DIGITAL COGNITION AND DEMOCRACY INITIATIVE

MEMORY

HOW DIGITAL TECHNOLOGIES INFLUENCE COGNITIVE INFORMATION STORAGE

THE DIGITAL COGNITION AND DEMOCRACY INITIATIVE

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About the Digital Cognition and Democracy Initiative

Digital technology has become a fixture in everyday life. The landscape has dramatically shifted in recent years, increasingly catering to individualized neurochemical reinforcement. Information mediation is now fast-paced, high-volume, low-friction, and extra-sensorial, garnering increasing concern about the impacts digital ubiquity is having on individuals, society, and democracy more broadly.

Documented risks to the individual include impacts on mental health, particularly among young people; the proliferation of false information; and an overreliance on outsourced information. Impacts at the individual level cumulatively manifest in societal level concerns, such as affective polarization–defined as the tendency to distrust people from the opposite end of the political spectrum–and risks to public health as a consequence of disinformation campaigns. While digital technologies are not the sole cause of these concerns, the facilitatory and amplifying role they play is significant. A sound ability to update one's beliefs and to engage in constructive discourse are key elements of civic engagement and therefore healthy democracy. These skills rely on a concert of cognitive processes that are increasingly influenced by rapid and extensive technological proliferation. The urgency of exploring this web of challenges has grown as the risks to individual and societal well-being have become more evident and the threats to democratic society more immediate.

This report is part of a series examining the effects digital technologies have on the following cognitive processes: "Memory," "Attention," and "Reasoning." The broader report series includes three additional papers looking at some of the society-level cognitive and democratic impacts of technology, titled: "Modulating Trust," "Shortcutting Critical Thinking," and "Exploiting Emotions." We have also compiled a capstone report, "Rewired: How Digital Technologies Shape Cognition," and a review of the literature on technology and cognition detailing many of the sources used for our analyses.

A note on methods

This report is informed by guidance from IST coalition members, but it is primarily derived from past and current cognitive science research findings relevant to the human relationship with digital technologies. It does not capture all the available cognitive science research on technology. Rather, it is a selection of literature that best captures how digital technologies impact cognitive processes in ways that are in turn important for a healthy democracy.

The Relationship Between Digital Technologies and Cognitive Processes

Why memory & digital technologies?

Memory is foundational to cognition. It enables individuals to operate with certain assumptions about truth based on prior validated beliefs. Memory informs individual decision making, reasoning, and problem solving. There are also significant societal implications rooted in memory function. Individual memories, collectively and cumulatively, inform the development of "national memory," which in turn influences "the construction of a democratic culture and collective identity."[1] This report provides a working definition of memory and focuses especially on long-term memory. (For analysis of short-term and working-memory please refer to our report in this series titled "Attention.")

The class of long-term memory identified as critical to our investigation is outsourced memory. Two key examples of digital technologies that "outsource" memory are: the Google effect and the GPS effect. The Google effect seems to have two important impacts: 1) The disincentivization to commit information to memory—one can always "Google it" later—leading to a diminished ability to recall information accurately;[2] and 2) The misattribution of general "Internet knowledge" to oneself as one's own knowledge.[3] The GPS effect shows that those who use a navigational application tend to have a diminished ability to retrace their route unaided by GPS when compared to those who had used a paper map.[4] That is, navigational memory seems to be more poorly constructed in the mind when using GPS.

Research thus indicates that many of us now think we know more than we do because we rely on and trust our devices (Google effect). In addition, we do not incorporate a robust cognitive understanding of where we are and where we go because we trust the presence and accuracy of

[1] Elizabeth Jelin, "The Politics of Memory: The Human Rights Movement and the Construction Of Democracy in Argentina," *Latin American Perspectives* 21, no. 2 (1994): 38-58, https://www.jstor.org/stable/2633874.

[2] Adam L. Alter et al., "Missing the Trees for the Forest: a Construal Level Account of the Illusion of Explanatory Depth," *Journal of Personality and Social Psychology* 99, no. 3 (2010): 436-461.

[3] Adrian F. Ward, "People Mistake the Internet's Knowledge for Their Own," *Proceedings of the National Academy of Sciences* 118, no. 43 (2021): 5, https://doi.org/10.1073/pnas.2105061118.

