Google Effects on Memory: Cognitive Consequences of Having Information at Our Fingertips

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The advent of the Internet, with sophisticated algorithmic search engines, has made accessing information as easy as lifting a finger. No longer do we have to make costly efforts to find the things we want. We can "Google" the old classmate, find articles online, or look up the actor who was on the tip of our tongue. The results of four studies suggest that when faced with difficult questions, people are primed to think about computers and that when people expect to have future access to information, they have lower rates of recall of the information itself and enhanced recall instead for where to access it. The Internet has become a primary form of external or transactive memory, where information is stored collectively outside ourselves.

In a development that would have seemed extraordinary just over a decade ago, many of us have constant access to information. If we need to find out the score of a ballgame, learn how to perform a complicated statistical test, or simply remember the name of the actress in the classic movie we are viewing, we need only turn to our laptops, tablets, or smartphones and we can find the answers immediately. It has become so commonplace to look up the answer to any question the moment it occurs, it can feel like going through withdrawal when we can't find out something immediately. We are seldom offline unless by choice and it is hard to remember how we found information before the Internet became a ubiquitous presence in our lives. The Internet, with its search engines such as Google and databases such as IMDB and the information stored there, has become an external memory source that we can access at any time.

Storing information externally is nothing particularly novel, even before the advent of computers. In any long term relationship, a team work environment, or other ongoing group, people typically develop a group or transactive memory (*1*), a combination of memory stores held directly by individuals and the memory stores they can access because they know someone who knows that information. Like linked computers that can address each other's memories, people in dyads or groups form transactive memory systems (*2*, *3*). The present research explores whether having online access to search engines, databases, and the like, has become a primary transactive memory source in itself. We investigate whether the Internet has become an external memory system that is primed by the need to acquire information. If asked the question whether there are any countries with only one color in their flag, for example, do we think about flags—or immediately think to go online to find out? Our research then tested if, once information has been accessed, our internal encoding is increased for where the information is to be found rather than for the information itself.

In Experiment 1, participants were tested in two within-subject conditions (*4*). Participants answered either easy or hard yes/no trivia questions, in two blocks. Each block was followed by a modified Stroop task (a color naming task with words presented in either blue or red) to test reaction times to matched computer and non-computer terms (including general and brand names for both word groups). People who have been disposed to think about a certain topic typically show slowed reaction times (RTs) for naming the *color* of the word when the word itself is of interest and is more accessible, because the word captures attention and interferes with the fastest possible color naming.

Paired within-subject *t*-tests were conducted on color-naming reaction times to computer and general words after the easy and difficult question blocks. Confirming our hypothesis, computer words were more accessible (color-naming RT $M = 712$ milliseconds (ms), $SD = 413$ ms) than general words ($M = 591$ ms, $SD = 204$ ms) after participants had encountered a series of questions to which they did not know the answers, $t(68) = 3.26$, $P < .003$, two-tailed. It seems that when we are faced with a gap in our knowledge, we are primed to turn to the computer to rectify the situation. Computer terms also interfered somewhat more with color naming ($M = 603$ ms, $SD = 193$ ms) than general terms ($M = 559$ ms, $SD = 182$ ms) after easy questions, $t(68) = 2.98$, $P <$

.005, suggesting that the computer may be primed when the concept of knowledge in general is activated.

Comparison using a repeated measures analysis of variance (ANOVA) of specific search engines (Google/Yahoo) and general consumer good brand names (Target/Nike) revealed an interaction with easy vs. hard question blocks, $F(1,66) = 5.02$, $P < .03$, such that search engine brands after both easy ($M = 638$ ms, $SD = 260$ ms) and hard questions ($M = 818$ ms, $SD = 517$ ms) created more interference than general brands after easy ($M = 584$ ms, $SD = 220$ ms) and hard ($M = 614$ ms, $SD = 226$ ms) (Fig. 1). Simple effects tests showed the interaction was driven by a significant increase in RT for the two search engine terms after the hard question block, $F(1,66) = 4.44$, $P < .04$ (Fig. 1). Although the concept of knowledge in general seems to prime thoughts of computers, even when answers are known; not knowing the answer to general knowledge questions primes the need to search for the answer, and subsequently computer interference is particularly acute.

In Experiment 2, we tested whether people remembered information they expected to have later access to—as they might with information they could look up online (*4*). Participants were tested in a 2×2 between-subject experiment by reading 40 memorable trivia statements of the type that one would look up online (both of the new information variety e.g., "An ostrich's eye is bigger than its brain" and information that may be remembered generally, but not in specific details, e.g., "The space shuttle Columbia disintegrated during re-entry over Texas in Feb. 2003."). They then typed them into the computer to assure attention (and also to provide a more generous test of memory). Half the participants believed the computer would save what was typed; half believed the item would be erased. In addition, half of the participants in each of the saved and erased conditions were asked explicitly to try to remember the information. After the reading and typing task, participants wrote down as many of the statements as they could remember.

