showed that it is only observed when participants trust the computer to retain access to the saved file and when the information being saved is substantial enough to interfere with the learning of the other information.

Accessing Information on the Internet

As information continues to accumulate on the Internet, so do the opportunities to rely on the Internet as a transactive memory partner. The information people seek is often just a search away, and companies are working every day to make interactions with the Internet more seamless. With the help of digital assistants like Alexa, for example, people can now access information from the comfort of their living room without even opening their eyes or lifting a finger. It is unclear how the increasing availability and power of the Internet to serve as a transactive memory partner might be changing how memory functions, but clearly it is changing the way people access information.

In their first experiment, Sparrow et al. (2011) examined whether people are primed to think of the Internet after experiencing a need to acquire new information. In their study, participants were presented with a block of easy trivia questions (e.g., Are dinosaurs extinct? Is a stop sign red in color?) and a block of difficult trivia questions (e.g., Did Benjamin Franklin give piano lessons? Is Krypton's atomic number 26?). After each block, they were given a modified Stroop task in which computer words (e.g., Google, browser) and non-computer words (e.g., Nike, piano) were presented in either red or blue font. The participants were instructed to respond to the words as quickly as possible by naming their color. As predicted, participants were slower to name the color of the computer words than the non-computer words, particularly after attempting to answer the difficult trivia questions. The interaction was most pronounced when comparing specific search engines such as Google and Yahoo to popular consumer-good brand names such as Target and Nike. According to Sparrow et al., the difficult trivia questions primed participants to think about the Internet, thus causing the Internet words to slow reaction times on the color naming task (but see Camerer et al., 2018).

The overall idea that people look to the Internet for information seems unassailable. The better question, perhaps, is the extent to which they do so, and whether such behavior interferes with the internal processes that would otherwise benefit memory and cognition. Indeed, there is evidence that people can become reliant on the Internet. Ferguson, McLean, and Risko (2015), for example, presented participants with a series of general knowledge questions. In one condition, participants responded by saying whether or not they knew the answer to each question; if they knew it, they were then asked to provide the answer. The other condition was the same except that if participants reported not knowing the answer, they were required to look it up on the Internet. Across three experiments, participants with access to the Internet were less willing to volunteer answers than participants without access to the Internet. That is, participants who expected to be able to look up the answers online were less likely to rely on their internal memory when answering the questions than participants who did not expect to have that opportunity.

Storm, Stone, and Benjamin (2017) explored this issue further by investigating whether using the Internet to retrieve information increases the likelihood of using the Internet to retrieve other information. Research has shown that people can become fixated on doing things or solving problems in certain ways even when simpler or more effective methods become available, a phenomenon known as Einstellung (Luchins, 1942). Analogously, in the context of deciding whether to rely on one's internal memory, participants were significantly more likely to search for answers to easy trivia questions after being instructed to search for the answers to a separate set of difficult trivia questions than after attempting to answer those same questions from memory. This effect was observed even when the Internet was made less convenient to use and even when the information being sought was likely already available in internal memory. Moreover, not only were participants who initially used the Internet more likely to rely on the Internet than they would have been otherwise, but they spent significantly less time trying to think of the answers before conducting their searches, and they reported significantly depressed levels of Need for Cognition (Cacioppo, Petty, & Kao, 1984). This finding suggests that relying on the Internet has the potential to exacerbate cognitive miserliness (see related evidence, see e.g., Barr, Pennycook, Stolz, & Fugelsang, 2015; Wang, Wu, Luo, Zhang, & Dong, 2017).

Much is still unknown about the consequences of becoming progressively more dependent on the Internet to access information. In many ways, forming a stronger and more integrated partnership with the Internet could be a good thing. The amount of information potentially available to a person at any given time has never been greater. That said, information stored externally is not entrenched or integrated with other information in the same way that it is when it is embedded within the structures of internal memory (Storm, 2019). Relatively, a memory system that relies on external memory stores could be less capable of supporting the type of expertise that one needs to flexibly use and apply information to new situations (Benjamin, 2008). For example, people may be less able to engage in spontaneous analogical reasoning (Gick & Holyoak, 1983) when information is stored externally than when it is stored internally. Moreover, research has shown that retrieval serves as an important mechanism for updating memory, both in terms of making retrieved information more accessible (Roediger & Karpicke, 2006; Rowland, 2014; see chapter by Karpicke), and in terms of making other, non-retrieved information less accessible (Anderson, 2003; Murayama et al., 2014; see chapter by Anderson). In this way, an overreliance on the Internet to access information could prevent people from benefiting from the type of internal memory processes that are critical for learning and the adaptive updating of long-term memory (R. A. Bjork & E. L. Bjork, 1992).

Metacognition and the Internet

Using the Internet to access information can make people believe they know more about a topic than they do. In nine experiments, for example, Fisher, Goddu, and Keil (2015) showed that searching for information on the Internet led participants to report inflated levels of internal knowledge, suggesting that people can misattribute the information available to them online with information that is actually stored in internal memory (Sloman & Rabb, 2016). In their study, participants were asked to answer questions such as “How does a zipper work” and then to use the Internet to confirm the details of the explanation. Then, during a separate phase of the experiment, participants were asked to rate their personal knowledge in several other domains unrelated to the earlier questions (e.g., “How do tornadoes form?”). Compared to control participants, who did not look up explanations on the Internet in response to the first set of questions, the experimental participants reported significantly higher levels of knowledge about the new topics and a greater ability to answer questions about those topics (see also, Hamilton, McIntyre, & Hertel, 2016; Ward, 2013b). It is interesting to juxtapose these results with those of Storm et al. (2017), discussed above. Specifically, if searching the Internet inflates people's confidence in their internal knowledge, then why would it also increase people's propensity to rely on the Internet to answer relatively easy trivia questions? Perhaps increased confidence in one's internal knowledge is not enough to prevent one from becoming increasingly fixated on the Internet as a transactive memory partner.