[4] Masashi Sugimoto et al., "Online Mobile Map Effect: How Smartphone Map Use Impairs Spatial Memory," *Spatial Cognition & Computation* 22, no. 1-2 (2022): 161-183, https://doi.org/10.1080/13875868.2021.1969401.

our GPS devices (GPS effect). This trust in and reliance on devices, tools, and platforms—which in fact have significant flaws and biases, and are often intentionally manipulative—may pose issues for behavior in other settings, and thus for societal and democratic functioning more broadly. Additionally, if people believe they store more information internally than they do, there is a risk of co-dependence on external information stores to supplement or supplant individual knowledge. Constantly seeking information externally also risks increasing the likelihood of exposure to biased, manipulated, or inaccurate information, which may also change how information is processed and synthesized across diverse contexts. Combined, these processes may adversely affect the information ecosystem, public discourse, and civic engagement.

Memory defined

What is meant by the term "memory"? And what aspects of this cognitive process are most pertinent to the DCDI project? There are two important dimensions to memory: functions and types. In terms of functions, memory is the cognitive process that "allows people to encode, store, and retrieve information."[5] This cognitive process is critical for retaining knowledge and personal histories, and therefore is strongly related to one's ability to learn. Together the three processes of encoding, storing, and retrieving enable the brain to form memories for later use.

In terms of memory types, according to neuroscientists Eduardo Camina and Francisco Güell, there are three types of memory: sensory, short-term, and long-term. Some argue that these three types also reflect the sequential nature of information storage.[6] Sensory memories occur first, often in liminality, and hold information for the duration of one second.[7] Next, when information is held for over one second but still for a brief period of time, short-term memory is activated, typically to support cognitive tasks.[8] Short-term memory is commonly understood using Alan Baddeley's model for working memory: "the system or systems that are assumed to be necessary in order to keep things in mind while performing complex tasks such as reasoning, comprehension and learning."[9] It is important to note that short-term memory is but one component of this family of cognitive abilities which support everyday tasks (see Figure 1). The working memory system rests on and interacts with other cognitive processes, particularly attention and reasoning. Lastly, long-term memory (which, in Figure 1: Baddeley's model, is the

[5] E. Bruce Goldstein, *Cognitive Psychology: Connecting Mind, Research and Everyday Experience*, 4th ed. (Boston: Cengage Learning, 2014).

[6] Eduardo Camina and Francisco Güell, "The Neuroanatomical, Neurophysiological and Psychological Basis of Memory: Current Models and Their Origins," *Frontiers in Pharmacology* 8 (2017): 438.

[7] Ibid.

[8] Richard C. Atkinson and Richard M. Shiffrin, "Human Memory: A Proposed System and Its Control Processes," In *Psychology of Learning and Motivation*, vol. 2 (Cambridge: Academic Press, 1968): 89-195.

[9] Alan Baddeley, "Working Memory," *Current Biology* 20, no. 4 (2010): R136-R140.

blue box) refers to information that has transitioned from a short-term store to an indefinite long-term store.

With this definitional structure in mind, this report explores how digital technologies impact these different functions and types of memory, with a focus on the acts of encoding and retrieving memories relative to long term memory. Our analysis centers on long-term memory, as the use of short-term memory has strong ties to the attention function and is discussed more extensively in our analytical paper, "Attention."

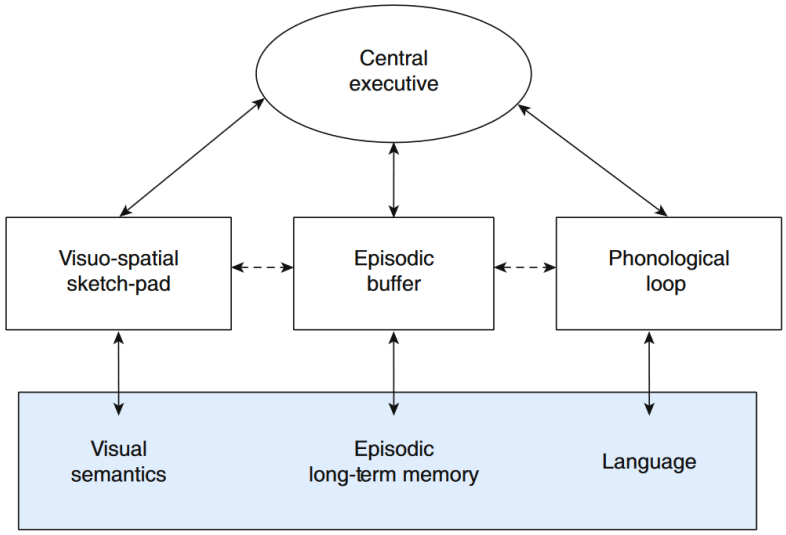

Figure 1: Baddeley's Working Memory Model. A later development of the multicomponent model. Includes links to long-term memory and a fourth component, the episodic buffer that is accessible to conscious awareness. This report will focus on long-term memory as the use of short-term memory has strong ties to attention.[10]

What Effects Do Digital Technologies Have on Memory?