A between-subjects 2 (saved/erased) $\times$ 2 (explicit memory instructions vs. none) ANOVA revealed a significant main effect for only the saved/erased manipulation, as those who believed that the computer erased what they typed had the best recall, omnibus $F(3, 56) = 2.80$, $P < .05$, (Erase $M = .31$, $SD = .04$ and Erase Remember $M = .29$, $SD = .07$, paired comparisons of erased conditions ns) compared to those who believed the computer would be their memory source (Save $M = .22$, $SD = .07$ and Save Remember $M = .19$, $SD = .09$, paired comparisons of saved conditions ns). This finding corresponds to previous work on directed forgetting, showing that when people don't believe they will need information for a later exam, they do not recall it at the same rate as when they do believe they will need it (*5*). Participants apparently did not make the effort to remember when they thought they could later look up the trivia statements they had read. Since search engines are continually available to us, we may often be in a state of not feeling we need to encode the information internally. When we need it, we will look it up.

The main effect of the instruction to explicitly remember or not was not significant, which is similar to findings in the learning literature on intentional versus incidental studying of material, which generally finds there is no difference of explicit instruction (*6,7*). Participants were more impacted by the cue that information would or would not be available to them later, regardless of whether they thought they would be tested on it.

In Experiment 3, we tested memory for where to find information that one might look up online. Participants again read and typed in items of memorable trivia, this time in 3 within-subject conditions (*4*). For one-third of the questions, participants were shown "Your entry has been saved." For a second third, participants were shown "Your entry has been saved into the (one of 5) folder ("FACTS" "DATA," "INFO," "NAMES," "ITEMS," "POINTS"—generic interchangeable folder names to which the statements had previously been randomly assigned) and for the final third, participants were told "Your entry has been erased." Participants were given the expectation that they would have access to what they saved through a pretend practice trial where they had access to the file folders during a "recall" task. Thus, generically saved, saved in a specific folder, and erased trials were created for all participants.

Participants were then given a recognition task. They saw all 30 statements, half of which had been altered slightly (names or dates altered). Participants had to judge yes or no whether the statement they were now shown was exactly what they had read, whether the statement had been saved or erased, and finally, if the statement had been saved to a folder, which folder it had been saved into (they were given the folder names, and also had "no specific folder" and "erased" as answer options to this last question).

Overall, in answer to the question "Was this statement exactly what you read?" participants recognized the accuracy of a large proportion of statements. But for those statements they believed had been erased, participants had the best memory (Erase $M = .93$, $SD = .09$, pairwise comparisons to both saved conditions $P < .05$) compared to the statements participants believed they would continue to have access to (Saved generically $M = .88$, $SD = .12$ and saved specifically to a folder $M = .85$, $SD = .12$ pairwise ns), repeated measures omnibus $F (1, 27) = 4.01$, $P < .03$.

However, the opposite pattern was found for the question, "Was this statement saved or erased?" Participants accurately remembered what they had saved (saved generically M = .61, $SD = .21$ and saved into a folder $M = .66$, $SD = .20$ pairwise

ns) more than they accurately remembered what they had erased ($M = .51$, $SD = .19$ pairwise comparisons with both saved conditions $P < .04$), repeated measures ANOVA omnibus $F(1, 27) = 5.34$, $P < .03$. Thus it appears that believing that one won't have access to the information in the future enhances memory for the information itself, whereas believing the information was saved externally enhances memory for the fact that the information could be accessed, at least in general.

In this recognition task, when asked "If the information was saved, what folder was it saved into?" participants did remember more that the information was erased ($M = .54$, $SD = .19$, pairwise comparisons with both saved conditions $P < .001$) than specifically whether the information was generically saved or which folder it was saved into (Saved generically $M = .30$, $SD = .20$ and saved into a specific folder $M = .23$, $SD = .14$, pairwise comparisons ns), repeated-measures ANOVA omnibus $F(1,27) = 21.67$, $P < .001$. This result is a reminder of the experience of remembering something you have read online that you would like to see again or share, but no longer remembering where you saw it or what steps you took to find it in the first place. Or even knowing that a file is saved onto your hard drive, but having to use the search feature to find it. The fact that some of the statements were saved in a general folder was important to include to rule out increased memory demands in the two saved conditions, but does not parallel the continuous access to information we experience with current technology, in that there is no nameless depository of leftover information we would check after searching the obvious places. In addition, recognition is not usually the task we are charged with when answering someone's question. We need to recall the information we have gathered.

