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How to Make the Internet a More Effective Learning Tool: The Role of Thinking-Before-Googling

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How to Make the Internet a More Effective Learning Tool:

The Role of Thinking-Before-Googling

A dissertation submitted in partial satisfaction

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in Psychology

by

Saskia Giebl

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ABSTRACT OF THE DISSERTATION

How to Make the Internet a More Effective Learning Tool:

The Role of Thinking-Before-Googling

by

Saskia Giebl

Doctor of Philosophy in Psychology

University of California, Los Angeles, 2023

Professor Elizabeth Ligon Bjork, Co-Chair

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The internet has revolutionized how we access information, allowing us not only to find new knowledge, but also to retrieve information that we may already have stored in our memory but does not readily come to mind. As a consequence, we are vulnerable to googling before even trying to retrieve such information (e.g., Storm et al., 2017; Sparrow et al., 2011), thus bypassing the benefits of "retrieval as a memory modifier" (Bjork, 1975): that is, making the recalled information more memorable in the future. Googling before thinking can have metacognitive costs as well, such as impairing judgments as to whether information will be recallable if needed in the future. In addition, even a failed attempt to retrieve yet-to-be-learned information can potentiate learning, versus simply being presented with that information, typically referred to as the pretesting effect (e.g., Grimaldi & Karpicke, 2012; Kornell, Hays & Bjork, 2009; Little & Bjork, 2016). To investigate the potential benefits of pretesting with the internet, I examined whether an attempt to guess the answer to a question or problem before using the internet to find the solution (aka thinking-before-googling) can make the subsequently googled information more memorable compared to simply googling the answer right-away. Additionally, I wondered as to whether thinking about yet-to-be-learned information can also strengthen the memory for relevant information learned prior to the Google search. (Chapter 2 & 3). Furthermore, I explored ways to enhance the attractiveness of engaging thinking-before-googling attempts without reducing its efficacy (Chapter 4). Overall, attempting to think, before consulting the internet, about a question or a solution to a problem promotes better memory for searched-for information found on the internet as well as relevant information learned prior to the Google search. Furthermore, the findings indicate that the idea of hint support may result in a higher self-reported willingness to engage in thinking-before-googling attempts, without compromising the benefits of pretesting in the context of internet-based learning. Taken together, these findings have implications for how one could use the internet as a more effective tool for learning.

The dissertation of Saskia Giebl is approved.

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2023

For my family and friends

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Chapter two is a version of the following article:

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CHAPTER 1

General Introduction and Overview

The internet has paved the way for a vast repository of knowledge that is accessible at our fingertips. With just one click, we can gain immediate and almost ubiquitous access to a treasure trove of information. If you want to know a mathematical equation or a fact about a specific ecosystem, you only need to search the world.wide.web.—making our lives easier and more convenient, and shaping how we acquire knowledge.

A Brief History of Research on Cognitive Offloading

It is hard nowadays to imagine staying on top of modern life without internet-based "crutches" (e.g., Google calendar, Siri, email reminder). Our tendency to offload information, however, is not new. Humans have sought out many ways to record, store, and retrieve information from external resources long before the existence of computers and the internet (Clark & Chalmers, 1998; Nestojko, Finley, & Roediger, 2013). Drawings of historical events on cave walls, finger counting and abacuses to lighten the load of mental calculations were developed more than 2000 years ago (Woodforth, 2023). Nowadays, people often rely on scraps of paper or receipts to jot down items they need to buy at the grocery store (e.g., "Remember to get baking soda"), and they may enlist the help of family members, friends, or neighbors to co-remember important tasks or events (e.g., "Please remind me to take my medication before lunch"). It is only in the past century that humans have had access to using a powerful external memory device with massive storage capacity that demands minimal input from the user - the computer.

The punched card data storage system, which was developed in the mid-1700s by inventors such as Charles Babbage and Herman Hollerith, represented the first electromechanical tabulating technology that enabled users to enter and store information in a machine and perform complex calculations. This invention laid the groundwork for the development of the first modern electronic computer, which utilized binary math to store numbers as digits. Dr. Atanasoff and Berry's electronic computer, developed in the late 1930s and early 1940s, was the first machine that uses electrical switches to store numbers, marking the beginning of a new era in computing. The first electronic computer designed for business, the IBM 650, was introduced in 1954. Finally, the personal computing revolution began in the late 1970s and early 1980s with the introduction of machines like the Apple II, developed by Steve Wozniak and Steve Jobs in 1977, the IBM PC in 1981, and the Macintosh 128, which was the first commercially available computer with a Graphical User Interface and Windows 1.0 (Woodforth, 2023).

In the last 40 years, an even faster, more accessible, and better organized external repository of information has entered our world. *The Internet,* currently accessed and used by more than 5.15 billion users worldwide (~64.4. percent of the global population; February, 2023 https://www.statista.com/statistics/617136/digital-population-worldwide/), has the ability with a single search (e.g., Google, founded in 1998) to share an enormous amount of information (e.g., Wikipedia, founded in 2001) and to connect hundreds of billions of people around the world at great distances and extraordinary ease (e.g., Facebook, founded in 2004) of use via the so-called wide area networks or WANs (Ward, 2013a). As online learning continues to expand, researchers and educators have started to raise questions about how technology, in particular the internet, is altering the ways in which we learn and retain information over time.

Dynamic Interplay Between Internal and External Memory Storage

Throughout history, humans have often relied on external tools and technologies to make tasks more convenient and efficient. This is evident in transportation, as humans initially relied on walking before transitioning to animal-powered transportation around 4,000 BC. The invention of the wheel in circa 3,500 BC revolutionized transportation, leading to advancements such as the development of the carriage around 600, the steam locomotive (1804), the subway (1863), and the gas car (1886). More recent innovations include the airplane (1903), the rocket (1961), and the self-driving car (2009-Prototype). [https://www.youtube.com/watch?v=FaLCQo8NJFA].

Much like humans have relied on external transportation aids to help us move from one place to another more efficient and conveniently, the internet has become a potent cognitive aid to our memory. Indeed, the internet provides quick and easy access to information that would have previously taken hours to gather from a library or other external sources. The use of external human sources, or transactive memory systems (TMS), can also be time-consuming and challenging (e.g., Peltokorpi, 2008; Wegner, 1987, 1995). For instance, it may take significant time to find someone who has sufficient knowledge about a particular topic and is available to meet. In contrast, the internet has become the ultimate memory partner and source of information. With just a few clicks, users can open up a search browser, input their search request, and sit back as the information is delivered to them. It is the paragon of convenience and speed.

Moreover, it seems impossible to master every field and store all the knowledge acquired over time (see Bjork & Bjork, 1992). Perhaps, the ability to recall how and where to access information might be of greater significance than being able to remember the information itself. Thus, it is not surprising that people may prefer the ease and convenience of a super-engineered online information delivery services, over the effort and time commitment required for information-seeking through traditional means.

One potential concern arising from the convenience of fast information delivery is the potential transformation of internet users into "lazy thinkers" (e.g., Barr, et al., 2015; Sparrow et al., 2011; Ward, 2013a; Ward, 2013b). Research has shown that individuals tend to rely on the internet to the extent of outsourcing their thinking to the internet, even if they already possess the answers to their questions (Storm et al., 2017; Ward, 2013b). This reliance remains present even in inconvenient situations, such as when internet access requires physical movement or outdated devices (Storm et al., 2017).

Moreover, our minds are primed to associate computer or computer-related tools like Google or web browsers as the primary means of finding answers, regardless of whether the information is stored in our memory or not. In a study by Sparrow and colleagues (2011), participants were presented with sets of yes/no general knowledge questions (e.g., "Was Moby Dick written by Herman Melville?" and "Do all countries have at least two colors in their flag?", respectively). Each set of questions was followed by a modified Stroop color-naming task that measured how long it would take participants to name the color of a computer-related word (e.g., browser, screen, internet, modem, Google, Yahoo) compared to a more general, non-computer word (e.g., hammer, piano, pencil, chair). The words were either presented in the color red or blue. Based on the typical effect of the Stroop Task, which shows a slower response time in color naming of a word that has previously been activated and is subsequently competing for attention and accessibility with new (not as accessible) words, the authors predicted that computer-related words such as browser, which are more prevalent in participants' minds due to the ubiquitous nature of the internet, would cause more interference during the ink naming task compared to non-computer terms.

As anticipated, participants required significantly more time to verbally say aloud the color of words related to computers compared to general non-computer related words, suggesting that the pairing of internet and information search is so strong that merely reading difficult trivia questions (without any mention of Google, search engines, or computers) seems to be sufficient to activate these concepts in one's semantic network. This finding provides further support for the notion of people's inclination to use the internet for answers.

A Better Way to Co-Exist with the Internet

Decades of research have shown that quizzing oneself on previously learned information (i.e., posttesting) can produce more durable and flexible learning than just restudying that material, a phenomenon called the *Testing effect* or *Retrieval practice* (e.g., Dunlosky et al., 2013; Pan & Rickard, 2018; Roediger & Butler, 2011; Roediger & Karpicke, 2006; Rowland, 2014; Soderstrom & Bjork, 2015). More recently, research work has shown that even quizzing oneself on new, to-be-learned content (i.e., pretesting)—in which case learners attempt to guess what the answers might be and are thus typically incorrect—can nonetheless then enhance their learning of that new material (Carpenter & Toftness, 2017; Carpenter et al., 2018; Kornell et al., 2009; Little & Bjork, 2012; Metcalfe & Huelser, 2020; Richland et al., 2009; Toftness et al., 2018).

In a study by Kornell et al., (2009) participants were presented with a total of 60 weakly-associated word pairs such as "whale-mammal" (with "whale" being the cue and "mammal" the weakly associated target) for a later memory test. During a learning phase, half of the word pairs were presented as a complete pair for 13 seconds. For example, a given participant would read the word pair "whale-mammal" for the entirety of the time. For the other half of word pairs, participants were shown the first word only (e.g., "whale-______") and were given eight seconds to try to come up with its related target word before being shown the correct pairing for five seconds ("whale - *mammal*"). Thus, participants always experienced the same time on task but the study trials studied the correct pairing for the entire time whereas the pretesting trials' time was divided between an attempt to generate the correct target word and studying the correct pairing.

After the learning phase, participants took a final memory retention test during which they were given the cue word of each word pair (e.g., "whale- _______") and tried to recall the related target word "whale- *mammal.*" Each participant tried did so for 60-word pairs: 30 from the study-only practice trials during the learning phase and 30 from the pretesting trials. It is worth highlighting that participants who attempted to come up with the correct target during the learning phase had only five seconds to view the correct pairing, whereas word pairs that were shown intact, gave participants the full 13 seconds to view the correct pairing.

Contrary to one's intuition, the results from the final cued-recall test showed that the act of guessing the target word (*whale*-________?), aka pretesting, prior to viewing the correct intact word pair (*whale-mammal*) resulted in a higher final score than viewing the correct intact pairing for the entire duration in lieu of a pretesting opportunity. Further, the potentiating effects of pretesting was present even though participants failed to come up with the correct responses the majority of the time.

The potentiating benefits of pretesting can be explained, in part, because attempting to answer a question from memory prior to being given the correct information may (a) increase learners' curiosity and interest in the material they are about to learn (Berlyne, 1954; Geller et al., 2017; see also Metcalfe & Finn, 2011), (b) enhance metacognitive evaluations, leading to greater awareness of what is known and unknown, which may make encoding of subsequent information more effective (Bjork et al., 2013; Carpenter & Toftness, 2017); or (c) may lead—via increased attentional processes—to an enhanced elaboration and a better organization of that material (e.g., Hannafin & Hughes, 1986; Peeck, 1970; Tannenbaum et al., 1990). Pretesting—attempting to generate potential candidates of what might be the correct answer, may also trigger a semantic activation of information and concepts related to the question, thereby strengthening a semantic network that can facilitate the retrieval of the correct answer at a later time (e.g., Kornell et al., 2009; also see, Potts & Shanks (2014) for research work showing that the potentiating benefit of pretesting is not limited to pre-existing semantic relationships).

In the context of using the internet to learn new information, attempting to generate an answer before googling it—akin to taking a pretest, even when initial guesses are likely wrong, might well lead to better memory of subsequently googled information than googling the information right-away. Perhaps such an attempt to tackle a question before looking up the answer on the internet would make learners more cognitively aware and attentive to the various types of new content sought out and found on the internet, which may, in turn, result in more elaborative and richer encoding of such content.

Additionally, querying one's own memory for a potential answer to a question prior to searching the internet could also enhance one's memory for the previously studied information. That is, an attempt to search our memories for any relevant information already existing there—aka retrieval practice before searching for the answer in Google—perhaps, can strengthen the pre-existing representation of that information in memory. Therefore, trying to generate an answer before consulting the internet may not only render any new relevant information found on Google more memorable but also strengthen the memory routes to previously studied related information.

If such memory benefits can be demonstrated, one might also wonder about how to encourage learners to engage in this approach. Prior research work has shown that when learners feel that they have a good chance in producing the correct answer to a question, they are more likely to engage in self-testing/quizzing efforts than when their perceived odds in succeeding in their attempt to produce the correct answer feels low. In a study by Vaughn and Kornell (2019), participants were presented with lists of unrelated cue-target word pairs (e.g., "wolf – knight"). After an initial study phase of all word pairs, participants were given the choice as to how they would like to study the word pairs again: (a) restudy; that is, studying the intact cue and the target word (e.g., "wolf – knight"); (b) receiving the cue and self-test on the target word (e.g., "wolf – _____"); or (c) seeing the cue word and receiving a letter-hint for the target word. For the option of hint support, participants could choose between a 2-letter or a 4-letter hint (e.g., "wolf – k____t"; "wolf – kn__ht", respectively).

Notably, when learners were given only the option to either restudy or test themselves, they overwhelmingly chose to restudy the word pairs. When learners were given the choice of testing themselves with the provision of hint support, however, they preferred testing over restudy. Critically, testing with hints was equally effective for learning as testing without hints. Learners seemed to be more motivated to engage in testing in the presence of hints, suggesting that learners were not afraid to try to recall the answer provided they felt they had a reasonable chance of succeeding. Even though this study was conducted in a laboratory with traditional learning materials, we can imagine that the idea of motivating learners to self-test with hint support could be applied to the context of learning new information from the internet.

Overview of the Current Dissertation

The purpose of this dissertation was to explore the possibility of making the internet a more effective tool for learning. Specifically, I explored the potential learning benefits of prompting people to think first, before consulting Google, about potential answers or solutions to a problem. First, I examined whether an attempt to search for relevant information in one's memory before turning to the internet for solutions to a complex problem-solving task could enhance the learning of new information encountered on Google, as well as for relevant information learned prior to the Google search (Chapter 2). Second, I investigated whether a similar memory benefit of thinking-before-googling could also be found when looking up random trivia questions and compared the finding to learning situations that do not include the help of the internet (Chapter 3). Third, I examined whether people can be motivated to express a greater willingness to engage in thinking-before-googling attempts when accompanied by hints. I also investigated the influence of hint strength on the effectiveness of thinking-before-googling in enhancing memory retention (Chapter 4).

CHAPTER 2

Answer First or Google First? Using the Internet in ways that Enhance, not Impair, One's Subsequent Retention

Technological advances have given us tools—Google, in particular—that can both augment and free up our cognitive resources. Research has demonstrated, however, that some cognitive costs may arise from our reliance on such external memories (e.g., Marsh & Rajaram, 2019; Sparrow et al., 2011; Storm et al., 2017). We examined whether pretesting—asking participants to solve a problem before consulting Google for needed information—can enhance participants' subsequent recall for the searched-for content as well as for relevant information previously studied. Two groups of participants, one with no programming knowledge and one with some programming knowledge, learned several fundamental programming concepts in the context of a problem-solving task. On a later multiple-choice test with transfer questions, participants who attempted the task before consulting Google for help out-performed participants who were allowed to search Google right away. The benefit of attempting to solve the problem before Googling appeared larger with some degree of programming experience, consistent with the notion that some prior knowledge can help learners integrate new information in ways that benefit its learning as well as that of previously studied related information.

The Internet has opened a virtual door to vast amounts of information. With a single search, we have immediate and nearly ubiquitous access to a wealth of facts and knowledge. Additionally, the Internet has become a convenient way to offload information that we think we may need in the future, rather than trying to store such information in our own memories (Clark & Chalmers, 1998; Nestojko et al., 2013; Risko & Gilbert, 2016). Indeed, recent research shows that people tend to rely on the Internet for accessing information, even when doing so is neither necessary nor convenient (Storm et al., 2017).

These uses of the Internet all seem like benefits—allowing us to access, share, and store an enormous amount of information, and with minimal effort. Might, however, they come with associated costs? In particular, do they lead us away from engaging in processing that might support our ability to recall needed information—from our own memories—at a later time? The ease of retrieving information via Google goes against research findings indicating that for information to be well-learned and accessible for transfer in the future, it needs to be learned under conditions that present some difficulties or challenges to the learner (e.g., Bjork & Bjork, 2011). By relying on the Internet to store and to provide access to information that we think we may need later, we may be bypassing the very processes that are known to enhance learning and retention.

Can Google Be Made a More Effective Tool for Learning

The goal of the present research was to explore whether there are ways to use the Internet to promote the subsequent retention of needed information. Specifically, we wondered whether asking people to think first, before consulting Google, about what might be a correct answer to a question—or solution to a problem—might be advantageous for learning. That is, before using Google to find an answer to a given question, could an attempt to search for relevant information in memory strengthen the representation of that pre-existing information? Moreover, could it enhance the learning of new information encountered on Google?