Research on memory and metacognition has shown that people rely on heuristics such as familiarity and subjective fluency when making judgments about what they know and do not know (e.g., Jacoby & Kelley, 1987; Koriat, 1993; 2000; Nelson, Gerler, & Narens, 1984; Schwartz, Benjamin, & Bjork, 1997). From this perspective, the findings of Fisher et al. (2015) are not particularly surprising. Easy and ready access to information on the Internet may provide people with a sense of fluency or personal ability that is unwarranted in the absence of the Internet. Indeed, there is ample evidence that people make inflated metacognitive judgments often because they fail to consider the external factors that might be supporting their performance.

In more recent research, Stone and Storm (2019) examined whether the ease of access to online information influences the extent to which people think they will be able to remember that information later on. In earlier research, Benjamin, Bjork, and Schwartz (1998) presented participants with easy trivia questions and measured the time it took for them to answer the questions. Participants predicted that they would better recall the answers to questions they answered quickly than the answers to questions they answered more slowly, despite actual performance going in the opposite direction. Stone and Storm observed a similar pattern in the context of finding information online. Participants were given difficult trivia questions to answer using the Internet. Answers found quickly were judged to be more likely to be recalled in the future (without the help of the Internet) than answers found more slowly, even though actual recall performance went, if anything, in the opposite direction. These results suggest that the subjective fluency experienced while searching for information online can have a direct impact on the judgments people make about what they will or will not be able to remember.

Finally, researchers have investigated the metacognitive judgments people make about the likelihood of being able to find information online. As memory is extended to encompass external resources like the Internet, it will be important to understand not only how people make judgments about what they know internally, but what they will be able to access externally. To explore this issue, Risko, Ferguson, and McLean (2016) employed a modified version of a paradigm traditionally used to study feeling-of-knowing judgments. Participants answered general knowledge questions and were asked to predict how long it would take them to find the answers online (i.e., feeling-of-findability judgments). Interestingly, when participants reported not knowing the answer to a given question, their judgment of how long it would take to find the relevant information significantly predicted the amount of time it actually took to find that information. Moreover, the feeling-of-findability judgments predicted search time in a way that was independent of feeling-of-knowing judgments, suggesting that they are driven by heuristics about the online search process and not just the extent to which relevant information is held internally.

Digital Photo Taking: Motivations and Consequences

The advent of smartphones with built-in digital cameras has led to an explosion in photo-taking. In contrast to just a few years ago, the vast majority of photos are now taken using smartphones. According to one online survey conducted in 2015, people report taking an average of 2.68 photos per day, a number that likely underrepresents the number of photos taken during trips and special events (Finley, Naaz, & Goh, 2018). Indeed, over one trillion photos have been taken each year since 2017. Photo collections have grown so large that the task of curating such collections or even finding a particular photo when it is sought, has become increasingly difficult (Bowen & Petrelli, 2011; Nunes, Greenberg, & Neustaedter, 2009; Whittaker, Bergman, & Clough, 2010).

Smartphones may not only be changing the frequency of photo-taking but the circumstances under which photos are taken. A handful of studies have explored the functions of photo-taking. Early investigations focused on the functions of photo-taking as it relates to displaying photos in one's home and curating family photo albums. Photos in this context serve to cue memory as well as document family events. The act of assembling a family photo album can be used to define a family narrative (Chalfen, 1987). More recently, this inquiry has grown to include casual photographers, as well as people who regularly post photos to online communities. Within this context, people report that photography serves several functions, which can be conceptually grouped into those related to memory, social, self-expressive, and self-representative functions (Van House, 2011; Van House et al., 2004). A similar pattern was also observed in survey responses when participants were asked to freely report the reasons they take photos, with the majority of responses including themes about memory, as well as social, aesthetic, and work or hobby-related functions (Finley et al., 2018). As digital cameras become increasingly accessible, and the costs of taking and storing massive collections of photos decrease, new functions may emerge.

The mnemonic effect of taking photos has received increased attention in recent years. In one study, Henkel (2014) investigated the effects of taking photos on memory for both photographed and non-photographed objects in a museum. In the study, participants were led on a guided museum tour and instructed to take photos of some pieces of art, but not others. The next day, memory for all of the art was assessed using several tests, including a multiple-choice visual detail test, a visual recognition test, and a verbal recognition test. A photo-taking-impairment effect was found such that participants recognized and answered visual detail questions less accurately for the photographed objects than they did for the observed objects. This finding replicated in Experiment 2, but only when participants took photos of whole objects. Specifically, the photo-taking-impairment effect was attenuated when participants used the camera's zoom function to focus on a particular part of an object while photographing it.