This paper is framed around one key class of digital technology: digital technologies that "outsource" memory. Memory "outsourcing" digital technologies include infrastructural technologies that enable or support the execution of tasks, like searching, acquiring new information, and navigational support. Examples include search engines like Google, navigational applications such as Waze, and financial trading technologies such as Robinhood.

[10] Figure 1 Diagram: Short term memory refers to the visuo spatial sketchpad and phonological loop (i.e., visual and auditory short term memories). Baddeley, "Working Memory," R138.

Memory "outsourcing" digital technologies become integrated into our ways of living and functional task execution.

Outsourced memory

Concerns over the role that technological innovation might have on our cognitive abilities is not novel. As far back as 350 BCE, Socrates expressed concerns that advancements in writing might be detrimental to the ability to retain knowledge:

"In fact, [writing] will introduce forgetfulness into the soul of those who learn it: they will not practice using their memory because they will put their trust in writing, which is external and depends on signs that belong to others, instead of trying to remember from the inside, completely on their own. . ."[11]

- *Plato, "Phaedrus."*

Historical concerns about the detrimental effects that widespread adoption of writing capabilities might have on cognitive function are mirrored in the contemporary concern about the habitual reliance on search engines for information retrieval.[12] Although the practice of outsourcing information from more knowledgeable sources, otherwise known as "transactive memory" systems, is not new, technological advancements have easily outcompeted the more traditional forms of asking a peer or a colleague or consulting a physical text.[13] Health and technology researchers Joseph Firth and his colleagues argue that use of the Internet for cognitive offloading differs from the traditional forms of information retrieval in two ways that are critical to the DCDI project:

[11] Plato, "Phaedrus," in *Plato: Complete Works*, eds. John M. Cooper and Douglas S. Hutchinson (Indianapolis: Hackett Publishing, 1997): 551-552.

[12] Evan F. Risko and Timothy L. Dunn, "Storing Information In-the-World: Metacognition and Cognitive Offloading in a Short-Term Memory Task," *Consciousness and Cognition* 36 (2015): 61-74, https://doi.org/10.1016/j.concog.2015.05.014.

[13] Daniel M. Wegner et al., "Transactive Memory in Close Relationships," *Journal of Personality and Social Psychology* 61, no. 6 (1991): 923, https://doi.org/10.1037//0022-3514.61.6.923.

"First, the Internet does not place any responsibility on the user to retain unique information for others to draw upon (as would typically be required in human societies). Second, unlike other transactive memory stores, the Internet acts as a single entity that is responsible for holding and retrieving virtually all factual information, and thus does not require individuals to remember what exact information is externally stored, or even where it is located."[14]

- *Joseph Firth et al., "The "Online Brain": How the Internet May Be Changing our Cognition."*

Search engines as a collective resource function uniquely as a transactive memory system, and have thus been characterized as "supernormal," and as a "superstimulus."[15] Although this digital technology allows users to navigate seemingly limitless information with unobstructed ease, research indicates this may occur at a cost to the core memory functions—encoding, storing, and retrieving. The reliance on search engines to provide people with information as and when it is needed has had two effects that are further detailed in the following sections. 1) The first effect is the disincentivization to commit information to memory—one can always "Google it" later—leading to diminished ability to recall information accurately. 2) The second effect is the misattribution of general "Internet knowledge" to oneself as one's own knowledge.

Disincentivizing remembering

Search engines and long-term memory encoding and storing

Digital technology use seems to be causing a decreasing commitment of information to long-term memory.[16] In what philosopher and cognitive scientist Robert Clowes refers to as the cognitive integration of "e-memory," the ubiquitous nature of hand-held computing technologies has enabled the documentation and storage of many aspects of our personal memories, from pictures to social correspondence.[17] This ubiquity has also influenced our relationship with seeking and storing new information. Psychologist Betsy Sparrow and her coauthors conducted

[14] Joseph Firth et al., "The "Online Brain": How the Internet May Be Changing our Cognition," *World Psychiatry* 18, no. 2 (2019): 122, https://doi.org/10.1002/wps.20617.

[15] Adrian F. Ward, "Supernormal: How the Internet is Changing Our Memories and Our Minds," *Psychological Inquiry* 24, no. 4 (2013): 341-348, https://doi.org/10.1080/1047840X.2013.850148; Joseph Firth et al., "The "Online Brain": How The Internet May Be Changing Our Cognition," *World Psychiatry* 18, no. 2 (2019): 119-129, https://doi.org/10.1002/wps.20617.