Existing research on pretesting showing that taking a test prior to being exposed to the to-be-learned information can enhance one's learning of that information (e.g., Grimaldi & Karpicke, 2012; Kornell et al., 2009; Little & Bjork, 2016; Richland et al, 2009; for related evidence, see work on interim testing effects, Wissman et al., 2011; forward testing effects, Pastötter & Bäuml, 2014; Szpunar et al., 2008; Szpunar et al., 2013; and test-potentiated new learning, Little & Bjork, 2016; Yue et al., 2015), thus indicating that the answer to both of these questions could well be "yes". Thus, when learners turn immediately to the Internet for answers, rather than first attempting to retrieve information on their own (Storm et al., 2017)—they may well be bypassing a potentially productive process and thereby limiting their learning outcomes.

The Benefits of Pretesting

In a typical pretesting study, a pretest condition is compared to some form of baseline condition. In the pretest condition, participants try to answer questions based upon a set of to-be-learned materials before being given the opportunity to study that set of materials; whereas, in the baseline condition, study of the to-be-learned material is not preceded by any kind of pretest. On a later final test given to all participants, those in the pretest condition tend to outperform those in the baseline condition, a result that is observed even when participants in the baseline condition are given additional time to study the to-be-learned material and participants in the pretest condition are not provided with corrected feedback (Carpenter & Toftness, 2017; Little & Bjork, 2016; Peeck, 1970; Pressley et al., 1990; Richland et al., 2009; Rickards et al., 1976).

One explanation offered for the benefits of contemplating a question prior to being given the information necessary to answer that question suggests that learners' curiosity about the to-be-learned material is thereby increased (e.g., Berlyne, 1954), leading to their enhanced attention, elaboration, and better organization of it during subsequent study as compared with learners who do not try to answer questions about the to-be-learned material prior to its presentation (Hannafin & Hughes, 1986; Peeck, 1970; Pressley et al., 1990). Another explanation for the benefits of pretesting is the suggestion that pretesting may provide learners with a more effective metacognitive evaluation of what they know and do not know (e.g., Bjork et al., 2013), thereby making their encoding of the subsequently presented information more efficient.

Other factors may influence whether, and to what extent, learners benefit from pretesting. Huelser and Metcalfe (2012), for example, have shown that learners are more likely to benefit from pretesting when they generate information that is related to the subsequently presented, to-be-learned information. Thus, having some degree of relevant prior knowledge that could be activated during a pretest might be critical for observing benefits of pretesting.

Aims of the Present Study

The present study was designed to address several questions. First, we sought to examine whether attempting to tackle a challenging problem before looking up the solution on the Internet—akin to taking a pretest—could enhance one's conceptual understanding and retention of the subsequently to-be-learned information. Perhaps such an attempt would make learners more cognitively alert and attentive to the various types of new content encountered, leading to more elaborative and deeper encoding of it.

Additionally, we wanted to explore whether such pretest activity might also benefit one's retention of previously studied relevant information. That is, could the attempt to tackle a challenging problem before searching for the solution on the Internet not only enhance one's learning of the additional relevant information found there, but also one's memory for the previously studied relevant information? Such an effect seems possible given that learners in the present study might draw upon both the information that they have just learned as well as previous existing relevant knowledge when attempting to generate solutions to a given problem. And, finally, would the occurrence of these potential benefits of pretesting be affected by the degree of a participant's pre-existing relevant knowledge?

Basic Experimental Design

To address these aims, we examined the potential learning benefits of a pretest problem-solving task on knowledge formation of fundamental concepts related to computer programming. In a first study phase, all participants studied information related to computer programming, followed by a second phase in which they were given the task of solving a challenging computer problem related to those concepts. Critically, this problem was constructed to be impossible to solve with just the information presented so far, allowing us to give a type of pretest to some but not all of our participants (the pretest vs. no-pretest groups). Participants in the no-pretest group were given immediate access to the needed information via a Google search, while those in the pretest group had to spend some time trying to solve the problem before gaining such access. Lastly, all participants were given a delayed multiple-choice transfer test to assess their retention and understanding of the presented information as well as their ability to transfer it to new contexts.

To examine the role of prior experience, we divided all participants on a post hoc basis into two groups based on their responses to a questionnaire: one in which participants had some degree of prior experience with computer programming and one in which they had no prior experience with computer programming. We predicted that participants with some experience would be more likely to benefit from a pretesting experience than would those with no experience owing to their being more capable of generating—during the pretest—more helpful connections to the to-be-encountered information.

Method

Participants

The participants were 240 undergraduate participants (194 identified as women of which 74 reported having programming experience and 120 reported having no experience; 45 identified as men of which 18 reported programming experience and 27 reported no programming experience; and 1 identified as non-binary; mean age for all participants = 20.3 years, mean age for participants with experience = 20.20, mean age for participants with no experience = 20.45, range 18-42 years) from the University of California, Los Angeles subject pool and all received course credit for participating. Participants were classified into two groups (some experience and no experience) based on a self-report questionnaire given at the end of the study, and the numbers of each type ending up in the pretest and no pretest conditions are shown in Table 1.

The 148 participants classified as having "No Experience" reported having not taken any kind of programming or statistics course that would have exposed them to a programming language or code. The 92 participants classified as having "Some Experience" reported having taken a class (or classes) where programming language or code was introduced, but that the class was not explicitly focused on teaching programming skills (e.g., Psychological Statistics or Biological Quantitative Reasoning). Such courses provide students with exposure to coding commands in R or other languages to analyze data, which could facilitate the learning of programming principles in the present study but would not be sufficient to allow participants to solve the pretest problem using only their existing knowledge. Participants with more than a year of programming experience and extensive knowledge of various computer languages, such as Python or C++, or who had taken a programming course or a computer science course in any language, were excluded.

Table 1

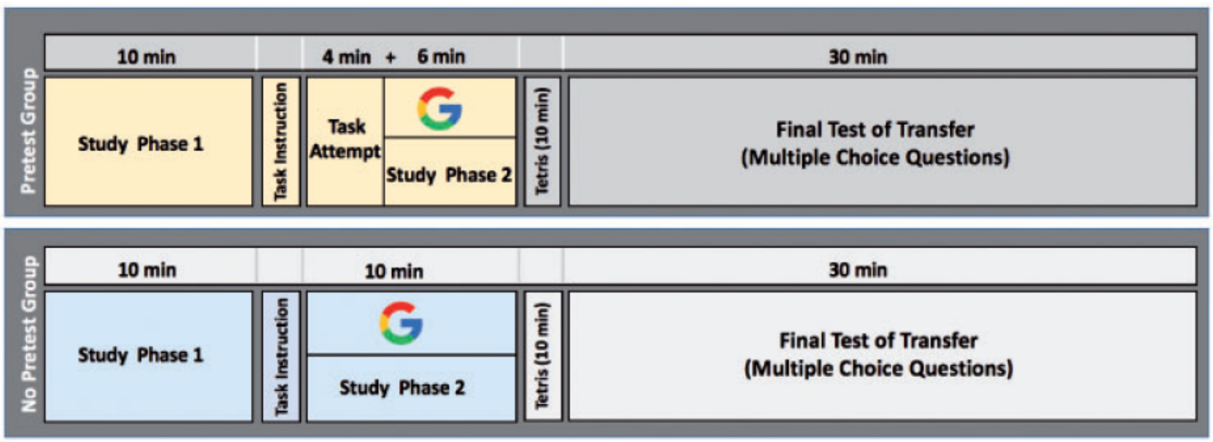
Number of Participants in Each Condition

	No Experience	Some Experience	Total
No pretest	74	42	116
Pretest	74	50	124
Total	148	92	240

The present experiment involved two study phases, as illustrated in Figure 1. In Phase 1, all participants studied fundamental computer programming principles and concepts about which they were told they would later be tested. In Phase 2, participants were presented with a challenging computer programming task—one for which they had not yet been exposed to all of the information necessary to solve. During this phase, half of the participants were randomly assigned to try to solve the computer programming task before being allowed to use a simulated Google search experience to find additional task-relevant information, including that necessary for solving the task (i.e., the pretest group). The other half did not have to try to solve the task first, but rather, were allowed to search for the task-relevant information immediately (i.e., the no-pretest group). Finally, to assess whether the pretest attempt enhanced the learning of both previously presented concepts, as well as subsequently presented concepts, a final multiple-choice test containing transfer-type questions was administered to both groups for all concepts presented in the experiment; that is, both those encountered before and after presentation of the computer programming task.

Figure 1

A Schematic Representation of the Experiment for the Pretest Group (top panel) and the No-pretest Group (Bottom Panel)



Materials

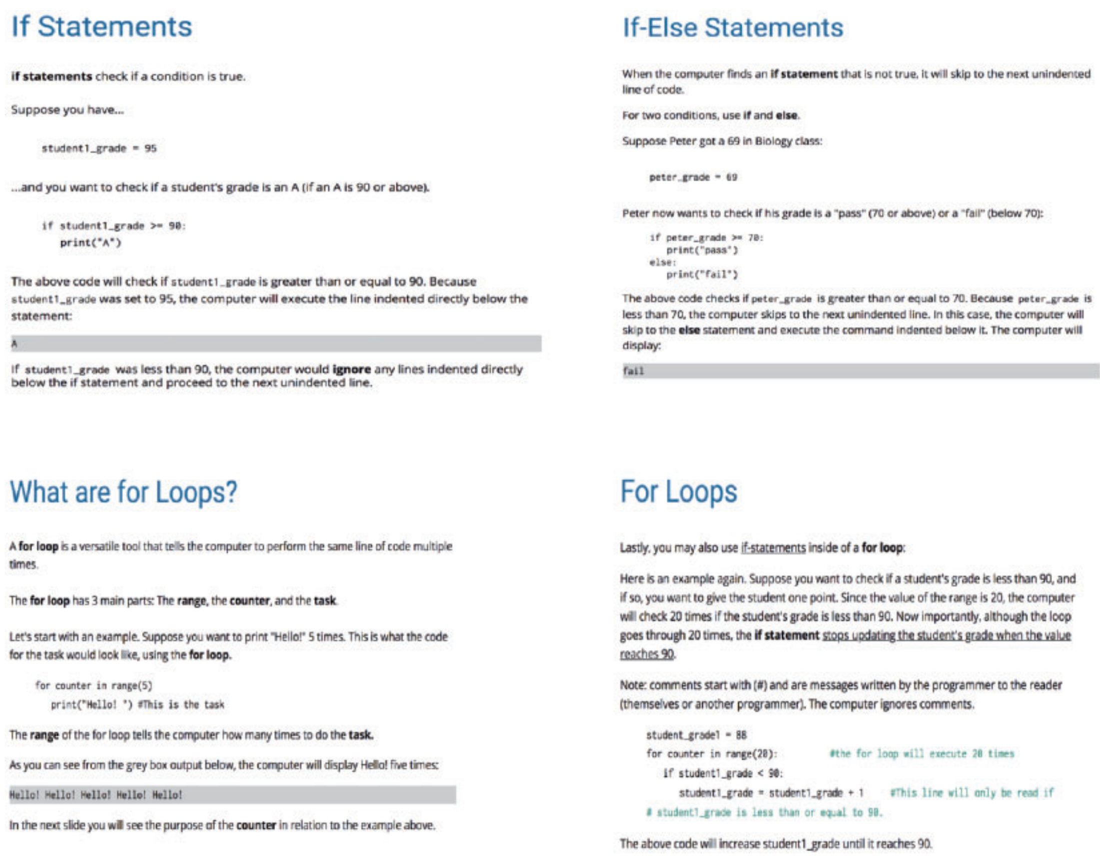
All study and test materials were developed by the experimenters, including the information participants encountered when using the simulated Google search engine. Specifically, participants learned a modified form of Python syntax, a programming language known for its limited use of syntactic symbols (such as semi-colons, parentheses, tildas, etc.) to accomplish complex tasks. Because our goal was to teach and test understanding of programming concepts, Python's intuitive syntax allowed us to limit the working-memory burden on participants during this learning attempt. The programming content was challenging, yet—as determined by pilot data—appropriate for novices. The materials presented during

Study Phase 1 and Study Phase 2 were matched for their conceptual difficulty and the number of to-be-learned programming principles.

Study Phase 1. During Study Phase 1, participants received instructions regarding three fundamental programming concepts: (a) how to store and replace a variable, (b) when and how to use if-statements, and (c) the concept of a for loop, which were introduced in a context requiring the manipulation of only one variable. For example, participants studied how to assign a grade to one student (e.g., peter_grade = 69) and how to check if that student's grade is a "pass" (70 or above) or a "fail" (below 70). Information was mostly presented in the form of short text passages (i.e., mini-tutorials) accompanied with examples, as depicted in Figure 2.

Figure 2

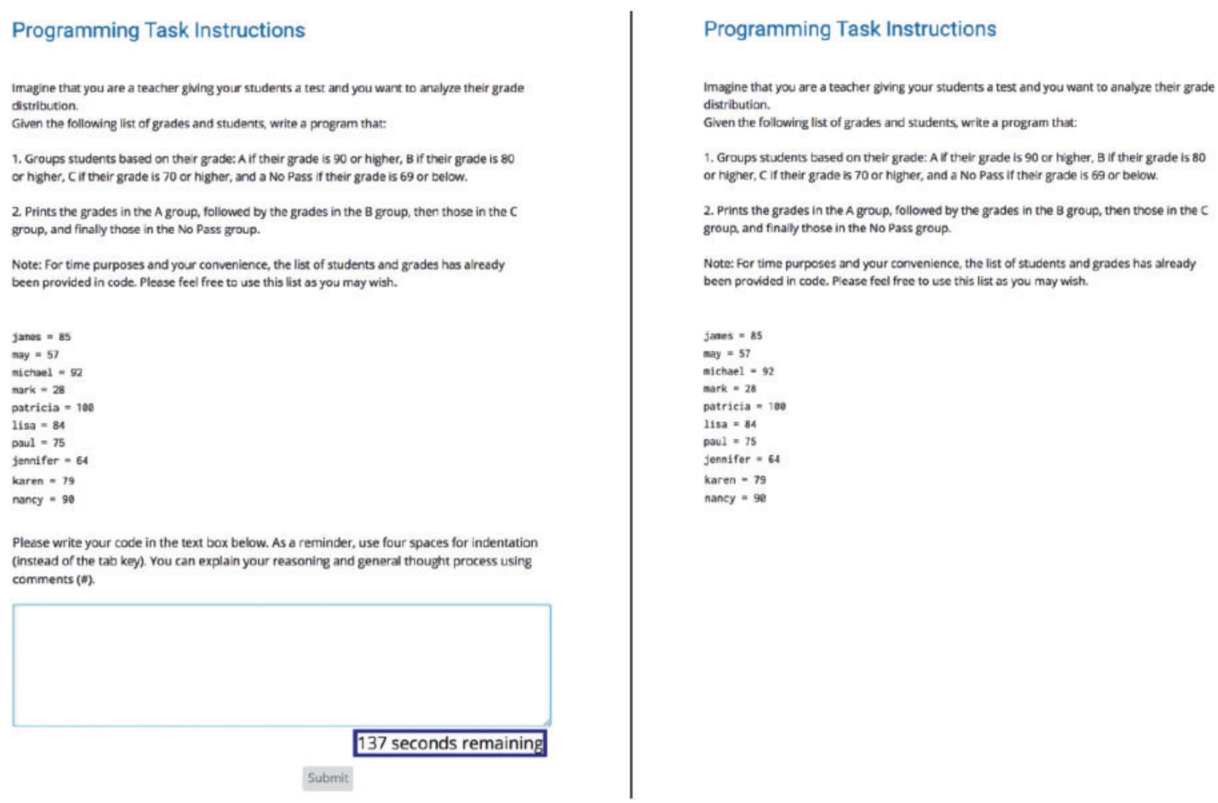
Examples of the computer programming content presented during Study Phase 1 in which all participants learned how to manipulate one variable using if statements and a for loop function



Study Phase 2. During Phase 2, participants were presented with a challenging programming task, similar to a homework problem in an actual programming course. In this task, for which the exact instructions appear in Figure 3, participants were asked to imagine themselves as a teacher who wanted to write programming code that would allow grouping of students based on their exam grades—a programming task requiring use of some concepts studied in Phase 1 (e.g., *how to manipulate one variable*). Importantly, however, this task also required some concepts only available via the Google search (e.g., *how to manipulate multiple variables*) to which participants assigned to the pretest group did not have immediate access. Instead, they were instructed to attempt to solve the task for a while before being given such access and, furthermore, no corrective information was provided to them during their problem-solving attempts. In contrast, participants in the no-pretest group did not attempt to solve the task before being able to access Google where the relevant information could be found.

Figure 3

Computer Programming task instructions. Solution of the programming task required some elements previously studied in Phase 1 (i.e., how to manipulate one variable using if statements and a for loop function) plus some elements that were only exposed in the information available via the Google search (i.e., group and index multiple variables using a list function.) Instructions for the pretest participants as well as an empty box in which they were to record their problem-solving attempts are shown on the left side of Figure 3. Instructions for the no-pretest participants are shown on the right side of Figure 3



The information necessary to solve the programming task could be found on the simulated Google page, which became available to participants once they were allowed to use Google. A simulated Google page—instead of an actual Google page—was created to rule out potential differences in the nature and quality of individual searches made by participants. Thus, every participant landed on the same web pages and was exposed to the same content (i.e., a continuation of the information presented in Study Phase 1, but now with an added focus on manipulating *multiple variable*s, the missing information necessary for solving the programming task).