Subsequent research has explored the mechanisms underlying the photo-taking-impairment effect. Although the effect is often cited as an example of cognitive offloading, similar to that which was reviewed above in the context of saving files on a computer (Sparrow et al., 2011; Storm & Stone, 2015), the evidence available to date is far from convincing. According to the cognitive offloading hypothesis, because photos "remember" the visual details of an experience, participants are thought to use the camera as a kind of transactive memory partner and strategically offload the task of remembering onto the camera. Contrary to this hypothesis, however, the photo-taking-impairment effect is observed even when photos are deleted immediately after being taken, either owing to the nature of the camera app (i.e., Snapchat), or to the instructions given to participants by the experimenter (Soares & Storm, 2018). Likewise, the photo-taking-impairment effect is not observed when participants use a body-worn automatic-capture camera (Niforatos, Cinel, Mack, Langheinrich, & Ward, 2017). Thus, the saving function of photo-taking appears to be neither necessary nor sufficient for the photo-taking-impairment effect of be observed. If offloading does occur while taking photos, it may not always result from a conscious or strategic decision to offload. An alternative explanation of the photo-taking-impairment effect is that of attentional disengagement. According to this hypothesis, photo-taking may cause people to disengage from the experience they are photographing, thus leading them to encode the experience less effectively than they would have encoded it otherwise (Soares & Storm, 2018).

Further complicating the story, Barasch, Diehl, Silverman, and Zauberman (2017) reported several studies in which photo-taking benefitted visual memory. In their studies, half of the participants took photos freely while going on an audio-guided tour of a museum. The other half did not take any photos. Memory for the art was then assessed using auditory and visual recognition tests. Across several studies, participants who used a camera consistently outperformed those who did not use a camera on the visual recognition test. Visual memory seemed to benefit most for objects that were themselves photographed, as photographed objects were consistently recognized more accurately than non-photographed objects. Of course, this benefit could have been driven by item effects since participants could have chosen to photograph their favorite or most memorable pieces of art. Perhaps more compellingly, in three of the six studies reported, participants were significantly more likely to recognize the art objects they chose not to photograph compared to participants in the no camera condition. Barasch, Diehl, and colleagues also found that participants in the camera condition recognized less auditory information than participants in the no camera condition.

One potential explanation for the discrepancy between the results of Henkel (2014) and Barasch, Diehl, et al. (2017) is that of volition. Specifically, choosing what to photograph may help focus visual attention and enhance engagement. Studies in which participants are assigned to photograph particular objects (e.g., Henkel, 2014; Niforatos et al., 2017; Soares & Storm,

2018) may bypass the cognitive process of choosing what to photograph, and so, the benefits. Consistent with this argument, volitional photo-taking has also been found to enhance the enjoyment of positive experiences, an effect mediated by self-reported engagement (Barasch, Zauberman, & Diehl, 2017; Diehl, Zauberman, & Barasch, 2016).

The Consequences of Photographic Review

Taking photos has the potential to impact memory in multiple ways. As described above, the mere act of taking a photo can affect what people remember about an experience. Later on, however, people can also review their photos, a process that also stands to impact how a given experience is subsequently recollected. Photos can cue memories of past events (e.g., Berry et al., 2007; Deocampo & Hudson, 2003; Finley, Brewer, & Benjamin, 2011; Hodges, Berry, & Wood, 2011; Loveday & Conway, 2011; St. Jacques & Schacter, 2013), and through the positive effects of retrieval practice (Roediger & Karpicke, 2006), reviewing old photos can make those events more memorable even in the absence of the photo (Koutstaal, Schacter, Johnson, Angell, & Gross, 1998; Koutstaal, Schacter, Johnson, & Galluccio, 1999). It is worth noting, however, that selective retrieval can also cause related, non-retrieved information to become less accessible than it would have been otherwise (Anderson, 2003; Storm et al. 2015). Indeed, participants who selectively review photos can sometimes show memory impairment for nonreviewed events relative to cases in which no review occurs (Koutstaal et al., 1999). As such, photographic review may cause photographed aspects of an experience to stand out by strengthening memory for those aspects, but through retrieval-induced forgetting, impair memory for non-photographed aspects of that experience.

Reviewing photos can also cause memory distortions. Altered photos have been shown to cause participants to report recollections of events or details that never actually occurred

(Frenda, Knowles, Saletan, & Loftus, 2013; Garry & Gerrie, 2005; Wade, Garry, Don Read, & Lindsay, 2002). Wade et al. (2002), for example, showed participants doctored photos of the participant riding a hot air balloon as a child, an event that did not actually take place. After repeated attempts to recall the photographed event, half of the participants fabricated partial or complete false memories. These findings are increasingly relevant in the digital age. Photos and videos can be altered easily and convincingly using accessible and inexpensive software, even on a smartphone. Technological advances have also made it difficult to identify altered photos. Users may even alter their own photos and forget that they altered them. Such photo alteration behavior could distort the way people remember their past experiences and think about old photos. Indeed, people may learn, over time, to naturally view photos with a sense of skepticism that did not exist in prior generations.