Experiment 4 was conducted to see if people would recall where to find information more than the information itself. All participants expected trivia statements they read and then typed to be saved to a specific folder with a generic name ("Facts, etc" as in the previous experiment, although in this case there were no practice trials and the names and number of folders was never explicitly called to the participants' attention) (*4*). Participants were then given a recall task, in which they were given 10 minutes to write down as many of the statements as they remembered. Participants finally were given an identifying feature of the statement that they read (and that had been saved), and they had to answer with the folder name in which it was saved. For example, for the statement "An ostrich's eye is bigger than its brain" the question would be "What folder was the statement about the ostrich saved in?" Participants had to type into a dialog box called "Items" to recall this particular folder correctly. Folder names were not mentioned again, past the original typing period, and participants were never explicitly told there were 5 folder names the items were saved in.

Overall, participants recalled the places where the statements were kept ($M = .49$, $SD = .26$) compared to the statements themselves ($M = .23$, $SD = .14$), between-subject $t(31) = 6.70$, $P < .001$ two tailed. These results seem remarkable on the surface, given the memorable nature of the statements and then unmemorable nature of the folder names. Also, these recall results are striking in comparison to the dismal level of recognition of which folder the statement was saved into in Experiment 3. However, several caveats need to be mentioned. Participants did have a cue to memory (a word from the trivia statement) with the folder recall that the statements themselves did not have. We were not able to counterbalance the trivia and the folders trials, such that the folders were as numerous as the statements, which would be necessary to counterbalance the un-cued and cued recall tasks.

However if we look at the pattern of what was remembered, the results do suggest "where" was prioritized in memory, with the advantage going to "where" when "what" was forgotten. You might expect with the advantages of cued recall, that participants would most remember the folder statements were saved in if they were cued both by our question, and by their recalling the statement in the first place. To examine this, an if/then analysis was then conducted giving participants separate scores for whether they 1) recalled both the statement and the folder it was saved into, 2) recalled the statement, but not the folder, 3) didn't recall the statement, but recalled the folder and 4) recalled neither the folder nor statement.

Participants were particularly poor at recalling both statement and folder ($M = .17$, $SD = .16$) and recalling the statement, but not the folder ($M = .11$, $SD = .08$ pairwise comparison, ns). They were significantly more likely to recall nothing ($M = .38$, $SD = .24$), but surprisingly equally likely to recall the folder, when they didn't recall the statement ($M = .30$, $SD = .16$ pairwise ns), repeated measures ANOVA omnibus $F(1, 31) = 11.57$, $P < .003$ (Fig. 2). It would seem from this pattern that people don't remember where when they know what, but do remember where to find it when they don't recall the information. This is preliminary evidence that when people expect information to remain continuously available (such as we expect with Internet access), we are more likely to remember where to find it than we are to remember the details of the item. One could argue that this is an adaptive use of memory—to include the computer and online search engines as an external memory system that can be accessed at will.

Relying on our computers and the information stored on the Internet for memory depends on several of the same transactive memory processes that underlie social information

sharing in general. These studies suggest that people share information easily because they rapidly think of computers when they find they need knowledge (Expt. 1). The social form of information storage is also reflected in the findings that people forget items they think will be available externally, and remember items they think will not be available (Expts. 2 and 3). And transactive memory is also evident when people seem better able to remember which computer folder an item has been stored in than the identity of the item itself (Expt. 4). These results suggest that processes of human memory are adapting to the advent of new computing and communication technology. Just as we learn through transactive memory who knows what in our families and offices, we are learning what the computer "knows" and when we should attend to where we have stored information in our computer-based memories. We are becoming symbiotic with our computer tools (*8*), growing into interconnected systems that remember less by knowing information than by knowing where the information can be found. This gives us the advantage of access to a vast range of information—although the disadvantages of being constantly "wired" are still being debated (*9*). It may be no more that nostalgia at this point, however, to wish we were less dependent on our gadgets. We have become dependent on them to the same degree we are dependent on all the knowledge we gain from our friends and coworkers—and lose if they are out of touch. The experience of losing our Internet connection becomes more and more like losing a friend. We must remain plugged in to know what Google knows.

References and Notes

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Supporting Online Material

Fig 1. Accessibility of brand names (as measured by color-naming reaction time) following blocks of easy or hard test items. Error bars are ±SEM.

Fig 2. An if/then analysis of memory for what the information is and where to find it. Scale is measured in proportion recalled. Error bars are ±SEM.