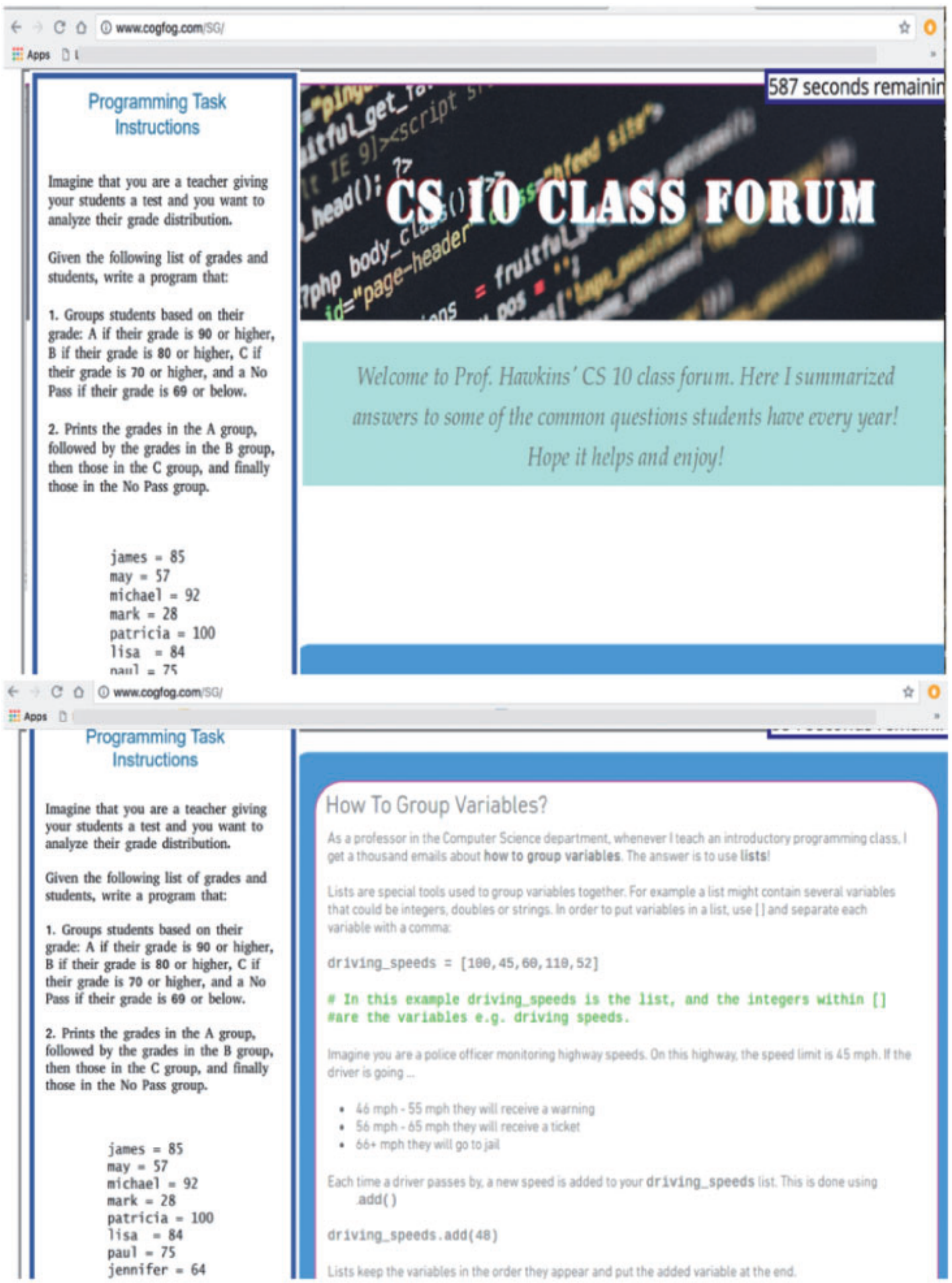
In order to ensure that all participants would believe they were searching the "real" Google, we presented everyone with "I'm Feeling Lucky!" instructions before they were able to type their search question into a made-up Google search bar. These instructions emphasized that after being directed to the Google search bar, participants should type in a search phrase relevant to the programming task and then click on the "I'm Feeling Lucky!" button.

It was explained to all participants that after entering their search phrase and then clicking on the "I'm Feeling Lucky" button, they would be sent directly to the website that would best address their query, rather than being shown a list of search results among which they would have to choose, as is the usual case with Google.

The simulated website that was then opened in response to all participants' Google search request took the form of a Google class forum on how to group and index multiple variables using a *list function,* as exemplified in Figure 4. It is important to note that if participants clicked "Search" instead of "I'm Feeling Lucky!" the computer screen still advanced to the same simulated website.

Figure 4

The simulated Google page, which was the same for all participants, appeared in the form of a class forum on how to group and index multiple variables using a list function

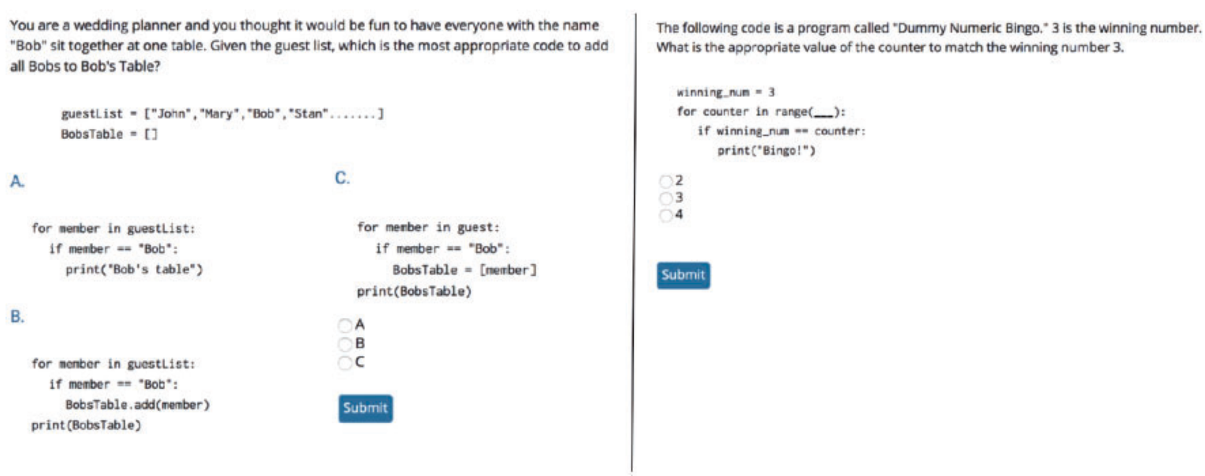


In the Google class forum, a problem related to the pretest task was illustrated showing participants how a computer program can assess from a list of recorded driving speeds (driving_speeds = [100,45,60,110,52,48]) how many *warnings*, *tickets*, and *arrests* a police officer has warranted in one day using *lists*, which is a powerful programming tool to group variables (warning = [ ]; ticket = [ ]; jail = [ ]). It is important to point out that the pretest task instructions continued to be available for both pretest and no-pretest participants for the duration of Study Phase 2, as indicated in Figure 4 on the left side of the computer screen.

Final Test. The final test materials consisted of 29 multiple-choice transfer questions on concepts from both study phases, and two of them are illustrated in Figure 5.

Figure 5

The final test materials consisted of multiple-choice transfer questions on concepts from both study phases. As illustrated by the two examples shown in Figure 5, each question had three possible answers: one correct and two incorrect alternatives



Each question had three possible answers: one correct and two incorrect alternatives. The presentation order of the test questions was block-randomized and counterbalanced across participants to control for order effects. While some participants received questions pertaining to Study Phase 1 content before seeing questions related to Study Phase 2, other participants received questions pertaining to Study Phase 2 content before seeing questions related to Study Phase 1. The questions were based on ones often used in programming courses: namely, participants were presented with a small task and then asked to choose from a list of possibilities the best code to accomplish that task. Incorrect options were inspired by common programming logic mistakes and misunderstandings of programming principles.

Procedure

The present experiment consisted of two study phases (Study Phase 1 and Study Phase 2) and a final test of which a schematic illustration is shown in Figure 1.

Study Phase 1 began with participants reading text passages on fundamental computer programming concepts, with each passage presented one at a time on a lab computer. Reading was self-paced except for some passages presenting more challenging concepts (e.g., for loop), and participants were required to stay on such passages for at least 10 seconds before being allowed to move on to the next passage.

Study Phase 2 with the challenging programming task followed immediately after Study Phase 1. Pretest participants were required to attempt to solve the task for at least 4 min before being allowed to consult "Google." In contrast, no-pretest participants were given immediate access to "Google" to aid with the programming task. In order, however, to ensure that the no-pretest participants had enough time to read the instructions for the to-be-solved programming task, they were required to wait for 20 s on the task instruction page before the computer screen automatically advanced to the simulated Google search.

For both groups, after typing in their search terms and clicking on the "I'm Feeling Lucky!" option, participants were shown the same simulated webpage. Critically, the time allotted to explore the webpage differed between the two groups. Pretest participants only had 6 min to explore the webpage containing the missing information necessary for performing the task after having to spend 4 min trying to solve the task (10 min total). In contrast, no-pretest participants had the entire 10 min to explore the webpage containing the additional information necessary for solving the task.

Considering this difference in the available time to encode Study-Phase 2 content, it would seem possible that the no-pretest participants might learn more of this content than would the pretest participants. If, however, attempting to solve a problem before being exposed to its solution—even when one's problem-solving attempts are not successful—promotes one's learning of subsequently presented relevant information, then perhaps the pretest participants might nevertheless outperform the no-pretest participants on the final test.

Following Study Phase 2 and a subsequent 10-min distractor task, all participants were given the final multiple-choice transfer test on which they had up to one minute to answer each question. At the end of the experiment, participants filled out a questionnaire to assess how much they enjoyed the experiment; whether they experienced any technical difficulties; and their level of programming experience before participating in the study. Then, they were debriefed and thanked for their participation.

Results

Pretest Performance

Responses to the pretest task were graded by research assistants who were blind to participant condition. The research assistants were instructed to follow a rubric out of 8 points that focused on overall concepts rather than syntax. A Welch's Two Sample *t* test showed that participants with some experience (M = 2.56, SD = 1.67) produced answers that were significantly better than participants with no experience (M = 1.45, SD = 1.64), $t(104.06) = 3.67$, $p < 0.001$, $d = .67$, $CI_{95\%} = [0.51, 1.72]$. As expected, however, none of the participants generated the correct answer to the pretest problem.

Final-Test Performance

Final-test performance on materials from Study Phase 1 and Study Phase 2 as a function of Practice Type (Pretest and No Pretest) for participants with Some Experience and No Experience is illustrated in Figure 6. To analyze this pattern of results, we first conducted a 2 (Practice Type: Pretest vs. No Pretest) x 2 (Experience: Some vs. No) x 2 (Study Phase: 1 vs. 2) mixed-design ANOVA, where practice type and experience were between-subjects factors, and Study Phase (1 vs. 2) was a within-subjects factor. This analysis revealed a significant main effect of practice type, $F(1, 236) = 5.65$, $p = .018$, $CI_{95\%} = [.01, .07]$, $d = 0.31$, such that final-test performance by participants who completed a pretest (M = .56, SD = .18) was significantly better than that of participants who did not complete a pretest (M = .50, SD = .18). A significant main effect of experience was also revealed, $F(1, 236) = 28.80$, $p < 0.001$, $CI_{95\%} = [.06, .12]$, $d = 0.71$, such that final test performance by participants with some experience (M = .60, SD = .17) was significantly better than that of participants with no experience (M = .47, SD = .17). No significant main effect of study phase was observed, performance on Study Phase 1 (M = .52, SD = .18) did not significantly differ from performance on Study Phase 2 (M = .51, SD = .23), $F(1,236) = .09$, $p = .77$, $CI_{95\%} = [-.02, .01]$.

The three-way interaction (Study Phase by Practice Type by Experience) was not significant, $F(1, 236) = .42$, $p = .52$, $CI_{95\%} = [-.01, .02]$, nor were the interactions between Study

Phase and Practice Type, $F(1, 236) = .48$, $p = .49$, $CI_{95\%} = [-.01, .02]$ or Practice Type and Experience, $F(1, 236) = 1.66$, $p = .20$, $CI_{95\%} = [-.01, .05]$. The interaction between Study Phase and Experience was significant, $F(1, 236) = 4.92$, $p = .03$, $CI_{95\%} = [.00, .03]$, partial-$\eta^2 = 0.02$, such that final-test performance based on information presented in each Study Phase depended on the participant's prior experience.

Although the three-way interaction was not significant, because one of our a priori predictions was that final-test performance would depend upon practice type—that is whether participants engaged in a pretest or problem-solving activity before being allowed to access the information presented on the Google page, we probed the main effect by conducting more targeted comparisons to see whether a significant pretesting effect was observed for each group of participants. Another a priori hypothesis was that participants with some experience would perform better on both Study Phase 1 and Study Phase 2 materials than would the participants with no experience.

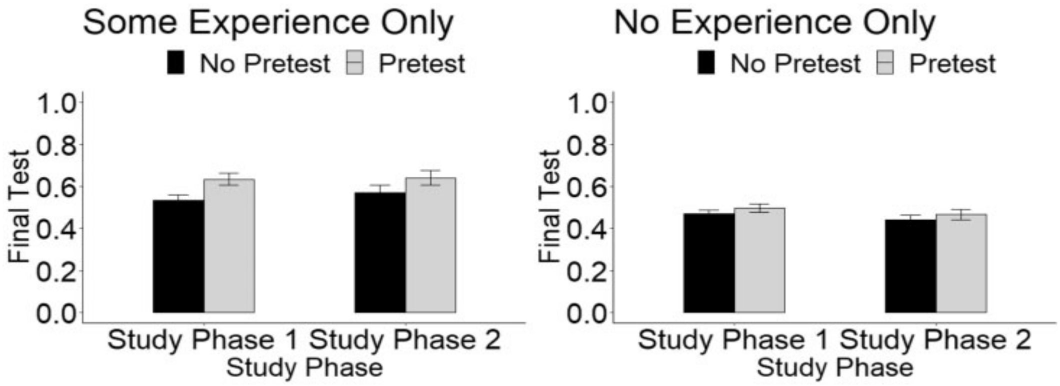
First, we focused our analysis on participants with some programming experience by conducting a 2 (Practice Type) x 2 (Study Phase) mixed design ANOVA. A significant main effect of Practice Type was observed, such that participants in the Pretest condition ($M = .64$, $SD = .23$) significantly outperformed participants in the No Pretest condition ($M = .55$, $SD = .20$), $F(1, 90) = 4.18$, $d = .31$, $p = .04$, $CI_{95\%} = [.00, .24]$. Two planned comparisons indicated that this difference was statistically significant with regard to Study Phase 1 performance (Pretest: $M = .64$, $SD = .18$; No Pretest: $M = .53$, $SD = .17$), $t(90) = 3.06$, $d = .54$, $p < .01$, $CI_{95\%} = [.04, .18]$, and marginally significant with regard to Study Phase 2 performance (Pretest: $M = .64$, $SD = .25$; No Pretest: $M = .57$, $SD = .24$), $t(90) = 1.92$, $p = .057$, $d = .29$, $CI_{95\%} = [.00, .17]$. The interaction between Study Phase and Practice Type, however, was not statistically significant, F (1, 90) = .72, p = .40, $CI_{95\%}$ = [-.03, .07].

Next, we conducted the same two-way ANOVA focusing on participants with no programming experience. For this group, participants in the Pretest condition (M = .48, SD = .20) did not outperform participants in the No Pretest condition (M = .46, SD = .16), F(1, 146) = .95, p = .33, $CI_{95\%}$ = [-0.12, .04]. Two planned comparisons failed to find evidence of a significant difference with regard to Study Phase 1 performance (Pretest: M = .49, SD = .18; No Pretest: M = .47, SD = .18), t(146) = .90, d = .11, p = .37, $CI_{95\%}$ = [-.03, .08], or Study Phase 2 performance (Pretest: M = .47, SD = .21; No Pretest: M = .44, SD = .18), t(146) = .71, p = .48, d = .15, $CI_{95\%}$ = [-.04, .10]. The interaction between Study Phase and Practice Type was not statistically significant, F (1, 146) = .00, p = .97, $CI_{95\%}$ = [-.04, .04].

Given that the interaction between Programming Experience and Practice Type was not statistically significant, we cannot make strong conclusions about whether participants with experience benefited more from pretesting than participants without experience. The results of the follow-up analyses, however, are suggestive. At a minimum, they provide additional evidence that at least participants with some experience benefited from pretesting. Whether participants without experience benefited from pretesting, however, is unclear, and the possibility that they do not is something that future research should investigate more closely.

Figure 6

Final test performance on materials from Study Phase 1 and Study Phase 2 as a function of Practice Condition (Pretest and No Pretest) for participants with Some Experience and No Experience



General Discussion

Participants in the present study received instructions regarding how to solve a programming task for which some of the information necessary to do so could only be found via a simulated Google search of the Internet. Critically, participants in the pretest group had to work at solving this programming task having only been instructed on some—but not all—of the necessary programming concepts for doing so, before being allowed to access information regarding the remaining needed concepts via the simulated Internet search. Thus, these participants could be said to have engaged in a unique type of pretest. In contrast, participants in the no-pretest group did not have to attempt to solve the programming problem before they could search the Internet via Google for the remaining needed concepts. Accordingly, the no-pretest participants also had more time to study the information presented in the simulated Internet search. Despite this advantage of having more time for solving the programming task while in possession of all of the information necessary to do so, the no-pretest participants were nonetheless outperformed by the pretest participants on the final delayed multiple-choice transfer test.