Reviewing unaltered photographs can also make people susceptible to false memories. From a reconsolidation perspective (e.g., Misanin, Miller, & Lewis, 1968; for review, see Hupbach, Gomez, & Nadel, 2013; see chapter by Nadel & Sederberg), the reactivation of memories through photographic review has the potential to make those memories susceptible to distortion. Across several studies, for example, participants who reviewed photos of a museum tour were susceptible to incorporating false details from novel photos of alternative tour stops (St. Jacques, Olm, & Schacter, 2013; St. Jacques, Montgomery, & Schacter, 2015; St. Jacques & Schacter, 2013). Similarly, viewing photos of plausible alternative events has been shown to cause participants to develop false memories of such events (Schacter, Koutstaal, Johnson, Gross, & Angell, 1997). A social media user needs only to click on or search a tag for an event to be inundated with other users’ experiences of the same event, perhaps mixed in with their own photos. As such, photos shared on social media can provide ample opportunities for the formation of false and distorted memories.

Finally, it is worth discussing lifelogging, a practice which involves continuously documenting one's life, such as through the use a wearable camera (for review, see Harvey, Langheinrich, & Ward, 2016). The idea originated long before the invention of wearable sensors and automatic-capture cameras (Bush, 1945), but has become more popular with the introduction of such technologies. Much of the research on lifelogging has focused on the use of wearable cameras to support remembering in people with memory disorders (for review, see Silva, Pinho, Macedo, & Moulin, 2018). Several studies report improvements in how many events or details participants, healthy or otherwise, remember after reviewing photos taken from an automatic-capture camera (e.g., Crete-Nishihata et al., 2012; Doherty et al., 2012; Finley et al., 2011; Kalnikaite, Sellen, Whittaker, & Kirk, 2010; Lee & Dey, 2008; Sas et al., 2013; Sellen et al., 2007; St. Jacques & Schacter, 2013; Woodberry et al., 2015). Beyond improving recall, some studies have reported that reviewing photos taken with an automatic-capture camera can enhance subjective measures of recollection like feelings of vividness (St. Jacques, Conway, & Cabeza, 2011) and memory specificity (Silva, Pinho, Macedo, & Moulin, 2013). It is interesting that despite the potential of lifelogging technologies to improve the recollection of one's autobiographical memories, it has nevertheless failed to catch on with a wide and diverse user base; most lifeloggers are individuals who work for or are invested in companies that sell lifelogging sensors (Sellen & Whittaker, 2010).

Digital Technology, Social Media, and Autobiographical Memory

Taking and reviewing photos can impact how people remember their lives and the way they form autobiographical narratives. Indeed, any technology that facilitates the selective retrieval of some experiences but not others can be expected to affect what is later remembered (for review, see Stone & Wang, 2018). In particular, events posted online are more likely to be recalled than unposted events (Wang, Lee, & Hou, 2017); a boost, however, that is unlikely to come without a cost. Selective retrieval, even of autobiographical memories, is associated with forgetting of related, non-retrieved autobiographical memories (e.g., Barnier, Hung, & Conway, 2004; for a review, see Storm et al., 2015). It seems likely, therefore, that technology-mediated retrieval has the potential to strengthen memory for documented experiences and impair memory for non-documented experiences.

The digital storage of experiences from the past in the form of photos and other digital media could serve to protect experiences from being forgotten. Indeed, 54% of participants in a recent survey reported that social media helps them to remember events that they would otherwise forget (Finley et al., 2018). Such protection from forgetting, however, may not be necessarily beneficial to users. Autobiographical memory is biased in many ways to maintain a coherent and positive sense of self (Conway, 2005; Conway & Pleydell-Pearce, 2000). Such biases function adaptively, at least most of the time, to facilitate not only the remembering of information that is positive and that fits with one's self-image, but to prevent or reduce the remembering of information that is negative or that does not fit with one's self-image (Berntsen, 1996; Suedfeld & Eich, 1995; Taylor & Brown, 1988; Walker, Skowronski, & Thompson, 2003). Indeed, phenomena such as rosy retrospection are often observed such that people remember events more positively than they were experienced (Mitchell, Thompson, Peterson, & Cronk, 1997). Although it has yet to be empirically investigated, it is possible that having increased access to information about one's self and one's past (via social media and digital diaries) has the potential to stand in the way of these adaptive processes. More specifically, a more indelible record of the past could disrupt the processes that facilitate the forgetting of negative past experiences (Storm & Jobe, 2012), thus making it more difficult to view the past positively and in a way that coheres with one's self-image.

The potential influence of digital technology on autobiographical memory is perhaps most obvious in the context of social media (i.e., websites and apps that are designed to allow users to create and share content with others in a social network). Research has shown that using social media can distract users and impair memory (Tamir, Templeton, Ward, & Zaki, 2018). Moreover, much of the research investigating the psychological effects of using social media has focused on whether the Internet is making people sad or lonely, with mixed results that seem to depend on how social media is used (e.g., Deters & Mehl, 2012; Ellison, Steinfield, & Lampe, 2007; Konrad, Issacs, & Whittaker, 2016; Kramer, Guillory, & Hancock, 2014; for review, see McKenna & Bargh, 2000; Kraut & Burke, 2015). Of course, not all social media posts look the same, and the affordances of different social media platforms influence the kinds of posts generated and how such posts are likely to affect people's well-being and autobiographical memory. Social media sites that involve developing a somewhat permanent persona with depth of information linked to an individual over time, for example, are likely to be particularly relevant to questions about how social media has the potential to influence autobiographical memory and views about the self in the long term (DeVito, Birnholtz, & Hancock, 2017).