[16] Curtis A. Olson, "Focused Search and Retrieval: The Impact of Technology on Our Brains," *Journal of Continuing Education in the Health Professions* 32, no. 1 (2012): 1-3, https://doi.org/10.1002/chp.21117; Daniel M. Wegner and Adrian F. Ward, "How Google Is Changing Your Brain," *Scientific American* 309, no. 6 (2013): 58-61, https://www.jstor.org/stable/26018230.

[17] Robert W. Clowes, "The Cognitive Integration of E-memory," *Review of Philosophy and Psychology* 4, no. 1 (2013): 107-133, https://doi.org/10.1007/s13164-013-0130-y.

an experiment and found that those who looked up information on the Internet were less likely to recall the information, confident in their ability to easily retrieve the information from the Internet again when needed.[18] Reinforcing this finding, psychiatric researchers Guangheng Dong and Marc Potenza analyzed the differences in neurological activity between people who used the Internet and people who used an encyclopedia to acquire information.[19] Compared to encyclopedia users, Internet users demonstrated lower brain activation in the middle temporal gyrus (MTG), the part of the brain correlated with long-term memory encoding. They also found less brain activation in the ventral stream, the part of the brain recruited for memory recall. These findings, as well as many other similar findings, point strongly towards a neurological maladaptive propensity to consume information without meaningfully committing it to memory for later use. As psychologists Daniel Wegner and DCDI coalition member Adrian Ward put it:

"In other ways, the Internet is not like any person we have ever met before—it is always present, is always on and knows virtually everything."[20]

- *Daniel M. Wegner and Adrian F. Ward, "How Google Is Changing Your Brain."*

The transformative cognitive impacts of integrating search engines into our knowledge acquisition practices have shifted our proclivity to commit information to our own memory. Instead, we tend to adopt external memory systems as a part of our larger transactive memory system. The importance of this fact cannot be overstated as we consider the effects on individuals, society, and democratic institutions.

The "Google Effect"

Metacognitive overconfidence and its risk to long-term memory recall

The seamless nature of acquiring new information has encouraged habitual dependence on external digital sources, resulting in a misattribution of Internet-based information as one's own knowledge. While the concept of the "illusion of explanatory depth" has existed outside the context of digital technologies, it is particularly significant when applied to the habitual and pervasive nature of Google.[21] In a series of experiments that compared "cognitive self-esteem"

[18] Betsy Sparrow et al., "Google Effects on Memory: Cognitive Consequences of Having Information at Our Fingertips," *Science* 333, no. 6043 (2011): 776-778, https://doi.org/10.1126/science.1207745.

[19] Guangheng Dong and Marc N. Potenza, "Behavioural and Brain Responses Related to Internet Search and Memory," *European Journal of Neuroscience* 42, no. 8 (2015): 2546-2554, https://doi.org/10.1111/ejn.13039.

[20] Daniel M. Wegner and Adrian F. Ward, "How Google Is Changing Your Brain," *Scientific American* 309, no. 6 (2013): 61, https://www.jstor.org/stable/26018230.

[21] Adam L. Alter et al., "Missing the Trees for the Forest: A Construal Level Account of the Illusion of Explanatory Depth," *Journal of Personality and Social Psychology* 99, no. 3 (2010): 436-461.

between a group who used Google to complete a knowledge test and a group who did not have access to an external support, Adrian Ward found "consistent evidence that thinking with Google blurs the boundaries between internal and external knowledge, causing elevated confidence in personal memory and erroneously optimistic predictions of how much one will know when external knowledge is no longer available."[22] Comparing the use of Google to that of Wikipedia, he also found that the Google users showed higher rates of misattribution, mistaking the Internet's knowledge for their own knowledge.[23] People are misattributing confidence in the veracity and quality of external information sources to their own understanding of that information by virtue of the near-seamless access to digital information sources. The "Google effect" phenomenon is corroborated by researchers Hu and their coauthors, whose experiment observed a boost in metacognitive confidence after giving participants the choice to save information on a computer to support the completion of a memory task.[24] The study found that choosing this cognitive offloading led to a boost in confidence in one's own cognitive abilities.

The implications of this research are vast as we consider our susceptibility to disinformation. These studies highlight the risks that easily accessible digital information stores pose to one's metacognitive awareness of their true ability to recall information, and in turn, what they actually understand. The implications for the misattribution of the Internet's knowledge as one's own extends to the ability to make informed decisions independent of access to technology. If people believe they store more information internally than they do, then there is a risk of co-dependence on external information stores to supplement individual knowledge. Furthermore, constantly seeking information externally naturally increases one's risk of exposure to biased or manipulated information, and may change how we process and synthesize that information across various contexts.