The present work builds upon an array of studies that have observed benefits of taking a pretest before studying the to-be-learned information (e.g., Grimaldi & Karpicke, 2012; James &

Storm, 2019; Kapur & Bielazuc, 2012; Kornell, 2014; Kornell et al., 2009; Little & Bjork, 2011; Richland et al., 2009). It also provides an important addition to this body of work in that several prior studies have not reported large or significant benefits of pretesting in learning situations more akin to those found in educational or classroom contexts (e.g., testing deep conceptual understanding and non-pretested portions of the learning content as opposed to simply testing memory for identical pretested factual questions; see Carpenter et al., 2018; Geller et al., 2017; McDaniel et al., 2011; but see Carpenter & Toftness, 2017; Little & Bjork, 2016), or that such benefits were relatively limited in scope (e.g., Hausman & Rhodes, 2018; James & Storm, 2019).

One could speculate that the benefits of pretesting observed in the present study might be, in part, attributable to or linked with the unique set-up of the present experiment in that participants (a) studied information related to computer programming;, (b) attempted to generate a solution to a challenging task related to computer programming (a type of pretest for which the participants—while having learned about some of the concepts necessary for solving the task—had not yet received all the information needed to solve that task;, (c) were then exposed to the additional information regarding computer programming necessary to solve the earlier task; and (d) were given a final multiple-choice transfer test to measure how well they had formed a conceptual understanding of the to-be-learned materials. This unique form of pretesting, as later discussed in more detail, may have triggered certain cognitive processes that not only potentiated their new learning but also enhanced their retrieval of the previously related learned information, thus leading to an overall deeper understanding of the to-be-learned material.

The present findings are also noteworthy because—to our knowledge—they arise from the first experiment designed to examine the potential benefits of pretesting in the context of learning new information via the Internet. Research has suggested that people tend to rely on the

Internet to store and access information in a way that may reduce the extent to which they store that information internally (Marsh & Rajaram, 2019; Sparrow et al., 2011). Importantly—as suggested by the present results—pretesting might have the potential to enhance the way students learn new information encountered on the Internet.

Two other aspects of the present results deserve further emphasis. First, participants in the pretest group outperformed participants in the no-pretest group on the final transfer multiple-choice test not only in their answering of questions about information studied after the pretest, but also in their answering of questions about information studied before the pretest. Perhaps attempting to solve a task for which learners have not yet learned all of the information necessary for doing so—a unique form of pretesting—may have evoked elaborative retrieval practice of the previously learned information on how to create and manipulate a single variable while trying to solve a programming task that involves manipulating multiple variables. This retrieval of prior information in relation to the to-be-learned programming concepts may not only have improved their comprehension and integration of the new knowledge (i.e., *interpolated testing effect* or *interim testing effect;* see Szpunar et al., 2008, Szpunar et al., 2013; Wissman et al., 2011) but also strengthened their memory traces of the recalled information itself (i.e., *the testing effect,* see Agarwal et al., 2008; Butler, 2010; McDaniel et al., 2007; Hinze et al., 2013; Roediger & Karpicke, 2006). As a result of the binding of previously and newly related information, a deeper understanding of the to-be-learned concepts may have been formed overall, as reflected in the apparent increased ability of pretest participants to connect and adapt the learned concepts to infer and answer novel conceptual questions on the final test.

Another possibility is that the prior problem-solving attempts of the pretest participants made them more effective and efficient processors of the new material once they were able to find it via the Google search. It seems reasonable to assume that the information they found on Google was processed more deeply as a consequence of initially trying to solve the problem as compared to simply googling the information, which would be consistent with prior research demonstrating the learning benefits of guided discovery (e.g., de Jong and van Joolingen, 1998) and problem-solving attempts prior to instruction (cf. Productive Failure: Kapur, 2010, 2012, Invention Studies: Roll et al. 2009, 2011; Schwartz & Martin, 2004). Perhaps by trying to think of how to solve the problem, the present pretest participants were encouraged to think more deeply about the various elements of the task, resulting in enhanced subsequent study of the task-related information encountered via their Google search, which then supported better subsequent transfer. In contrast, perhaps the no-pretest participants who were able to consult the Internet without spending time contemplating the problem first were led away from thinking deeply about the various elements of the task, thereby rendering their subsequent learning less likely to support subsequent transfer. A direction for future research would be to explore the effectiveness of different pretesting set-ups or types of pretest activities (e.g., pretest tasks *with* versus *without* an initial study phase; attempting to solve a problem relative to other kinds of pretest activities) in a systematic attempt to discover the necessary and/or sufficient characteristics for producing benefits of pretesting.

Finally, it should be noted that the benefit of pretesting was somewhat tenuous for participants without any programming experience. Given that the interaction was not statistically significant, however, we hesitate to make too much of this finding. Nevertheless, it is consistent with the idea that learners need some degree of prior knowledge to engage with a pretest in a way that is likely to enhance learning. It is possible, for example, that having some background knowledge on programming principles helped participants in the present experiment to remember better the information studied prior to presentation of the to-be-solved programming problem. If so, these participants might have been more effective at integrating that information with the new task-related information subsequently found on Google.

In comparison, participants with no prior experience in computer programming may have struggled more to form connections between the task requirements and the previously learned information, resulting in their poorer conceptual understanding of both the previously learned information and of that encountered during their Google search (for research on the importance of relatedness of the generated pretest response to the to-be-learned information see Huelser and Metcalfe, 2012; Kornell et al., 2009, experiment 2; Slamecka & Fevreiski, 1983; for research on the association between prior knowledge and new learning, see also work on the expertise reversal effect, e.g., Cooper et al., 2001, experiment 4; Kalyuga 2007; Leppink et al, 2012; McNamara, 2001; see also Carpenter et al., 2016 and Karpicke et al., 2014 for research work on the relationship between individual differences in student achievement and retrieval-enhanced learning.) An important avenue for future research will be to identify more fully how the effectiveness of pretesting may vary in relation to differing levels of pre-existing domain knowledge.

Conclusion

With the constant pressure and heightened expectations for the adequate preparation of students for higher education and/or the workforce, encouraging learners to think before seeking out easily accessible answers via the Internet or other sources, such as the back of a textbook, would seem to hold much promise as a useful addition to effective teaching practices in any field. Although the extent of the generalizability of pretesting on the learning of various types of skills and knowledge remains unknown and requires additional research to determine, the present results are encouraging and offer perhaps a new and effective way for making instruction more effective in the digital age.

Take away note

For every maxim there seems to be an equal and opposite maxim. In this case, perhaps, the counterpart to “Look before you leap” is “Think before you Google.”

CHAPTER 3

Thinking First Versus Googling First:

Preferences and Consequences

On the internet we can look up information that is not in one's memory, but also information that is in one's memory, but does not come immediately to mind. We become susceptible, therefore, to googling before trying to retrieve, which bypasses the benefits of "retrieval as a memory modifier" (Bjork, 1975), including that even a failed attempt to retrieve yet-to-be-learned information can potentiate learning of new information. Across four experiments, participants were asked to either generate answers to trivia questions before consulting the internet (Thinking-before-googling), search for answers on the internet (Googling-right-away), read questions and answers presented simultaneously (Presented-with), or generate answers before being presented with answers (Thinking-Before-Presented). Overall, Thinking-before-googling led to better recall than did Googling-right-away. Such a finding is striking in several respects, including that 81% of participants said they tended to immediately search the internet as opposed to thinking first.

Imagine that 1 day in the future you are trying to convey to a child or grandchild why the “Beatles” music was so impactful. You could illustrate by recalling one of your favorite Beatles songs, but—aside from any performance anxiety you might have—it is far more likely that you would access the internet and play one of your favorite Beatles songs. Research has demonstrated, however, that such a reliance on the internet comes with costs as well as benefits. Using Google can free up cognitive resources to focus on other tasks of the moment, but it can also nullify the benefits of retrieval, which include making the retrieved information more recallable in the future (e.g., Marsh & Rajaram, 2019; Storm, 2019). More specifically, recent research has shown that the act of trying to generate a potential answer before exposure to necessary information can potentiate one’s future learning of such information. Furthermore, this beneficial effect holds true even if participants must essentially guess and even when their responses are incorrect, a result often referred to as the pretesting effect (e.g., Carpenter et al., 2022; Grimaldi & Karpicke, 2012; Huelser & Metcalfe, 2012; James & Storm, 2019; Kornell et al., 2009; Little & Bjork, 2011; Richland et al., 2009).

The present research was designed to examine in more detail both the costs of having the internet available and the possible ways in which we might use the internet as a powerful memory companion while also enriching and expanding our own memories. Pretesting can promote subsequent learning, in part, because generating a potential answer to a question from memory may (a) trigger an activation of the semantic network of information associated with the question or the problem to-be-solved (Kornell et al., 2009; Kapur & Bielaczyc, 2012; for pretesting benefits without semantic activation, see Potts & Shanks, 2014); (b) arouse curiosity and interest (see Berlyne, 1954, 1962); (c) help with metacognitive evaluation of what one knows and does not know about a particular topic (Bjork et al., 2013); or (d) familiarize the learner with the material and form a better organization of it (Hannafin & Hughes, 1986; Mayer, 1984), all of which may enhance attentional processing, thereby producing more elaborate and deeper encoding of the information.

In the context of using the internet, searching for and finding information can itself serve as a pretesting learning opportunity. Typically, a search engine requires the user to input a question or command to initiate the search process; and this requirement forces users to consider possible search terms–even possible answers—with the possible consequence of igniting one’s curiosity about a topic and/or leading to a search of one’s own memory for information in order to facilitate the current internet search. Such retrieval/generation and metacognitive evaluation processes, coupled with enhanced attentional processing, can promote deeper processing of the information during and after the actual search. As a consequence, internet users may—at least on some occasions—engage in processes that benefit their own memories, as well as finding the answer to a query.

Research carried out by Storm et al. (2020) provide support for the idea that searching the internet for an answer may engage learners in the type of learning processes that enhance memory. Across two experiments, participants were presented with difficult trivia questions. For half of the questions, participants were asked to use Google to answer the questions. For the other half, question-answer pairs were presented and participants typed them into the computer. On a final cued-recall test, participants demonstrated better memory when the sought-out information was found on the internet as opposed to simply being presented.

Realizing such memory benefits, however, requires that we actually engage in the types of activities that can benefit our later recall of the searched-for information—versus, say, turning immediately to the internet for answers. Research findings suggest, though, that the ease of using Google often leads learners to offload thinking to the internet, even when they have been told that it is important to remember the information for a later time in the absence of the internet (Marsh & Rajaram, 2019; Storm et al., 2017).

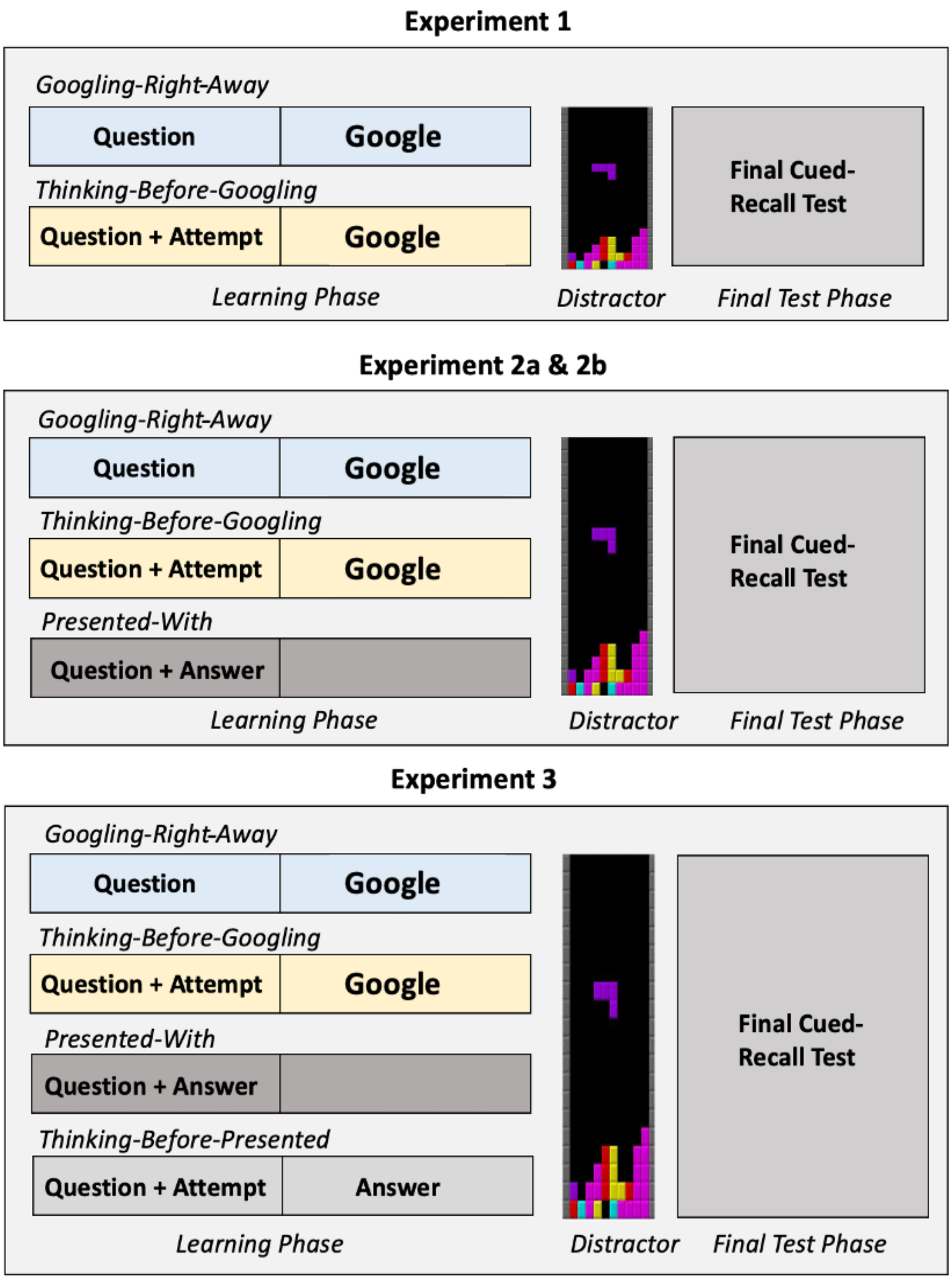
To break this cycle of excessive reliance on the internet and instead, seeing the internet as a memory partner, we might profit in two ways: (a) better memory for any associated or relevant information already stored in our memories and (b) storing some of the new/related information we encountered during such a search. Indeed, Giebl et al. (2021) recently found such a result when participants attempted to solve a task before turning to Google for help. In their experiment, one group of participants was asked to solve a complex task, one that required using both already learned computer coding techniques as well as not-yet-learned information before using Google to solve the task. In contrast, another group of participants was allowed to google task-related information right away without making an initial attempt to solve the problem. On a later test involving transfer, participants who attempted to solve the task before consulting the internet outperformed participants who had been given immediate access to the internet. This finding was more pronounced in participants with some background knowledge in programming as compared to novices. Basically, the mere act of contemplating a possible answer to a question before being allowed to google the answer may enhance both one’s learning of that new information as well as one’s prior encoding of already learned related information.

The present research explored whether similar benefits might result from trying to retrieve fact-type information before asking Google to retrieve it for us. Perhaps, even in this frequent activity, the costs associated with relying on the internet to access information can be lessened if people try to generate such information on their own before searching for it on Google.

Across four experiments, we asked whether people will remember a googled answer to a general knowledge question better if they first attempt to answer the question (thinking-before-googling) rather than immediately turning to Google for the answer (googling-right-away*)*. Additionally, we wanted to compare the benefit of thinking-before-googling to both the situation when (a) one is simply shown (presented-with) the correct information (Experiment 2a & 2b) *and* (b) one is asked to try to answer a question before being presented with the solution, which is the more traditional pretesting set-up (i.e., thinking-before-presented condition, Experiment 3). All of these experiments, illustrated in Figure 7, were conducted using within-participants research designs and consisted of three phases: learning, short distractor, and final test.

Figure 7

A schematic illustration of the Designs and Phases for Experiments 1-3



Note: See the online article for the color version of this figure.

Experiment 1

In Experiment 1, we assessed whether an initial attempt to answer a question would be more beneficial, based on the aforementioned pretesting benefits, for learning than immediately googling the answer. Additionally, we explored whether the level of difficulty of the to-be-learned content would influence potential pretesting effects when using the internet. Our thinking was that when answers could be easily generated, the activity of doing so would become less engaging and, thus, less likely to produce a pretesting benefit for such items, which, in turn, would lessen the likelihood of our observing a significant overall benefit for thinking-before-googling over googling-right-away.

Method

Participants

A total of 62 undergraduate students recruited from the University of California, Los Angeles (UCLA), Sona subject pool served as participants in exchange for research credit. Of these, 46 listed their gender as female, 15 as male, and 1 as other. Participants' ages ranged from 18 to 45 years, with a mean of 21.7 years and a standard deviation of 4.9. We excluded 22 participants for technical difficulties (e.g., internet problems, persistent distractions) or for not following instructions properly (see page 12 for more information on exclusion criteria). IRB approval for all experiments in this research work was obtained from Applying Cognitive Psychology to Enhance Educational Practice: II, IRB#11-002880.