To examine the influence of social media on well-being and positivity in autobiographical memory, Konrad et al. (2016) assigned participants to use a smartphone application to record everyday events. Participants used the app daily for three weeks, with half of the participants assigned to only record events, and the other half assigned to record and subsequently revisit and reflect upon the recorded events. Both groups reported improvements in well-being compared to a control group. Participants also seemed to reflect in such a way that the emotionality associated with negative experiences faded more quickly than the emotionality associated with positive experiences. This result is consistent with the fading affect bias, the finding that negative affect fades more quickly than positive affect (e.g., Holmes, 1970; Matlin & Stang, 1978; Thompson et al., 1996).

Overall, the participants in Konrad et al.'s (2016) study who were assigned to use the app did not show any evidence of disruption to the memory biases that favor positive remembering. As has been observed in other contexts (Walker et al., 2013), participants demonstrated a robust bias toward recording positive events over negative and neutral events. If people use social media in a way that is similar to how participants used the app in Konrad et al.'s study, then it would seem that they are at little risk of disrupting memory processes that facilitate positive recollection. Because positive experiences might be more likely to be posted to social media than negative or neutral experiences, use of social media might even intensify the bias toward positivity in autobiographical memory. Furthermore, disclosing an autobiographical memory to a listener, or recalling an event collaboratively, can reduce the negative valence associated with that memory (Maswood, Rasmussen, & Rajaram, 2019; Skowronski, Gibbons, Vogl, & Walker, 2004). It should be noted, however, that the app used by Konrad and colleagues (2016) was designed specifically to encourage reflection and ultimately improve well-being (Isaacs et al., 2013). Thus, future work should address the effects of technology-mediated recollection and social media use in the context of the types of apps and websites that people use more frequently in their everyday lives. Moreover, it will be important to consider the effects of exposure to other people's posts, feedback, and online personas.

Collective Memory, Fake News, and the Appropriation of Misinformation

Memory and the processes of remembering and forgetting can be studied not only at the level of individuals but at the level of groups and the interactions between individuals and the groups with which they identify (Halbwachs, 1980; Hirst & Manier, 2008; Roediger & Abel, 2015; Wertsch & Roediger, 1980). In part, collective memory reflects the dynamic process by which groups of individuals remember and misremember together, with the emergent qualities of what is remembered reflecting the schemas and narratives of the group and the shared sense of identity that connects people across time and space. The Internet, as a medium of social interaction, has had a profound impact on collective memory, both with regard to how individuals remember alone and with regard to how groups of individuals remember together.

As an example, consider flashbulb memories. Flashbulb memories are vivid episodic recollections characterized more by the high degree of confidence and perspective with which they are held and re-experienced than by their actual accuracy or consistency over time (Neisser & Harsch, 1992; Talarico & Rubin, 2003; Weaver, 2003). Many people feel like they can remember, for example, with clear perceptual detail, the moment in which they first learned of the attacks on 9/11 (Conway, Kitka, Hemmerich, & Kershaw, 2009; Hirst et al., 2009). Flashbulb memories are just as susceptible to bias and distortion as other memories, however, and they can be shaped to a significant degree by how stories are told and events are rehearsed (Brown & Kulick, 1977; Finkenauer et al., 1998; Tinti, Schmidt, Testa, & Levine, 2014; cf. Conway et al., 1994). In this context, the nature of news coverage is critical, as it has the power to determine whether and to what extent people rehearse and think about a public event in the days, weeks, and years to follow.

False news stories and misinformation campaigns are not new to the Internet. Fake news often consists of information that resembles news media, but that is not fact-checked through the same editorial oversight. As such, fake news is more easily created today than it was before, since users can easily post information online or create websites that resemble legitimate news media without high barriers to entry like printing costs. The Internet might be a particularly effective device for spreading fake news and, more broadly, misinformation because of the vast quantities of information shared and the format in which it is shared.

The sheer scale of information shared on the Internet means that by volume alone, misinformation is more likely to reach Internet-users than Internet-non-users. Misinformation can be propagated easily through social networks (Gabbert, Memon, Allan, & Wright, 2004; Hoffman, Granhag, Kwong See, & Loftus, 2001; Meade & Roediger, 2002), and socially sharing information itself can lead to the introduction of errors as information is passed along (Bartlett, 1932; Basden, Reysen, & Basden, 2002; French, Garry, & Mori, 2008; Gabbert, Memon, & Wright, 2006; Maswood & Rajaram, 2019; Meade & Roediger, 2002; Roediger, Meade, & Bergman, 2001). Consistent with these findings, Vosoughi, Roy, and Aral (2018) found that false information spreads faster, farther, and deeper through social media networks than true information, particularly if the false information is political. Fake profiles or “bots” can be used to boost the signal of some messages over others and are often blamed for the spread of misinformation. Contrary to this argument, however, Vosoughi et al. showed that bots were equally likely to spread true and false information, indicating that humans may be to blame for the selective spread of fake news. Indeed, the social nature of the Internet and social media websites seem to invite the propagation of false information.

Handling the volume and breadth of information available on the Internet can be cognitively taxing, making it difficult if not impossible to correct for the misinformation to which one is exposed. Interestingly, De keersmaecker and Roets (2017) found that cognitive ability—in this case, as indicated by the vocabulary subtest of the WAIS—predicted the extent to which participants changed their attitudes after reading corrections to false information. Experiencing too much information may distract participants or otherwise tax their cognitive resources, making it difficult to tap into the resources needed to shift one's attitude or beliefs about a given issue. Indeed, corrections do not seem to change participants' belief in misinformation unless they can fully attend to those corrections (Ecker, Lewandowsky, Swire, & Chang, 2011). In models that predict the relative value of information based on quality, when attentional constraints and cognitive load are taken into account, high-quality information is only slightly preferred over low-quality information (Qiu, Oliveira, Shirazi, Flammini, & Menczer, 2017). It is worth noting that using the Internet repeatedly can affect a person's cognitive style (Storm et al., 2017). As such, using the Internet could make users more susceptible to misinformation by making them both less willing and less able to fact-check the information to which they are exposed.