The "GPS Effect"

How does our reliance on navigational tools affect our spatial memory

The digital infrastructures that support everyday life extend beyond information retrieval tools, and now include powerful and ubiquitous geographical navigational aids. GPS technologies and other similar contemporary iterations are now readily available on smartphones. How has our relationship with spatial memory changed with the increased adoption of these technologies?

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[22] Adrian F. Ward, "People Mistake the Internet's Knowledge for Their Own," *Proceedings of the National Academy of Sciences* 118, no. 43 (2021): 5.

[23] Ibid.

[24] Xiao Hu et al., "A Role for Metamemory in Cognitive Offloading," *Cognition* 193 (2019): 104012, https://doi.org/10.1016/j.cognition.2019.104012.

In an experiment, Neuroscientist Amir-Homayoun Javadi and his coauthors found that when people were not given the option to use a navigational aid during a task, they exhibited increased activity in the hippocampus, the part of the brain attributed to memory and spatial navigation, and the prefrontal cortex, an area of the brain that is also responsible for spatial planning.[25] Those who did use a navigational aid did not show the same increases.

This was again illustrated by researchers Louisa Dahmani and Veronique Bohbot, who tested 50 car drivers on their spatial memory strategy use, cognitive mapping, and spatial memory when not aided by a navigational device.[26] A subset of the initial 50 subjects then completed another driving task with the aid of GPS. Reinforcing initial findings, the results showed that greater use of GPS correlated with a steeper decline in hippocampal-related spatial memory. Masashi Sugimoto and co-authors echoed this result again, finding that those who used a navigational application were less able to retrace their route unaided compared to those who had used a paper map.[27] This implies that conceptual pathways—at least those modeling literal pathways—are not being constructed in a way that keeps them stored in long term memory. These studies signal an obvious shift, not only in physical neurological make-up, but also in navigational performance and broader learning from engagement with geography over time.

Conclusion

The phenomenon of media impacting memory is not new, but contemporary media and information technologies are unprecedented in power, scale, and speed of proliferation. Reliance on transactive memory systems is at least as old as written language, but recent research has rightly focused on how digital technologies facilitate habitual information retrieval in a way that produces overconfidence in one's own knowledge. The reliance on infrastructural technologies like Google and Wikipedia disincentivize people to commit information to long-term memory.

This has effects on the ability to reason and form judgements. Judgements are formed based on prior knowledge and past experiences. Thus, we need to question how a diminished commitment of information to long-term memory might influence on-the-fly judgment and how this might consequently influence choices and behaviors. This report also highlights the concerning meta-cognitive behavior of taking ownership of the Internet's information as one's own. This behavior might pose significant risks to our ability to make critical judgments and decisions without having to rely on one's digital device to supplement the cognitive process of

[25] Amir-Homayoun Javadi et al., "Hippocampal and Prefrontal Processing of Network Topology to Simulate the Future," *Nature Communications* 8, no. 1 (2017): 1-11, https://doi.org/10.1038/ncomms14652.

[26] Louisa Dahmani and Véronique D. Bohbot, "Habitual use of GPS Negatively Impacts Spatial Memory During Self-guided Navigation," *Scientific Reports* 10, no. 1 (2020): 1-14, https://doi.org/10.1038/s41598-020-62877-0.

[27] Masashi Sugimoto et al., "Online Mobile Map Effect: How Smartphone Map Use Impairs Spatial Memory," *Spatial Cognition & Computation* 22, no. 1-2 (2022): 161-183, https://doi.org/10.1080/13875868.2021.1969401.

judgment formation and decision making. The abundance of misleading and inaccurate information online only exacerbates the problem.

However, relying on infrastructural technologies is not always conclusively maladaptive. Although heavy reliance on navigational tooling might mean changes to one's physical neurological composition, it still is up to debate whether this is necessarily a bad thing. Might the outsourcing of our spatial memory free up our cognitive capacity for other higher-level activities? Might ephemeral digital communications encourage people to commit information to long-term memory? As search engines act as transactive memory systems, do they encourage long-term memory storage, inhibit it, or have a neutral effect?

More research is needed, particularly as it applies to the effect that affective technologies might have on memory. Our long-term memory stores play a crucial role in shaping preconceptions and assumptions about the world around us and informing our behaviors. They thus critically inform judgments and, consequently, decisions. A deeper understanding of these digital effects will contribute insights to create greater resilience against misinformation and disinformation. Protecting the practice of storing information long-term for later use is critical for informed democratic discourse and civic engagement more broadly.

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