Design

The experiment used a 2 x 2 within-participants design with two independent variables: condition (thinking-before-googling vs. googling-right-away) and question difficulty (easy vs. hard).

Materials

The materials for the consisted of 28 general-knowledge questions, selected from the norms created by Tauber et al., (2013). These were split into 14 easy questions with a probability of recall ranging from 0.33 to 0.79 (e.g., “Which sport uses the terms “Gutter” and “Alley”?: Bowling; “What is the name of the mountain range in which Mount Everest is located?”: Himalayas) and 14 relatively hard questions with a probability of recall ranging from 0 to 0.05 (e.g., “What is the name of the unit of measure that refers to a six-foot depth of water?”: Fathom; “What is the name of the substance derived from a whale that is used to make perfume?”: Ambergris). Results of a pilot study indicated that this method of manipulating difficulty for the general-knowledge questions was effective.

Setting and Initial Instructions

Participants used a lab desktop computer and their personal laptop to complete the experiment online. The majority of the experiment was performed on the lab desktop computer using Collector (http://github.com/gikeymarcia/Collector), a Hypertext Preprocessor-based open-source tool for running psychology experiments over the internet. Personal laptops were used for Google searches only. Participants were required to conduct Google searches on their personal laptops instead of the lab desktop computer (where all general-knowledge questions appeared) in order to prevent them from simply copying and pasting the questions from one Google window into another Google window on the same computer, which they might do without even looking at or reading the question in order to complete the study as quickly as possible. We thought having participants type out the exact general knowledge question on their own computer, but then having to type out whatever answers they found in the designated answer box back on the lab computer, would prevent participants from rushing through the experiment without careful reading or consideration of the questions or answers found in Google.

At the outset of the experiment, participants were told that they would be presented with a number of general-knowledge questions, and that for each question, they would either be asked to "look up the answer on Google" or to "try to come up with the answer [yourself] first before googling it". Participants were informed that some of the general-knowledge questions were easy and others were relatively hard, but for all questions—even when they believed they already knew the answer—they should still look up the answer on Google when instructed to do so. Additionally, for questions to which they were instructed to think what the answer might be before being allowed to search for it, they should try to come up with some answer on their own even though they felt their answer was unlikely to be correct. In such cases, participants were instructed to enter whatever seemed like it could be a possible answer. Lastly, participants were asked to type each question into the Google search bar, instead of using Google's autocomplete function in order to ensure that they were attending to and reading the question at least once[1].

Control Measures

During the learning phase, as indicated in Figure 7, half of the general-knowledge questions were presented to participants in the googling-right-away condition and half were presented in the thinking-before-googling condition. Additionally, across participants, the assignment of questions to conditions (i.e., googling-right-away vs. thinking-before-googling) and to presentation order during the learning phase was determined randomly.

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[1] There is room for future work to assess the potential role of elaborative/active processes when using Google. For example, would internet users engage in different levels of processes when they are instructed to type out the exact question versus using their own words, or whether they are asked to use Google's autocomplete function?

Procedure

For the googling-right-away trials, participants were provided with a general-knowledge question on the lab computer and were told to google or search for the answer on their personal laptop and then return to the lab computer in order to type that answer into the appropriate box on the lab computer. Participants had up to one and a half minutes to complete the search and type in the answer. In the thinking-before-googling trials, participants were instructed to attempt to answer a question first before turning to Google, even if an answer did not readily come to mind and they thought that they would not be able to think of the correct answer. Critically, participants had to spend a minimum of 5 seconds contemplating and entering an answer attempt before the computer program would allow them to advance to the Google search. This 5-s delay prevented participants from simply deciding that the question was too difficult and thus choosing to consult Google too quickly when struggling to produce an initial guess. Participants were then given 1.5 min to use their personal laptops to search Google for the correct answer before typing that answer into the empty answer box on the lab computer.

Finally, after playing Tetris for ten min as a distractor task, participants were given a cued-recall test for all 28 general knowledge questions. Questions were presented one-by-one, in random order, with participants asked to recall the correct answers retrieved from Google, and no feedback was provided. After the final test, participants were asked the following questions about the experiment:

1. For those questions for which you were instructed to look up answers on Google immediately, did you actually look them up on Google as instructed (even if you knew the answer in your head)?

2. For those questions for which you were instructed to try to answer the questions first before using Google, did you actually try to answer the questions (even if you struggled to come up with an answer)?
3. Did you type out the *exact* question in Google as opposed to using your own words or autocompletion to look up the answer?
4. Did you use the Google Chrome browser?
5. What is your go-to search engine? (E.g., Google, Yahoo, Bing, etc.?)

Data from participants answering "no" to any of the first two questions were excluded.

Results

Pretest Attempt Performance

We first analyzed participants' performance on the pretest items. Not surprisingly, participants generated more correct answers to easy trivia questions ($M = .44$, $SD = .21$) than to hard ones ($M = .05$, $SD = .11$).

Final Test Performance

Final test performance for Experiments 1, 2a, and 2b are presented in Table 2. To analyze the results shown there for Experiment 1, we conducted a 2 (difficulty: easy vs. hard) x 2 (learning strategy: thinking-before-googling vs. googling-right-away) repeated-measures Analysis of Variance (ANOVA). This analysis revealed a significant interaction, $F(1, 61) = 10.98$, $p = .002$, between difficulty and learning strategy; namely, for hard questions, a significant difference in performance was observed when participants thought about the answer prior to their Google search (thinking-before-googling: $M = .44$, $SD = .25$) than when they immediately googled the answer on the internet (googling-right-away: $M = .35$, $SD = .22$), $t(61) = 3.92$, $p < .001$; whereas, for easy questions—as we suspected might be the case—no significant effect of learning strategy for thinking-before-googling (*M* = .86, *SD* = .17) versus googling-right-away (*M* = .88, *SD* = .13, $t(61)=0.84$, $p = .40$) was observed.

Table 2

Means and standard deviations for final cued-recall scores as a function of Difficulty and Learning strategy *for Experiments 1, 2a, and 2b*

	Difficulty			
	Easy		Hard	
Learning strategy	*M*	*SD*	*M*	*SD*
Experiment 1				
Googling-right-away	0.88	0.13	0.35[a]	0.22
Thinking-before-googling	0.86	0.17	0.44[a]	0.25
Experiment 2a				
Googling-right-away	0.87	0.18	0.39[b]	0.30
Presented-with	0.81	0.23	0.38	0.27
Thinking-before-googling	0.88	0.15	0.47[b]	0.30
Experiment 2b				
Googling-right-away	0.87	0.19	0.36[c]	0.28
Presented-with	0.79	0.22	0.38	0.27

Thinking-before-googling	0.85	0.20	0.44^{c}	0.30

Note. Matching letters denote significant difference ($p < 0.05$) among pairs of conditions.

Experiments 2a and 2b

Experiments 2a and 2b replicate the conditions of Experiment 1 while adding a third condition: presented-with. In this condition, participants were presented with question-answer pairs and never consulted Google for answers.

The addition of a presented-with condition was to allow a comparison of the potential benefits of learning information with the internet as compared to learning the same information without internet use. Perhaps the way people learn from googling is somehow special. Maybe just the act of searching for, identifying, and selecting relevant pieces of information on the internet (googling-right-away condition) — even though in the present research, the trivia questions had only a single clear-cut answer — is itself a more elaborative learning process than simply studying the correct relevant information when it is presented intact (presented-with condition of Experiment 2a and 2b; e.g., Marsh & Rajaram, 2019).

If, however, learners simply use Google as a means to cognitively offload memory processes—failing to exert effort to process and store information internally, and instead trusting Google to remember the information (e.g., Ward, 2013b; Wegner & Ward, 2013)—it seems plausible that googling right away might be no more, and possibly less, effective than simply being presented with information.

Method (Experiments 2a and 2b)

Participants

A total of 67 undergraduate students (44 in Experiment 2b) recruited from the UCLA Sona subject pool participated in exchange for research credit. Of these, 50 listed their gender as female, and 17 listed their gender as male. Participants' ages ranged from 18 to 28, with a mean of 20.19 years and a standard deviation of 1.71. Of the 44 in Experiment 2b, 38 listed their gender as female, and 6 listed their gender as male. Participants' ages ranged from 18 to 28, with a mean of 20.39 years and a standard deviation of 1.56. We excluded 26 participants in Experiment 2a, and 22 participants in Experiment 2b for technical difficulties (e.g., internet problems, persistent distractions, etc.) or for not following instructions properly.

Design

Experiments 2a and 2b employed a 3 x 2 within-participants design with two independent variables: learning strategy with three levels (thinking-before-googling vs. googling-right-away versus presented-with), and difficulty with two levels (easy vs. hard questions).

Based on pilot testing, it was determined that in the two Google learning conditions (googling-right-away and thinking-before-googling), participants would spend about 6 s with the question and answer together before moving on to the next question. Although prior science-of-learning research has shown that how one engages with the to-be-remembered information is more important for its retention than is its presentation duration, the possibility remained that having each question-answer pair presented for 10 s in the presented-with condition as compared to only 6 s in the two other learning conditions (thinking-before-googling and googling-right-away) might have served to obscure potential effects of the act of googling itself. Experiment 2b, therefore, sought to test this alternative explanation by making the exposure duration of the question-answer pairs consistent across those conditions. All other aspects of the materials and procedure remained the same as in Experiment 2a.

Materials and Instructions

The materials for Experiment 2a included 30 general knowledge questions taken again from the Tauber et al. (2013) norms, with 15 easy and 15 hard questions randomly divided across the three learning strategy conditions (e.g., 5 easy googling-right-away questions and 5 hard googling-right-away questions and so on for the other two learning strategy conditions).

Initial learning instructions were adjusted owing to the addition of the presented-with learning strategy, in which participants were asked to simply read the general knowledge question and its corresponding answer when they were presented on the lab computer screen (e.g., What is the last name of the man who created the comic strip “Woody Woodpecker? - Lantz).

Procedure

Experiment 2a involved four phases: introductory instructions; presentation of the individual general knowledge questions with the appropriate instruction regarding googling or just reading; distractor task; and final cued-recall test. In the googling-right-away and thinking-Before-Google conditions, participants were allotted 1.5 min to search for an answer on Google using their personal computer and then to record that answer in an empty answer box that appeared on the lab computer screen. In the presented-with condition, participants were shown a question and its answer simultaneously for 10 s on the lab computer before advancing to the next question. After a 10-min Tetris distractor task, participants were tested on all general knowledge questions and were then asked a number of questions exactly as they had been in Experiment 1, with the addition of two new questions in Experiment 2b, as shown below:

1. In your own daily life, what do you typically do when you want to know the answer to a question (e.g., "Who won the Superbowl two years ago?" or "Which president was elected into office four times?") Please be honest!!

    A. I look up the question on the internet

    B. I try to answer the question myself first before looking up the answer.

2. In this study, you experienced three different instructions throughout the experiment. For each question, you were asked to look up the answer on Google, try to come up with the answer yourself first before googling, or simply read the question and corresponding answer presented to you on the lab computer screen. Which one of these three types of instructions do you think was better for remembering the googled information later?

    A. look up the answer on Google;

    B. try to come up with the answer yourself

    C. read the question and corresponding answer presented to you.

After answering the final questions, they were thanked for their participation and dismissed from the experiment.

Results: Experiment 2a and 2b

Pretest-Attempt Performance

Pretest performance was similar to that observed in Experiment 1; that is, easy questions (Experiment 2a: $M = .46$, $SD = .26$; Experiment 2b: $M = .46$, $SD = .28$), were answered correctly more often than were hard questions (Experiment 2a: $M = .06$, $SD = .14$; Experiment 2b: $M = .05$, $SD = .10$).

Final Test Performance

For Experiments 2a and 2b we planned three comparisons: (a) performance in the thinking-before-googling versus the googling-right-away conditions for hard questions only; (b) performance in the presented-with versus the googling-right-away conditions for hard questions only; and (c) to test for a generation effect, given the suggestion from Experiment 1 that participants could produce answers for easy questions regardless of instructions. The additional presented-with condition allowed us to test whether generating an answer (as happened in either of the Googling conditions) was more effective for learning than being presented with the information.

Planned Comparisons Results

Planned Comparison 1 result showed that we replicated the results found in Experiment 1 for hard questions: Both the thinking-before-googling conditions of Experiment 2a and Experiment 2b (M = .47, SD = .30; M = .44, SD = .30, respectively) led to significantly better final performance than did their respective googling-right-away conditions (M = .39, SD = .30 and M = .36, SD = .28 respectively), Experiment 2a: $t(66) = 2.39$, $p = .02$, 95% CI = [.01, .10.]; Experiment 2b: t(42) = 2.07, $p = .04$, 95% CI = [.001, .11].

For Planned Comparison 2, we found that for hard questions, googling-right-away (Experiment 2a: M = .39, SD = .30; Experiment 2b: M = .36, SD = .28) did not produce a significantly better final recall benefit compared to the presented-with condition (M = .38, SD = .27 and M = .38, SD = .27 for Experiments 2a and 2b, respectively), Experiment 2a: $t(66)$ = .24, $p = .81$, 95% CI = [-.05, .06.]; Experiment 2b: $t(42) = .71$, $p = .48$, 95% CI = [- .07, .03].

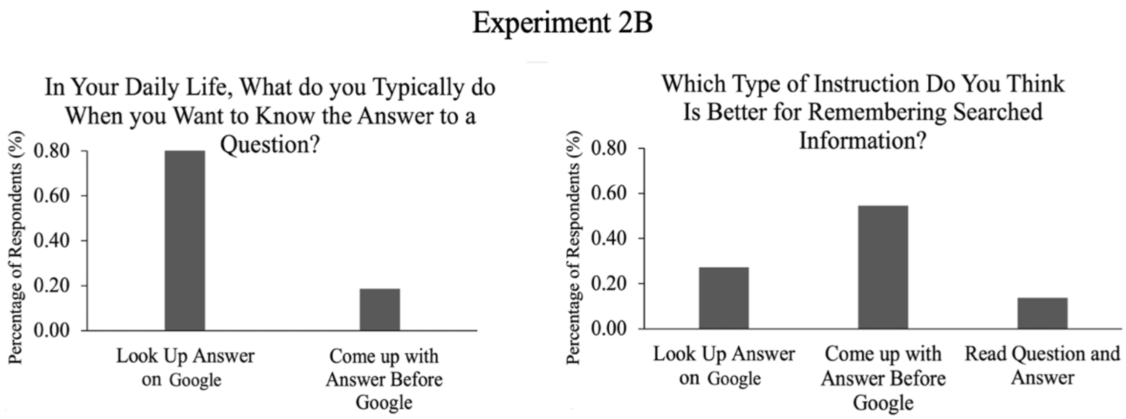
Our third planned comparison tested for a possible generation effect for easy questions. Results showed an advantage of Googling either before or after trying to think of the correct answer (i.e., averaging the googling-right-away condition and the thinking-before-googling condition, $M = .88$, $SD = .13$ and $M = .86$, $SD = .16$ for Experiments 2a and 2b, respectively) over being presented with the information intact (presented-with condition, $M = .81$, $SD = .23$ and $M = .79$, $SD = .22$ for Experiments 2a and 2b, respectively) as evidenced by a paired-samples t test, Experiment 2a: $t(66) = 2.09$, $p = 0.04$, 95% CI = [.002, .10]; Experiment 2b: $t(42) = 2.4$, $p = 0.02$, 95% CI = [.01, .11]. Thus, it would seem that the act of googling can function as a generation activity with beneficial effects on long-term memory similar to the findings of Jacoby (1978) and Slamecka and Graf (1978). Additionally, the present lack of a performance difference between the thinking-before-googling and googling-right-away conditions may mean that when answers come to mind for the easy questions they mostly come to mind right away, whatever the instructions.

Responses to the Post-experiment Questions (Experiment 2b only)

Finally, we examined answers for the metacognitive post-experiment questions, which are shown in Figure 8. As indicated in the left panel of Figure 8, a large majority of participants (81%) report that when faced with a question, their first act is to look up the answer on Google while only a minority (around 19%) report that they first try to come up with the answer before using the internet. In contrast to this report about their own behavior, the pattern shown in the right panel of Figure 8 reveals that more participants (55%) report thinking that trying to come up with the answer to a question first before searching for it on the internet would be more effective for learning that information than would be immediately looking up the answer or having the question and its corresponding answer presented together (which are endorsed as being the most effective by only 31% and 14% of the participants, respectively). Easy access to the internet would thus seem to be leading individuals to frequently engage in behavior that they know is not inducive to their own learning.

Figure 8

Results From Metacognitive Post-experiment Questions in Experiment 2b



EXPERIMENT 3

Experiment 3 mimicked Experiment 2b but with an additional learning strategy: thinking-before-presented. Participants were shown a question and asked to think about the answer, after which they were given the correct answer instead of searching for it on Google (akin to a traditional pretest paradigm).

Based on the aforementioned mechanisms underlying pretesting benefits, we expected the two "thinking before" learning conditions to result in better memory for the to-be-learned information than the two "presented-with" conditions (googling-right-away and presented-with), both of which seem to represent more passive approaches to learning information.