Another difference between the fake news of today and the fake news of the past is the format in which it is propagated. The online transmission of information is inherently social, with users commenting on stories and sharing them on social media websites. This social aspect may cause information shared online to be particularly memorable (Mickes et al., 2013; Reysen & Adair, 2008). Mickes et al. (2013), for example, found that participants remembered social media posts more accurately than comparable sentences from books, an effect they attributed in part to the social, gossipy nature of social media posts. Memorable information can also be mistaken for true information. The illusory truth effect is observed when participants rate familiar information as more believable than unfamiliar information (Hasher, Goldstein, & Toppino, 1977; for a meta-analytic review, see Dechêne, Stahl, Hansen, & Wänke, 2010). As observed with the sleeper effect, even false information presented with a cue indicating that the information is false can become more believable over time (Hovland, Lumsdaine, & Sheffield, 1949; cf. Gillig & Greenwald, 1974; for meta-analytic review, see Kumkale & Albarracín, 2004).

Features beyond what is written can also cause information to appear more believable. Websites can include photos, videos, and audio more cheaply and easily than print formats. Some studies have shown that when participants encounter information in tandem with a photograph, they rate that information as feeling more subjectively true than they would have otherwise, even when the photograph does not provide evidence in support of the relevant information (Newman, Garry, Bernstein, Kantner, & Lindsay, 2012; Newman et al., 2015). Thus, including multimedia in posts may make readers more prone to believe what they are reading, even if the photos, videos, or audio do not confirm the claims of the post.

Overcoming and Reducing the Effects of Fake News and Misinformation

Given people's general inability to identify the sources of their subjective experience (Koriat, 2000), it seems unlikely that they would ever be able to fully protect themselves from being influenced by misinformation. Starting from the metacognitive perspective that information encountered online should be assumed suspect, however, may be one way in which users can partly protect themselves. Indeed, at least at some level, Internet users seem to be developing an awareness of how easily misinformation spreads online, and they seem to be adjusting their beliefs in the information they read accordingly. Fenn, Griffin, Uitvlugt, and Ravizza (2014), for example, investigated the propagation of false information through social media using a website designed to resemble Twitter. Participants first viewed a series of images detailing a mock-crime. Then, participants read snippets of information on a feed that was designed to either look like Twitter or a control feed. Participants were more skeptical of misinformation presented on the Twitter feed than on the control feed, suggesting that people are at least somewhat aware of the fact that social media can be used to spread misinformation, leading them to adjust their expectations accordingly. In fact, there is evidence that social media users can and do consider the authors' relationship to the material when encountering possibly false information online (Griffin, Fleck, Uitvlugt, Ravizza, & Fenn, 2017).

When it comes to the Internet and social media, some users may be more susceptible to fake news than others. Several studies have explored the abilities and traits associated with participants' ratings of the profundity of 'pseudo-profound bullshit' (PPBS); statements randomly generated from buzzwords in a syntactically plausible order (see Pennycook, Cheyne, Barr, Koehler, & Fugelsang, 2015). Participants who endorse PPBS are more likely to believe a fake news story, as are participants who overestimate their knowledge about the news topic (Pennycook & Rand, 2019). These participants are also more likely to endorse "epistemologically dubious" beliefs such as conspiracy theories (Pennycook et al., 2015), alternative medicine (Čavojová, Secară, Jurkovič, & Šrol, 2019), and the merits of neoliberalism (Sterling, Jost, & Pennycook, 2016). Individuals who fall for fake news also generally score lower on the Cognitive Reflection Test (Frederick, 2005), a measure of the extent to which participants engage in the type of reflection that allows them to override fast, intuitive, but ultimately incorrect answers while solving problems (Pennycook & Rand, 2019).

Users who are most vulnerable to fake news, therefore, may not benefit from being confronted with empirical evidence to correct the misinformation they encounter. Some researchers have also suggested disrupting news "echo chambers" or "filter bubbles," which are thought to insulate users against information inconsistent with their worldview (e.g., Pariser, 2011; Schmidt et al., 2017). There seems to be limited evidence, however, that users systematically avoid exposure to particular news content (for review, see Garrett, 2017). Large studies examining data from tens of thousands of online users have shown that news sites seem to attract a wide ideological range of users regardless of their perceived bias (Flaxman, Goel, & Rao, 2016), and that online interactions may actually expose users to more diversity of opinion than face-to-face interactions (Gentzkow & Shapiro, 2011).

Evidence-based approaches should be taken to combat the problem of fake news. Lewandowsky, Ecker, and Cook (2017) propose changes to online platforms and infrastructures that incorporate principles of psychology to protect against misinformation. Such technologies, they propose, might include algorithmic fact-checkers, warnings for individuals about to share suspicious information, and active management of comments in online forums. Rapp and Salovich (2018) echo this proposal, calling for the implementation of online tools to support the interrogation of potentially false claims. They also propose improvements to media literacy education to encourage accurate source monitoring and improve the detection of inconsistencies. These arguments suggest that if digital technology can exacerbate the spread of misinformation, digital technology should also be able to stem the tide.

Navigation and Spatial Memory

The costs of becoming overly reliant on digital technology are perhaps most obvious in people’s transition from the use of paper maps and their own personal navigational systems to the use of satellite navigation systems like the Global Positioning System (GPS) in the United States and BeiDou in China (Field, O’Brien, & Beale, 2011). The widespread use of such systems has led to growing concerns that they are disrupting people’s ability to navigate independently (McKinlay, 2016). Spatial navigation services are designed to help users with wayfinding, not developing knowledge structures about the spatial layout of a route. While GPS devices may cause users to reach their destination with fewer errors or detours than with other strategies, and even avoid traffic while doing so, users learn less about the routes traveled, as assessed by direction estimates and drawing maps (Münzer, Zimmer, & Baus, 2012). When using a mobile device to navigate, forming a mental map or other representation of the area can become unnecessary, which may explain why participants who use navigation devices are outperformed by participants assigned to use a paper map (Münzer, Zimmer, Schwalm, Baus, & Aslan, 2006). Likewise, GPS-related impairments could grow over time because participants repeatedly rely on the GPS rather their memory to navigate (Kelly, Carpenter, & Sjolund, 2015).

Using GPS over other methods of navigation might also cause users to focus their attention differently. In one study, participants were asked to navigate a virtual town using a GPS-like mini-map while their eye movements were being tracked. Participants who spent more time looking at the GPS-like display took longer to retrace their path without GPS (Hejtmánek, Oravcová, Motýl, Horáček, & Fajnerová, 2018). Using maps on mobile phones also appears to result in more regionalized or disjointed mental representations than using paper maps and more inaccurate estimates of distance traveled (Willis, Hölscher, Wilbertz, & Li, 2009). Focusing on a small subsection of a map might cause participants to fail to connect navigated-to areas in space, relative to paper maps which cover more area. GPS users also do not need to plan out their trip start-to-finish but can instead receive directions along the way (Field et al., 2011).

To address the issue that GPS seems to impair spatial learning, some researchers have proposed adding more contextual information to GPS displays (Kim & Dey, 2009; Li, Zhu, Zhang, Wu, & Zhang, 2014). Li and colleagues (2014) had some participants use a standard GPS display, and others use a novel dual-scale GPS display that included contextual information along with a zoomed-in display of the user's location. Participants who used the dual-scale GPS developed more spatial understanding while navigating than participants in the single-scale condition and also navigated better under simulated driving conditions. However, driving while using a GPS with a complicated visual display in traffic scenarios could cause distraction and lead to driving errors (Jensen, Skov, & Thiruravichandran, 2010). Moreover, with the seemingly inevitable introduction and proliferation of autonomous vehicles, knowing how to get around town may not be as important of a memory skill as it once was.

Education and Online Learning

Interactions between digital technology and learning have been studied extensively in the context of education, with large areas of literature focusing on online classrooms, media multitasking, and educational games. Digital technologies have the potential to provide promising new vehicles for learning, including online classrooms that can reach students who might otherwise not have access (Fini, 2009). Some have raised concerns, however, that not enough is known about the effects of digital technology on learning to implement its effective use in the classroom (Willingham, 2019).

The Internet has made it possible to offer large online courses for free to the general public. Massive open online courses, or MOOCs, have the potential to reach a wider and less affluent audience than a typical college classroom. MOOCs have notoriously low completion rates though, with one study reporting only 10% of students completing the course (Gütl, Rizzardini, Chang, & Morales, 2014). More generally, universities have increasingly implemented “flipped classrooms” in which content learning is done primarily outside the classroom (often through video lectures) and activities and projects are completed inside the classroom (Bergmann & Sams, 2012). To date, most of the research on flipped classrooms has involved case studies of individual classes, so it is difficult to know whether flipped classrooms are more or less effective than traditional lectures (Akçayır & Akçayır, 2018; Betihavas, Bridgman, Kornhaber, & Cross, 2016; Bishop & Verleger, 2013; Willingham, 2019). Future work should focus on elucidating the methods that make flipped classrooms effective for promoting learning and memory as well as developing teacher training protocols for their successful implementation.

Promoting student engagement during online lectures can be particularly difficult. Students report high levels of mind-wandering during online lectures, with more mind-wandering and worse retention for material as the lecture goes on (Risko, Anderson, Sarwal, Engelhardt, & Kingstone, 2012). High rates of mind-wandering can occur, however, even when video lectures are kept short (Szpunar, Khan, & Schacter, 2013). Some methods, such as the implementation of activities like interpolated tests, have been shown to help students maintain focus during video lectures (Szpunar, Moulton, & Schacter, 2013). For traditional courses, many instructors hesitate to post recordings of their lectures online because students may be less prone to attend class in person (Copley, 2007). However, video lectures or supplemental videos have been shown to improve course grades and reduce dropout (Brecht, 2012).