Method

Participants

Given that for Experiment 3, we were adding yet another within-subjects condition, we performed an ad hoc power analysis using the effect sizes attained in Experiment 2b. The power analysis determined that a sample size of 230 is needed to reach 80% probability of detecting a small effect, and we were able to recruit 223 participants from the UCLA Sona subject pool who served for course credit. Of these 223, 175 listed their gender as Female, 46 listed their gender as Male, and 2 listed their gender as other. Participants' ages ranged from 18 to 35 with a mean age of 20.2 and a standard deviation of 2.4. We excluded 57 participants for technical difficulties (e.g., internet problems, persistent distractions, etc.) or for not following instructions.

Design

Experiment 3 used a 4 x 2 within-participants design with four levels of the learning strategy variable (googling-right-away vs. thinking-before-googling vs. presented-with vs. thinking-before-presented) and two levels of question difficulty (easy vs. hard).

Materials

The materials for the experiment consisted of 32 general knowledge questions, selected again from the Tauber et al. (2013) norms. The questions were split into 16 easy questions and 16 relatively hard questions.

Procedure

All aspects of the procedure remained the same as Experiment 2b with one addition: To encourage real engagement with the trivia question in the thinking-before-presented condition, participants were required to wait 5 s after presentation of the question alone (same as in the thinking-before-googling condition) before being presented with the question and correct answer together for 6 s. Initial task instructions were updated to reflect this new learning strategy condition.

Results

Pretest-Attempt Performance

First, we examined pretest performance for easy and difficult questions, finding similar performance on easy questions in both the thinking-before-googling condition (*M* = .52, *SD* = .29) and the thinking-before-presented condition (*M* = .50, *SD* = .28) and also on hard questions for both the thinking-before-googling condition (*M* = .09, *SD* = .16) and the thinking-before-presented condition (*M* = .08, *SD* = .16).

Final-Test Performance

The pattern of performance on the final cued-recall test across the four learning conditions of Experiment 3 is shown in Figure 9. First, we performed the same planned comparisons as in Experiment 1, 2a, and 2b: thinking-before-googling versus googling-right-away with hard questions. Once again, the pattern of results demonstrates better retention of the searched-for-information when participants thought about a difficult trivia question prior to using the internet (thinking-before-googling: *M* = .59, *SD* = .31) as compared to when participants immediately searched for the information on Google with no prior thinking (googling-right-away: *M* = .52, *SD* = .32), $t(222) = 2.67$, $p = .008$, 95% CI = [.012, .078].

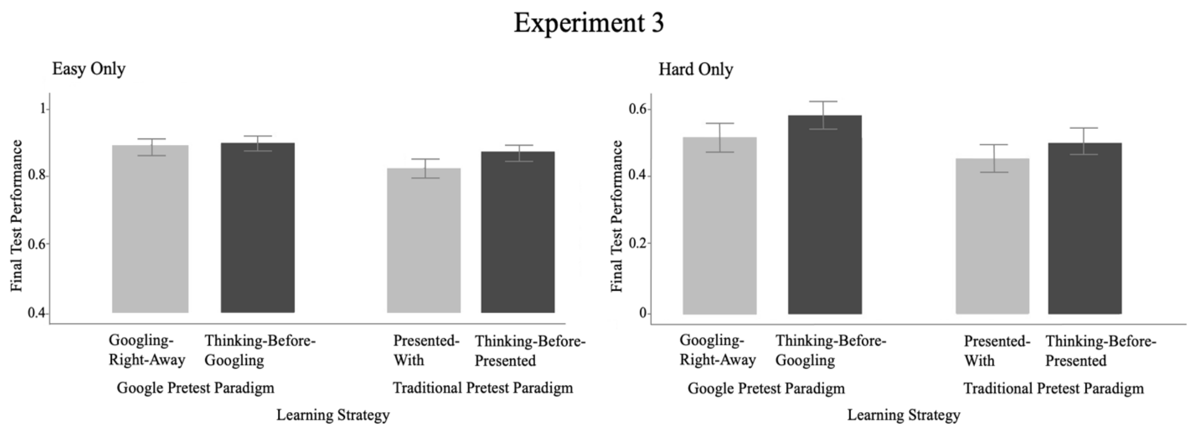
The goal of Experiment 3 was to compare performance obtained between the traditional pretest paradigm conditions (thinking-before-presented vs. presented-with conditions) and our Googling pretest paradigm conditions (thinking-before-googling vs. googling-right-away). To that end, we first compared the traditional pretest paradigm conditions and obtained a pattern of results demonstrating a significant benefit of pretesting under conditions similar to the traditional pretesting paradigm (e.g., Grimaldi & Karpicke, 2012; James & Storm, 2019; Kapur & Bielazuc, 2012; Kornell et al., 2009; Little & Bjork, 2011; Richland et al., 2009) for questions of both low and high difficulty. Specifically, for hard questions, participants correctly recalled significantly more answers when they had been asked to think first what the answer to questions might be before being presented with the answer (thinking-before-presented: *M* = .50, *SD* = .29) versus when they were immediately given the answer (presented-with: *M* = .46, *SD* = .31), $t(222) = 2.03$, $p = .044$), 95% CI = [.001, .059]. Similarly, for the easy questions, participants' performance on the delayed final cued-recall test was significantly higher when they were asked to think about the answer before it was presented than when they were merely presented with the correct answer along with the question (thinking-before-presented: *M* = .87, *SD* = .19 vs. presented-with: *M* = .83, *SD* = .21), $t(222) = 2.65$, $p = .009$, 95% CI = [.008, .057].

After confirming that both the traditional pretest paradigm and googling pretest paradigm results were replicated, we compared the active conditions from each pretest paradigm (thinking-before-googling vs. thinking-before-presented) with one another and the passive conditions from each pretest paradigm (googling-right-away vs. presented-with) for hard questions only. Results showed: (a) higher performance in the thinking-before-googling condition (*M* = .59, *SD* = .31) versus the thinking-before-presented condition (*M* = .50, *SD* = .29), $t(222) = 3.51$, $p<0.001$, CI = [.026, .09]; and (b) higher performance in the googling-right-away condition (*M* = .52, *SD* = .32) than in the presented-with condition (*M* = .46, *SD* = .31), $t(222) = 2.65$, $p=0.009$, CI = [0.01,0.07].

Finally, we compared effect sizes of the traditional pretest paradigm to the Google pretesting paradigm for hard questions, finding the traditional pretesting paradigm (thinking-before-presented condition vs. presented-with condition) to yield a Cohen's *d* of .136 and the Google pretesting paradigm (thinking-before-googling condition vs. googling-right-away condition) to yield a Cohen's *d* of .25.

Figure 9

Final Test Performance for Experiment 3 as a Function of Learning Strategy (Googling-Right-Away vs. Thinking-Before-Googling vs. Presented-With vs. Thinking-Before-Presented) and Question Difficulty (Hard vs. Easy)



Note. Performance on the final cued-recall test for the google-right-away and thinking-before-googling conditions (i.e., Google pretest paradigm) and presented-with and thinking-before-presented conditions (i.e., traditional pretest paradigm,) for easy questions (left panel) and for hard questions (right panel). To facilitate comparisons, although each graph's ordinate differs in their starting and ending values, the range has been kept the same.

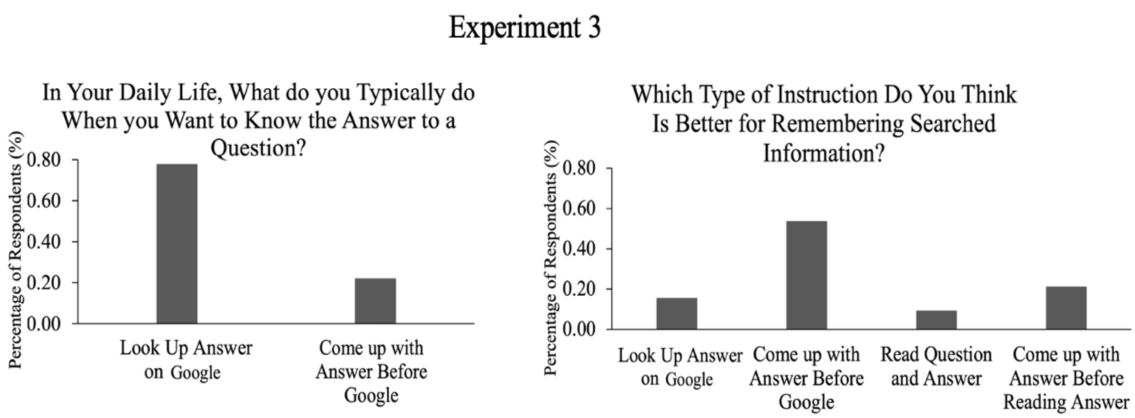
Participants' Answers to the Post-experiment Questions

Finally, we examined participants' answers to the metacognitive questions, which are illustrated in Figure 10. As shown in the left panel of Figure 10, 78% of participants report that when presented with a question, they typically immediately search for the answer whereas only 22% say they typically try to generate the answer prior to searching for it on the internet.

Additionally, as shown in the right panel of Figure 10, 16% of participants believe that looking up the answer on the Google is most beneficial for remembering that answer; 54% believe that coming up with the answer before searching for it on the internet is most beneficial for remembering it; 9% of participants believe that reading the question and corresponding answer is most beneficial for remembering the answer, and 21% believe that coming up with an answer before being presented with it is most beneficial for remembering it.

Figure 10

Metacognitive Question Results From Participants from Experiment 3



General Discussion

The internet is a remarkable source of information, one that makes it seem less important to remember things on our own and creates a growing dependence on the internet, a dependence that appears to affect the functioning of our own memories (Carr, 2008; Giebl et al., 2021; Marsh & Rajaram, 2019; Sparrow & Chatman, 2013; Storm & Soares, in press; Storm et al., 2020; Ward, 2013a & b). Offloading information to the internet and then only remembering *where* to find it bypasses the retrieval processes that might not only enhance our learning and understanding of information we already possess, but of related new information as well.

Participants in the present research were presented with trivia questions. In Experiment 1, they were asked to think about the answer before consulting the internet (thinking-before-googling condition) or were instructed to immediately search for the answer online without attempting to answer the question (googling-right-away condition). Experiments 2 and 3 added conditions in which learners either had no access to the internet or question-answer pairs were presented in order to create a study event, rather than a retrieval event. A fourth experiment used a traditional version of the pretesting paradigm, with learners presented with questions that they were to try to answer from memory before being given the answer.

Across all experiments, attempting to answer a question before consulting the internet—that is, thinking-before-googling—led to greater learning than did googling the answer right away, thus, emphasizing the importance of retrieval and generation processes in optimizing the functioning of human memory (also see Bjork 1975; Bjork & Storm, 2011; Roediger & Karpicke, 2006; Roediger & Butler, 2011; Storm et al., 2010; for reviews on the testing effect, see Carpenter, 2012; for meta-analyses, see Adesope et al., 2017; Rowland, 2014; for a review on the Generation Effect, see Bertsch et al., 2007).

As asserted in Bjork and Bjork (2011), based on research that predates Google, "…any time that you, as a learner, look up an answer or have somebody tell or show you something that you could instead, drawing on current cues and your past knowledge, generate yourself, you rob yourself of a powerful learning opportunity." (p. 61). An argument might be made, of course, that spending time trying to retrieve information in some domain where we know in advance that succeeding is highly unlikely is a waste of time. As intuitive as that argument might be, research on pretesting effects (e.g., Kornell et al., 2009; Little & Bjork, 2011) has demonstrated that even a failed attempt at retrieval can nonetheless enhance subsequent encoding and retention of to-be-learned information.

The findings from Experiment 2a and 2b were consistent with the proposition that when learners immediately search the internet for answers, their memory for those answers will be no better than had they simply been given that information. Thus, if—as indicated by participants' answers to our metacognitive questions—our tendency is to google immediately rather than first thinking, our nearly ubiquitous access to the internet provides us with nearly unlimited opportunities to rob ourselves of powerful learning events.

On the brighter side, it is possible that using the internet engages the learner in at least some of the processes known to potentiate learning and remembering. For example, searching the internet may seem more interesting than simply being given the to-be-learned information. If so, googling might ignite greater curiosity about the material we seek, which may then focus our attention to and our processing of the relevant information we find on Google, resulting in better learning and retention of that information (e.g., Berlyne, 1954. Hannafin & Hughes, 1986; Peeck, 1970; Pressley et al., 1990). Furthermore, a search on the internet may motivate elaborative thinking. Perhaps looking for an answer on the internet requires the user to think ahead about an appropriate keyword in quest of the desired information. Thinking about the "right search" may cause us to evaluate what we currently hold in memory and what pieces of the puzzle are missing to complete the picture, or to think more deeply about the way to formulate a search question—all of which may promote more active user-internet interaction than if the information is simply studied or presented (Greenfield, 2015). Results from Experiment 3 as well as research conducted by Storm et al. (2020) provide preliminary support for the idea that answering questions with the help of the internet may produce benefits similar to the effects of a traditional pretesting effect.

Another finding worth highlighting is that thinking-before-googling not only produced better memory for the sought-out information versus when participants googled the information right away, but also led to superior memory in comparison to when participants were required to try to generate a possible answer before being presented with the correct information (thinking-before-presented condition). This finding suggests a role for agency: When we turn to the internet, we are consciously seeking out knowledge. In contrast, when the answer simply appears on our screen, without our having to search for it, our role in the learning process is more passive. It seems possible, then, that contemplating a potential answer first and then searching for it on Google could lead to a greater sense of agency over the learning process than when, after a pretest, learners are just presented with the correct answers without further action on their part (i.e., traditional pretest paradigm).

Another aspect of the present research that deserves discussion is that the type of practice was manipulated within participants. Thus, participants googled answers for some trivia questions and attempted to think before googling for other trivia questions. Thus, some carry-over effects across conditions may have occurred in the present research. In particular, perhaps having been required to think about trivia questions before googling the answer on some trials, led participants to continue engaging in such internal memory processes on trials where they were allowed to google right away, thereby enhancing learning in the same way as in the thinking-before-googling condition. That performance on these two types of trials were significantly different, however, would argue against any such carryover effects playing a major role in the present pattern of results.

Additionally, established findings in the testing effect literature would argue against the possibility of carry over effects playing a major role in the present pattern of results. Abel and

Roediger (2017), for example, have shown that the benefit of retrieval practice seems to be unaffected by the exact format of practice. (For retrieval practice benefits in various practice formats, see Karpicke & Roediger, 2008; Pyc & Rawson, 2010, for between-participant designs; Butler, 2010; Zaromb & Roediger, 2010, for within-participant designs; Carpenter & DeLosh, 2006; Carpenter et al., 2008; Karpicke & Zaromb, 2010, for mixed within-participant designs, and Rowland, 2014, for a recent meta-analysis).

Consonant with the findings that testing boosts memory to an equal extent regardless of practice format, we also found no evidence of possible spillover effects among our four practice conditions. Indeed, in all experiments we found that thinking of a possible answer to a trivia question boosts memory for that information more than when the internet is immediately consulted without first guessing.

Finally, it is important to consider the implications of the present metacognitive results and what they might imply regarding how we can best make use of the internet. Although the results of the present study indicate that thinking before googling is better for learning and memory, the majority of participants in Experiments 2b and 3 reported that in their everyday life they look up answers on the internet right away as opposed to trying to come up with an answer first on their own. This finding suggests that most users of the internet are just seeking to find information they need quickly and have no initial intention of actually learning that information as well. Or possibly, they are just assuming that just by finding it, they will remember it. When, however, our participants were asked the question of what they thought was better for remembering searched information on the internet—thinking about an answer first or googling it right away—they overwhelmingly reported that thinking-before-googling promotes better learning and memory. This apparent inconsistency may arise, in part, from these particular responders having just experienced such an effect while participating in the present research and, thus may go on to change—for at least some of them some of the time—how they interact with the internet. It seems likely that future research aimed at addressing questions of this type might reveal some promising directions for how to encourage more effective use of the internet, especially when we do, in fact, want to enrich our memories with the information we find there.

Conclusion

We cannot and do not want to go back to a world in which the internet is not a resource for us. Indeed, most of us feel we cannot live without it. The present findings suggest one possible way in which human memory and the internet can enjoy a symbiotic relationship, but much more needs to be learned regarding how best to live with this amazing resource.

CHAPTER 4

What Might Motivate Learners to Think Before Googling?

The Role of Hints

Attempting to generate a potential answer to a question before consulting the internet, aka thinking-before-googling, can promote better memory than simply googling the answer right away (Giebl et al., 2021, 2022). Yet, when asked about daily interactions with the internet, people overwhelmingly indicate that they typically turn to the internet for immediate access to answers rather than attempting to recall the answer first (Giebl, 2021). As a means of finding a way to motivate learners to engage more frequently in thinking-before-googling attempts, one goal of the present study was to investigate if the provision of hint support could lessen people's tendency to google the answer right away. A second goal was to examine if the strength of the thinking-before-googling effect would be reduced as the "strength" of the hint increased. Across three experiments, participants were presented with general knowledge questions. For half of the questions, participants were told to attempt to answer before turning to the internet. Critically, these questions were accompanied with the first letter (Exp. 1), the first two letters (Exp. 2), or the first three letters of the answer (Exp. 3). For the other half of questions, participants were instructed to google the answer right away. At the end of all three experiments, participants were asked to report their thoughts on a hypothetical "Google Think" feature that would promote thinking-before-googling. Our data revealed that, overall, thinking-before-googling trials led to better memory retention than googling the answers for trivia questions right away, thus replicating the thinking-before-googling effect. We also found, consistent with Vaughn and Kornell (2019), that the strength of the hint; that is, the number of letters participants received when thinking-before-googling, did not change the degree to which memory benefitted from thinking-before-googling efforts. Further, when presented with the idea of a hypothetical "Google Think" feature, learners reported a greater desire to engage in thinking-before-googling (Exp. 4). Taken together, our results provide additional evidence that the mere act of taking a moment to think about an answer prior to searching for it, can enhance memory retention, regardless of the quantity of cue support.