Finally, video games also provide an opportunity for educators to develop new and engaging learning environments. Although research on the effectiveness of individual games is mixed, two meta-analyses concluded that games can be effective educational tools (Clark, Tanner-Smith, & Killingsworth, 2016; Wouters, van Nimwegen, van Oostendorp, & van der Spek, 2013). Games appear to be most effective when they are paired with traditional instruction and when they employ designs that are more schematic and less cartoon-like (Wouters et al., 2013). Even games that are not more effective than traditional instruction may still promote learning if students are more willing to engage with them on a consistent basis. One recent study, for example, found that while a second-language learning game was no more effective than plaintext slides as a learning aid, participants found the game more enjoyable and less difficult to learn from (James & Mayer, 2019). As such, Clark and colleagues (2016) suggest that researchers shift their emphasis from investigating whether students can learn from games to studying the design choices that make games into more effective educational experiences.

Digital Devices in the Classroom

As any teacher can attest, digital devices can be exceedingly distracting. The use of digital devices like laptop computers in the classroom has been controversial. Laptop multitasking can distract students from lecture material and harm their academic performance relative to students who take notes on paper (e.g., Aguilar-Roca, Williams, & O'Dowd, 2012; Fried, 2008; Hembrooke & Gay, 2003; Risko, Buchanan, Medimorec, & Kingstone, 2013). Multitasking with laptops can also distract students in close proximity to laptop users (Sana, Weston, & Cepeda, 2013). For this reason, many instructions have banned laptops in their classrooms (Young, 2006), often citing Mueller and Oppenheimer's (2014) finding that participants assigned to take class notes on a laptop were outperformed by participants assigned to take notes longhand, even though the laptop was not connected to the Internet and could not be used to multitask (but see, Morehead, Dunlosky, & Rawson, 2019).

There are several reasons to hesitate before banning the use of laptops in classrooms. Students report, for example, that they can take notes more actively on laptops if the instructor provides materials ahead of time, and that having a laptop allows them to engage more effectively with academic resources in class (Kay & Lauricella, 2014). Likewise, using laptops for in-class activities can enhance student enjoyment, engagement, and even performance (Dykstra, Tracy, & Wergin, 2013; Stephens, 2005). It is also worth noting that laptops can be critical tools for students with disabilities, including those who may have physical difficulty writing longhand. Though accommodations or exceptions can be made, students with disabilities may feel singled-out to the rest of the class, and best teaching practices should vary enough to suit many kinds of students (Rose & Meyer, 2002). More generally, it stands to reason that with training or advances in technology, learners might be able to take advantage of note-taking strategies while using their laptops that they might not be able to take advantage of while taking notes longhand, and in ways that would enhance learning and memory.

It can be difficult for instructors to tell when students are off task when using laptops, but such is less the case when students use mobile phones. Multitasking with mobile phones can disrupt both classroom learning and studying (for review, see Chen & Yan, 2016). In one study, participants who were assigned to not use their phones during a video lecture took more detailed notes and performed better on a multiple-choice exam than participants who were allowed to use their phones (Kuznekoff & Titsworth, 2013). Findings such as these have also led many instructors to ban the use of mobile phones in class. Even if students do not acknowledge the notifications they receive, they can still be distracted by the mere thought of those notifications piling up (Stothart, Mitchum, & Yehnert, 2015). Indeed, this sort of smartphone-induced "brain-drain" has been observed experimentally, effectively reducing cognitive capacity and particularly among students who are most dependent on their smartphones (Ward, Duke, Gneezy, & Bos, 2017). Moreover, one study found that workers who had to resist the temptation to watch a funny video online while their coworkers laughed at the video were less productive than their co-workers who actually watched the video (Bucciol, Houser, & Piovesan, 2013). Some instructors have begun to implement "tech breaks" to combat these effects (Rosen, 2012). Tech breaks allow students to compartmentalize the time they check the Internet without requiring the large amount of willpower that seems to be required to ignore one's phone.

According to the results of a recent survey, over 92% of students reported being at least somewhat distracted by the use of digital devices in school (McCoy, 2016). Students are not always aware of the costs of media multitasking. Students who believe themselves to be effective multitaskers still tend to suffer deficits to learning and attention while engaging in media multitasking (Bannister & Remenyi, 2009; Ophir, Nass, & Wagner, 2009). Some have raised concerns that engaging in media multitasking regularly could even change the structure and functioning of people's brains (Loh & Kanai, 2016). People who grow up using the Internet (i.e., digital natives) have been argued to show deficits in working memory and multitasking compared to individuals who learned to use the Internet later in life (Nicholas, Rowlands, Clark, & Williams, 2011). Indeed, chronic media multitasking in general has been associated with impairments and disruptive changes in the functioning of working memory and long-term memory (Uncapher, Thieu, & Wagner, 2016). Reading information online also seems to encourage browsing and scanning behaviors, which can lead to shallower levels of encoding (Liu, 2005). Ultimately, instructors may need to adapt to a world full of digital distractions to figure out the best ways to facilitate student learning.

Concluding Comments

The present chapter discussed just a few of the ways in which memory is changing in the digital age. With additional research, we expect the scope and types of questions researchers ask to continue to develop, moving beyond overly-simplistic questions such as whether the Internet is good or bad for memory, to focusing more on the specific ways in which internal and external processes work together to form an integrated or extended memory system, and the implications of such a system for the broad range of experiences and behaviors that rely on memory. Moreover, it is important to remember that the Internet and the digital technologies upon which people rely are ultimately just tools, and it will be up to researchers to investigate the ways in which such tools can be designed and used in a way that effectively expands, rather than constrains, the abilities and functions of human memory.

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