Since its introduction in the 1960s, the internet has become a major source of information, one that provides direct access to an ocean of continuously updated knowledge (Sparrow & Chatman, 2013; Ward, 2013a; Ward, 2013b). And the ocean is truly massive. As an example, the final book in the Harry Potter series, Harry Potter and the Deathly Hallows*,* takes the reader on a 500-page adventure that takes nearly 22 hours to narrate. Yet that is nothing compared to the information held within the internet, which contains the information equivalent of over 35 billion such 500-page books (Ward, 2013b).

Having such content at our fingertips is a remarkable asset, but the consequences do not seem entirely positive (see Carr, 2008; Clark & Chalmers, 1998; Giebl et al., 2021; Giebl et al., 2022; Loh & Kanai, 2016; Marsh & Rajaram, 2019; Sparrow & Chatman, 2013; Sparrow et al., 2011; Storm, 2019; Storm & Soares, in press; Ward, 2013a & b). There are clearly substantial benefits of having rapid access to so much information (Runge et al., 2019; Storm & Stone, 2015), but offloading search processes to the internet, rather than searching our own memories, may result in *an* overdependence on this external tool, with some potentially negative consequences for learning (Storm et al., 2017).

Learning With the Help of the Internet: The Good, The Bad, and A Better Way

The Good

One benefit of the internet is its ability to provide what is, in effect, a transactive memory system among individuals (Wegner, 1987). In a transactive memory system, members develop and exhibit task-specific expertise and share such knowledge with other individuals in the system. Traditionally, a transactive memory system consists of only people as memory partners; however, such networks increasingly involve digital tools (Wegner, 1995; Wegner, 1987). The internet has positioned itself as the elite of all transactive memory partners: With a single search on Google, information that would be unrealistically difficult and time-consuming to collect from other sources can be quickly located within a digital cloud (Sparrow & Chatman, 2013; Ward, 2013a, Wegner & Ward, 2013). Furthermore, in contrast to people as transactive memory partners, who can become sick, hard to reach, or may even leave the system permanently, the internet is consistently accessible (Wegner, 1995).

Additionally, seeking information from the internet may provide an opportunity for the user to learn. The process of thinking about a question and deciding on an appropriate search term prior to googling may lead internet users to engage in more retrieval and evaluation processes of what they do or do not already know. Further, this metacognitive evaluation may encourage productive engagement with the searched information as compared to simply being exposed to the information. A recent study conducted by Storm and colleagues (2021) showed that using the internet to answer a series of difficult trivia questions promoted better memory retention compared to learning trials on which questions and answers were simply shown together to the learner. Across two experiments, participants were presented with difficult trivia questions and instructed to use Google immediately to answer some of the questions (internet retrieval condition), search their own memory for answers (memory retrieval condition), or simply read question-answer pairs presented together with the instruction to copy the answer by typing them out on the computer (control study-only conditions). Interestingly, better memory for trivia-question *answers* was demonstrated when participants searched for the answers–via using the internet or one's own memory–as compared to when the correct answer to the question was simply presented to learners.

This type of phenomenon is often called the pretesting effect and refers to the finding that attempting to generate an answer or grapple with a problem before being presented with the solution can promote one's subsequent learning of that information (and even related information) more than the mere exposure to the to-be-learned information (e.g., Carpenter et al., in press; Grimaldi & Karpicke, 2012; Huelser & Metcalfe, 2012; James & Storm, 2019; Kornell et al., 2009; Little & Bjork, 2011, 2016; Richland et al., 2009).

One possible explanation for the pretesting effect is that the attempt to guess the answer, even when unsuccessful, may spark curiosity and interest in the to-be-learned information (e.g., Berlyne, 1954a, 1954b). Pretesting may also trigger semantic activation of question-related knowledge (e.g., Kornel et al., 2009; Richland et al., 2009). Both processes may enhance attentional processing of the new information, leading to more elaborate and deeper encoding of the subsequent information when it is presented (e.g., Carpenter et al., in press).

The Bad

As wonderful as the idea that there are ways of engaging with the internet that can benefit one’s learning may sound, research has shown that people are becoming more inclined to use the internet to access information despite their being likely to already know the answer—and even when accessing the internet has been made difficult. Storm et al. (2017) presented participants with eight difficult trivia questions (e.g., “In what state have the most presidents been born?”), one at a time, and asked them to provide answers to the questions as quickly and as accurately as possible. Importantly, one group of participants was asked to attempt to answer the questions from their own memory, whereas another group of participants was told to use the internet to search for the answer, even if they thought that they knew it. No feedback was provided to either group. An additional control group of participants was not presented with any trivia questions. Next, participants were again presented with eight trivia questions, but ones that were relatively easy (e.g., “What is the center of a hurricane called?”), and were asked to respond as quickly and as accurately as they could. All participants were also given the *option* to use the internet or to search their own memory. Using the internet to look up answers for the initial set of difficult trivia questions (as opposed to trying to come up with an answer oneself) made participants 20% more likely to use the internet again. However, in Experiment 1a, the computer was within reach, thus making internet use highly convenient. This changed in Experiment 1b. In this experiment, participants had to walk across the room to access an old, incredibly slow iPad. This substantial inconvenience, however, did not deter learners who used the internet in the initial phase of the study from using the internet again.

These results suggest that depending on the internet to search for information makes one more likely to depend on the internet for future searches again, and thus may rob one of the opportunities to query their own memory for answers first. With this in mind, the question begs if there is a way to use the internet as a more effective learning tool, one that still continues to offer convenience and speed in access information but this time, with an active participation of the learner.

A Better Way? Using Pretesting when Learning via the Internet

In a recent study by Giebl et al. (2021) participants were taught several basic computer programming principles (e.g., how to store and replace one variable) followed by a difficult programming task for which they had not yet learned all of the coding skills necessary to solve the task (e.g., how to manipulate multiple variables). One group of participants searched the internet immediately for task-relevant information (no pretesting group), whereas the other group of participants attempted to solve the task prior to a Google search (pretesting group). Learning was assessed via an immediate multiple-choice test containing transfer-type questions. Consistent with the pretesting effect, participants who attempted to solve the programming task prior to consulting the internet performed better on the final transfer test than participants who consulted the internet right away, and participants with a little background knowledge in computer programming (but, importantly, not the specific knowledge needed for solving the present programming task) seemed to benefit the most from generating a potential solution to the task prior to consulting the internet.

Giebl et al. (2022) also found that trying to bring forward a potential answer to a question (aka pretesting) as opposed to googling the information right-away can boost memory for the searched content. Across four experiments, participants were presented with a series of difficult and easy general knowledge trivia questions and asked to attempt an answer before searching the internet (i.e., thinking-before-googling condition), to search Google for the answers immediately (i.e., googling-right-away condition), to attempt an answer to the question before being presented with the answer (i.e., thinking-before-presented, aka traditional pretesting format), or to simply read the question-answer pair (i.e., presented-with). Overall, thinking-before-googling led to better memory retention than googling the information right away or simply being presented with the question-answer pair. Taken together, these findings indicate that attempting to retrieve the correct answer to a question before using Google to find the answer is a potent way to promote new learning. But in daily life**,** do learners actually engage in retrieval attempts while using Google as a source of information?

According to a post-experiment survey from Giebl et al., (2022) more learners believed that thinking-before-googling was a better learning strategy than googling the answer right away, in line with the test performance data. Nevertheless, the majority of learners reported that, when faced with a question, their first response is to search the Internet for the answer instead of attempting to come up with a potential answer themselves. Together, these results suggest that, although people may believe thinking-before-googling may lead to enhanced retention of searched content, internet users generally do not do so, potentially to their detriment.

Why Pretesting May Not Appeal to Learners

Pretesting oneself while using search engines may not common for a variety of reasons. For one, people may find pretesting effortful and time consuming. That is, spending time thinking about something that one already believes they do not know stands counter to what the users imagine to be the purpose of the internet: a fast delivery service of information. With this in mind, one can understand why learners may not even consider making the effort to generate a possible answer to a question, and, instead, search the internet right away.

Learners may also find pretests unconventional and almost counterintuitive to complete. Such feelings seem likely to be evoked when learners are asked for answers to information that they have not yet learned, but may also arise in cases when learners know the information but may not be confident in their knowledge yet. Learners may also prefer to "double check " their knowledge, regardless of their confidence in it, if given the option.

It is also possible that learners may feel that there is no point in trying to answer a question that they are very likely to fail in answering. For example, research work in a similar domain to the pretesting effect has shown that learners are more likely to engage in the learning benefits of testing themselves on previously learned information over restudy when they feel a greater level of competence in producing the right answer (For research work on the learning benefits of testing effect, see Bjork & Bjork, 2011; Carpenter et al., 2008; Karpicke & Roediger, 2008; Rawson & Dunlosky, 2011; Roediger & Karpicke, 2006; also see a meta-analytic review on the testing effect by Adesope et al., 2017; Rowland, 2014). Kornell and Bjork (2007) presented participants with the choice on how to study language word pairs across multiple study trials: self-testing versus being presented with the information-to-be-learned. Interestingly, the majority of participants chose to start off with a presentation of the new vocabulary pairs as opposed to testing themselves on the pairs but then quickly switched from study mode to self-testing mode, suggesting that when learners feel a greater sense of getting the answer right, they are more motivated to engage in self-testing/retrieval practice (for similar results, see Son, 2005).

How to Make Pretesting Attractive When Using the Internet: Need a Hint?

Vaughn and Kornell (2019) found that learners can warm up to the idea of self-testing/retrieval practice. More specifically, their paper demonstrated that learners are more likely to engage in challenging (but effective) learning strategies, such as self-testing, when they think their odds of being correct increase. Undergraduate students were tasked with learning sets of unrelated word pairs (e.g., menu - hordes). When only given the choice between restudying the word pair or recalling it completely from memory, students chose to restudy over 80% of the time. When, however, students were given the option to practice test with a hint (receiving the first 2 or 4 letters of the word), they chose to practice test 71% of the time. Notably, this scaffolded practice was just as effective for learning as practice testing completely from memory.

As the authors conclude, learners were not shirking from the challenge or effort required of practice testing, or even avoiding the opportunity to make and learn from errors. Instead, they seemed to find making retrieval attempts without these hints unappealing, given the high likelihood of failure, but were willing to engage in retrieval when they perceived that they had a reasonable chance of succeeding at the attempt.

The Present Study

An Overview

The present study was designed with two goals in mind: (1) to evaluate what effect cue support might have on learning when participants engage in pretesting when learning with the internet (aka thinking-before-googling versus googling-right-away) and (2) to explore participants' preferences for pretesting when using the internet in daily life, as thinking-before-googling (aka pretesting) is beneficial only to the degree that learners actually engage in such retrieval attempts. In Experiments 1-3, a within-subject design format, participants were presented with easy and hard general knowledge questions and instructed to either attempt to provide an answer to a question prior to googling (i.e., thinking-before-googling) or search for the information on the internet immediately (i.e., googling-right-away). For thinking-before-googling trials, learners were cued with either one-letter (Experiment 1), two-letter (Experiment 2) or three-letter (Experiment 3) hints. After a brief delay, memory for the answers to the trivia questions was assessed via a final cued-recall test. Varying the number of letters provided allowed us to examine if the strength of the pretesting effect would be impacted by the "strength" of the hint. In Experiment 4, a survey-based study, participants provided open-ended responses to questions about their likelihood to engage in thinking-before-googling efforts.

Predictions

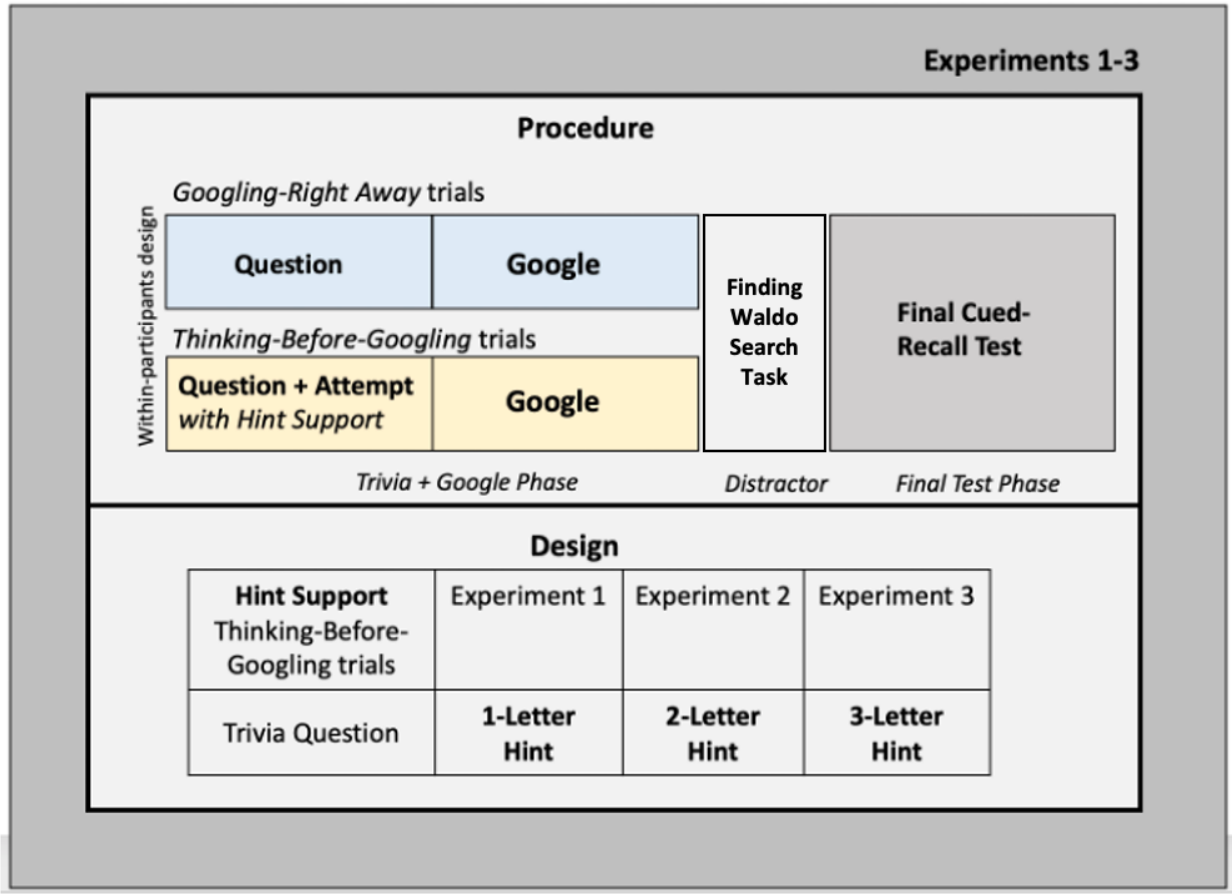
In line with the findings of Vaughn and Kornell (2019), showing that providing learners with a hint in their attempt to retrieve information is just as effective for retention as providing no hints, as long as the answer is not guessable, regardless of the amount of cue support, we predicted that providing participants in our experiments with an initial cue support in their attempt to think about a potential answer to a question prior to their Google search would yield a memory advantage compared to simply searching the internet for answers right-away (in line with the findings of Giebl et al., 2021, 2022).

On the other hand, it is possible that cue support variation could change the effect of cue support in thinking-before-googling efforts, in keeping with a retrieval-effort hypothesis. It is the case, for example, that more effortful retrieval of information can lead to better overall later memory performance than less effortful retrieval[2] (Bjork, 1975; Cepeda et al., 2008; Pyc & Rawson, 2009; see also work on retrieval accessibility, Bjork & Bjork, 1992). In other words, the effort expended to recall a piece of information (e.g., from prior knowledge or a studied word list) is often positively associated with the likelihood that that item will be recallable on a later test. Accordingly, one might suggest that pretesting—or, in the present study, thinking-before-googling–may be less beneficial as the amount of cue support increases, as increased cue support may reduce the effort participants need to expend to correctly retrieve the prompted answer. In a similar vein, Carpenter & DeLosh (2006) showed that impoverished cues led to better memory than engaging in retrieval practice with more cue support. Indeed, participants' memory performance on the final test was greatest when fewer letter hints (e.g., "c_ _ _ _" vs. "ca_ _ _" vs. "cab_ _" vs. "cabi_") were provided during retrieval practice. Consistent with the elaborative-processing view, the authors suggest that conditions of learning designed to provide more potential for elaborative retrieval or generation–in the present study, fewer cues vs. more cue support in thinking-before-googling trials–often lead to better memory retention. With this result in mind, one could also predict that participants in the present study would not only learn more when thinking-before-googling than when googling the information right-away, but that this benefit would be greater as cue support decreases (2-letter cue support versus 1-letter cue support; Carpenter & DeLosh (2006). If so, we may see the greatest memory performance with one cue and the least with three-letter cue support in Experiment 3 (counter to the findings of Vaughn & Kornell, 2019).

[2] This finding is largely found in the absence of feedback

Figure 11

A schematic illustration of the designs and phases for Experiments 1-3



Experiment 1

In Experiment 1, we were interested in examining the effect of cue support on memory retention when learners engage in thinking-before-googling. More specifically, we wondered whether providing participants with a one-letter hint in their attempt to come up with a potential answer to a trivia question (aka thinking-before-googling) would promote better memory retention than simply looking up the answer on the internet (aka googling-right-away).

Method

Participants

A total of 51 undergraduate students were recruited from the University of California, Los Angeles Sona subject pool. We excluded 11 participants in Experiment 1 for technical difficulty or for not following instructions properly. IRB approval for all experiments was obtained from Applying Cognitive Psychology to Enhance Educational Practice: II, IRB#11-002880.

Design

Experiment 1 used a 2 x 2 within-participants design with two independent variables: Learning Strategy (thinking-before-googling versus googling-right-away) and Question Difficulty (easy versus hard). For thinking-before-googling trials, participants were provided with a question and a one-letter hint support and asked to attempt to come up with a potential answer before googling. For googling-right-away trials, participants were asked to search Google for the correct answer immediately. To illustrate the differing levels of cue support, participants might be asked "What is the last name of the football player known as "The Galloping Ghos*t*"?" *with the provision of* "G________" as a cue (Experiment 1)***;*** or "Gr_____" as a cue (Experiment 2)***;*** or "Gra_____" as cue (Experiment 3). The order of trivia question difficulty and learning strategy type was randomized across participants. Memory was assessed via a final cued-recall test (e.g., "What is the last name of the football player known as "The Galloping Ghost: _________?").

Materials

Twenty-eight general knowledge questions, selected from the norms created by Tauber et al., (2013), were employed as the study material. Half of the questions were relatively easy, with a probability of recall ranging from 0.33 to 0.79 (e.g., "What is the last name of the brothers who flew the first airplane at Kitty Hawk?: "Wright"") and half were relatively difficult ranging from a 0 to 0.05 probability of recall (e.g., “What was the name of the unsuccessful auto manufactured by the Ford Motor company from 1957-1959?: “Edsel””). The study was carried out using an open resource tool for running online psychology experiments (see http://github.com/gikeymarcia/Collector).

Procedure

Initial Instructions & Setting

At the beginning of the experiment, participants were told that they would be presented with a number of general knowledge trivia questions. For half of the questions, participants were instructed to try to put forward an answer before consulting the Internet (i.e., thinking-before-googling trials). For the other half of the questions, participants were told to search Google for the answer immediately (i.e., googling-right-away trials). Additionally, participants were informed that some questions were easy and some were difficult, so they may not know the answers. Critically, for questions which participants were asked to look up the answers on Google, they were asked to do so even when the answer to the trivia question came easily to mind. Conversely, for questions in the thinking-before-googling trials, participants were instructed to attempt to produce an answer to a question first before consulting the internet, even when they felt that they may not be able to come up with a possible answer. In that case, participants were asked to write down the closest related answer that they could think of.

Lastly, participants were instructed that, once they arrive at the Google search page, they should type the exact question into the search bar and ignore the auto-completion function. This approach ensured a baseline and consistent level of engagement across participants and question types and helped control for variations in elaborative processing. Participants completed the study using their own computer for the majority of the experiment and their cell phone for the Google searches.

In the first stage of the experiment, the trivia phase, participants were presented with 14 easy and 14 hard general knowledge questions. The questions appeared on the screen one at a time in a random order. In thinking-before-googling trials, participants were presented with a trivia question and the first letter of the correct answer and asked to come up with a potential answer. Participants had to spend at least five seconds attempting to generate an answer before they were allowed to go onto Google and search for the answer. This time constraint was put into place to ensure that participants would actually try to engage in memory retrieval efforts. In the googling-right-away trivia trials, participants were asked to simply use Google to search for the correct answer. Once on the Google search page, participants were allotted up to 1.5 minutes[3] to search for the answer. When an answer was found, participants returned to their computer screen and typed their response into an empty text box. Then, the next trivia question was presented. After a 3-min-long distractor task (Finding Waldo, a visual search game), all general knowledge trivia questions were tested one at a time in a random order. No feedback was provided to participants.

Results

Thinking-Before-Googling Attempt Performance

Overall thinking-before-googling attempt performance was much higher for easy trivia questions (M = .70, SD = .19) than for hard questions (M = .17, SD = .23), t (37) = 14.14, p < .001, d = 2.29.

Final Test Performance

[3] Participants were given 1.5 minutes to search the internet for the correct answers across both conditions, thinking-before-googling and googling-right-away.

Final test performance for Experiments 1, 2, and 3 are presented in Table 3. A 2 (learning strategy: googling-right-away versus thinking-before-googling) x 2 (question difficulty: easy versus hard) within-subjects analysis of variance (ANOVA) was conducted using IBM SPSS 28.0. In line with our hypotheses, a main effect of learning strategy was obtained, with thinking-before-googling (M = .74, SD = .18) leading to better final test performance than googling-right-away (M = .64, SD = .17), F (1, 37) = 21.19, p < .001, η_p^2 = .36. A main effect of question difficulty was also observed, with participants performing better on easy trivia questions (M = .91, SD = .11) as compared to hard questions (M = .46, SD = .24), F (1, 37) = 207.67, p < .001, η_p^2 = .85. The learning strategy x question difficulty interaction was not significant, F (1, 37) = 1.83, p = .18, η_p^2 = .05. Visual inspection of the data, however, suggested that the effect of learning strategy on easy questions was numerically smaller than its effect on hard questions, so we conducted additional tests to examine if the difference between conditions remained significant when levels of question difficulty were examined separately. That was the case: Paired samples t-tests indicated that thinking-before-googling (M = .94, SD = .12) led to significantly higher final test performance than googling-right-away (M = .88, SD = .15) for easy questions, t (37) = -2.26, p = .03, d = -0.37. Thinking-before-googling (M = .53, SD = .30) also led to better final test performance than googling-right-away (M = .39, SD = .27) for hard questions, t (37) = -2.95, p = .006, d = -0.48.

EXPERIMENT 2

The design of Experiment 2 was the same as that of Experiment 1 except for one change: In the thinking-before-googling trials, participants were presented with a trivia question (e.g., “What is the name of the football player known as “The Galloping Ghost”?) and a two-letter hint (e.g., “Gr___________”). The addition of a second letter hint offered the opportunity to examine if increasing the strength of the cues provided during thinking-before-googling trials would diminish the memory benefits of an attempt to answer a question first before googling it.

As mentioned earlier, similar work by Vaughn & Kornell (2019) found that increased cue support did not reduce the benefits of memory retrieval. However, other work suggests that reducing the effort and elaboration required by retrieval does impact learning from retrieval.

Method

Participants

A total of 64 undergraduate students were recruited from the University of California, Los Angeles Sona subject pool. We excluded 16 participants in Experiment 1 for technical difficulty or for not following instructions properly. IRB approval for all experiments was obtained from Applying Cognitive Psychology to Enhance Educational Practice: II, IRB#11-002880.

Results

Thinking-Before-Googling Attempt Performance

Thinking-before-googling attempt performance was similar to that observed in Experiment 1; that is, easy trivia questions (M = .74, SD = .20) were answered correctly more often than were hard questions (M = .18, SD = .22), t (47) = 16.48, $p < .001$, d = 2.38.

Final-Test Performance

Overall, the pattern of results in Experiment 2 fully replicated the results obtained in Experiment 1 (see Table 3). Again, thinking-before-googling (M = .74, SD = .17) led to better performance than googling-right-away (M = .65, SD = .20), F (1, 47) = 21.24, $p < .001$, η_p^2 = .31. Further, a significant main effect of difficulty was again observed, with participants answering more easy (M = .88, SD = .11) than hard (M = .51, SD = .27) questions correctly, F (1,

47) = 142.74, $p < .001$, $\eta_p^2 = .75$. As in Experiment 1, the interaction between condition and difficulty was nonsignificant, F (1, 47) = 3.45, $p = .07$, $\eta_p^2 = .07$. There was a significant benefit of thinking-before-googling ($M = .90$, $SD = .13$) over googling-right-away ($M = .85$, $SD = .14$) for easy questions, t (47) = -2.40, $p = .02$, $d = -0.35$**,** and likewise a significant benefit of thinking-before-googling ($M = .57$, $SD = .27$) over googling-right-away ($M = .45$, $SD = .30$), t (47) = -4.06, $p < .001$, $d = -.59$ for hard questions.

EXPERIMENT 3

The findings of Experiment*s* 1 and 2 provide further evidence that trying to answer a question before consulting the internet is beneficial for memory retention, even when there was a low likelihood that participants would retrieve the correct answer from prior knowledge. Indeed, thinking about a question before googling the information led to better memory retention than googling the information right away, providing further support for the thinking-before-googling effect.

Furthermore, thinking-before-googling led to better memory than googling-right-away even when cue support doubled from one letter to two letters. Consistent with the findings of Vaughn and Kornell (2019), these results also suggest that providing learners with an initial cue support in their attempt to answer a question prior to their Google search does not affect their rate of learning the sought-out information. In Experiment 3, we investigated further whether providing participants with yet more cue support would change the learning efficiency of thinking-before-googling trials. So far, findings from Experiment 1 and 2 have suggest that increased cue support does not diminish the potentiating benefits of thinking-before-googling. However, given that a three-letter hint could reduce the search space to a greater amount, thereby making it easier for learners to come up with the answer, we may see a real possibility of an effect of cue support on memory retention.

Method

Participants

A total of 80 undergraduate students were recruited from the University of California, Los Angeles Sona subject pool. We excluded 12 participants in Experiment 1 for technical difficulty or for not following instructions properly. IRB approval for all experiments was obtained from Applying Cognitive Psychology to Enhance Educational Practice: II, IRB#11-002880.

Procedure

The procedure used in Experiment 3 was the same as that employed in Experiment 1 and 2 except that the first three letters of the correct answer were provided to participants in the thinking-before-googling trials.

Results

Pretest-Attempt Performance

Pre-test performance for hard trivia questions (M = .26, SD = .28) was found to be significantly lower than that for easy trivia questions (M = .83, SD = .18), t (67) = 18.28, p < .001, d = 2.22.

Final-Test Performance

In contrast to Experiments 1 and 2, a significant interaction between learning strategy condition and question difficulty was obtained in Experiment 3, F (1, 67) = 18.08, p < .001, η_p^2 = .21. The effect of learning strategy condition, therefore, was assessed for easy and hard questions separately. The difference in performance between googling-right-away and thinking-before-googling for easy questions was not significant, M_{diff} = -.01, SD = .18, t (67) = -0.57, p = .57, d = -.07, whereas the effect of learning strategy for hard items was significant, M_{diff} = -.16, SD = .26, t (67) = -5.00, p < .001, d = -.61 (see Table 3).

Table 3

Final Test Performance by Learning Strategy (Thinking-Before-Googling vs. Googling-Before-Thinking) and Difficulty of Questions (Easy vs. Hard)

		Question Difficulty			
		Easy		Hard	
Learning Strategy	*n*	*M*	*SD*	*M*	*SD*
Experiment 1 (One-Letter Cue)	38				
Googling-Right-Away		.88	.15	.39	.27
Thinking-Before-Googling		.94	.12	.53	.30
Experiment 2 (Two-Letter Cue)	48				
Googling-Right-Away		.85	.14	.45	.30
Thinking-Before-Googling		.90	.13	.57	.27
Experiment 3 (Three-Letter Cue)	68				

Googling-Right-Away	.86	.19	.38	.26
Thinking-Before-Googling	.87	.18	.54	.28

Participants' Responses to the Post Experiment Question: Experiments 1-3

At the end of the experiment, participants were presented with the open-ended response question as to whether they would use a Google feature that prompts internet users to think about an answer before consulting the Internet or skip the feature and google the answer right away. Given recent research showing that most people would immediately consult the internet when presented with a question as opposed to trying to answer the question first themselves (Giebl et al., 2022), we felt it would not be surprising if our participants preferred to rely on the internet to do the thinking for them. See Table 4 for participants' responses to if they would use an internet feature which promotes thinking-before-googling attempts.

To obtain more detail regarding the reasons participants chose either to engage in a think-first attempt or to search the internet for answers right away, we asked participants to provide an open-ended explanation for their choice. The open-ended responses were blindly coded by three research assistants based on six categories (see Table 5 and 6). Participants' responses were only assigned to one response category. For example, a participant responding with "I would skip it as it takes more time to think about the answer when I could have gotten it already by searching it up on Google." would have been placed in the category "Skip & Google" and more specifically under the sub-category "Fast Access to Information". A participant saying: "Yes. Genuinely my memory is getting worse, I don't want to be such a passive learner as what's the point in looking something up if you're going to forget it 30 minutes later." would have been placed in the category “Use Google Feature” and more specifically assigned to the subcategory “Appreciates Memory Benefit” of thinking-before-googling. Lastly, participants were presented with final questions about their experience with the study[4] and were thanked for their participation.

Table 4

Participants' Responses to if They Would Use a Hypothetical Google Think Feature which Promotes Thinking-Before-Googling in Experiments 1-3

		Learning Strategy	
		Google Think Feature	Skip & Google
Experiments	Number of Participants (N)		
1	38	10 (26%)	28 (74%)
2	48	13 (27%)	35 (73%)
3	68	15 (22%)	53 (78%)

Notes. Percentages are shown in parentheses.

Table 5

Reasons for Using Hypothetical Google Think Feature

[4] Responses from participants answering “no” to the following two questions were excluded from the analyses.
Q1: “For those questions you were instructed to look up answers on Google immediately, did you actually look them up on Google as instructed (even if you knew the answer in your head)?”
Q2: “For those questions instructed to try to answer the questions first before using Google, did you actually try to answer the questions (even if you struggled to come up with an answer)?”

	Reasons				
	No Reason Provided	Appreciates Memory Benefits	Likes the Challenge	Likes Gamification Aspect	Do Both: Feature & Skip
Experiments					
1 (N = 10)	1 (10%)	1 (10%)	5 (50%)	1 (10%)	2 (20%)
2 (N = 13)	3 (23%)	5 (38.5%)	2 (15.4%)	0	3 (23%)
3 (N = 15)	5 (33%)	6 (40%)	3 (20%)	1 (7%)	0

Note. Percentages are shown in parentheses

Table 6

Reasons for Not Using Hypothetical Google Think Feature

	Reasons				
	No Reason Provided	Don't Know the Answer ("Why Guessing?")	Fast Access to Information	No Need Felt to Remember Information	Do Both: Feature & Skip
Experiments					
1 (N = 28)	2 (7.1%)	7 (25%)	16 (57%)	2 (7.1%)	1 (3.6%)
2 (N = 35)	1 (2.9%)	9 (25.7%)	20(57%)	3 (8.6%)	2 (5.7%)
3 (N = 53)	7 (13.2%)	13 (24.5%)	29 (55%)	2 (3.8%)	2 (3.8%)

Note. Percentages are shown in parentheses

EXPERIMENT 4

The primary aim of the present research was to examine the impact that cue support might have on memory retention (Experiment 1-3). A second aim was to assess whether cue support can make learners report a greater likeliness or willingness to engage in thinking-before-googling attempts. Based on the findings by Vaughn and Kornell (2019)—showing that hint support can increase learners' desire to self-test—we wondered whether participants would indicate a willingness to guess a potential answer to question when the question is presented with the provision of a letter hint. Additionally, we wondered whether informing learners about the potentiating learning benefits of thinking-before-googling could have a positive effect also on their desire to think *before* googling.

Method

Participants

A total of 194 undergraduate students were recruited from the University of California, Los Angeles Sona subject pool. We excluded 20 participants from survey question 1 and 9 participants from survey question 2 for technical difficulty or for not following instructions properly.

Procedure

Participants were presented with two questions about a new "Google feature" that prompts learners to generate an answer to a question before looking for that answer on the internet. In keeping with our research interests, the first question appeared with a piece of information; namely, information telling participants about the memory retention benefit of thinking-before-googling. The second question contained a description about the new "Google feature" that now had the addition of hint support. Survey questions:

- "Research has demonstrated that information found on the internet is better remembered later on when people try to answer the question themselves before searching Google for it. In other words, attempting to answer a question before looking it up on the Internet, makes the searched information more memorable later on. Now, what if there was a Google feature that would ask you to think about a question before you search for it on the internet. Would you use the Thinking-Before-Googling feature or click the Skip and Google button to see the answer right away? Please go to the next page to share your answer. Yes (use the Thinking-Before-Googling feature) or No (Skip and Google). Please be honest."
- "What if Google is providing you with the first letter of the correct answer (aka a hint), would you try to attempt to answer the question yourself or skip and google right away? Please go to the next page to share your answer. Yes (use the letter hint) or No (skip and google). Please be honest."

For both survey questions, participants were instructed to indicate whether they would use the thinking-before-googling feature before looking up information on the internet, or skip it and turn immediately to the internet. The survey questions were presented online using an open resource tool for running online psychology experiments (see http://github.com/gikeymarcia/Collector).

Results

Participants' Responses to the Survey Questions

Table 7

Participants' Responses to if They Would Use a Hypothetical Google Think Feature which Promotes Thinking-Before-Googling

		Learning Strategy	
		Google Think Feature	Skip & Google
Survey Questions	Number of Participants (N)		
1. Feature + Memory Benefit	174	65 (37%)	109 (63%)
2. Feature + Hint	185	95 (51%)	90 (49%)

Notes. Percentages are shown in parentheses.

Table 8

Reasons for Using Hypothetical Google Think Feature

	Reasons					
	No Reason Provided	Appreciates Memory Benefits	Likes the Challenge	Likes Gamification Aspect	Confident in Getting the Answer	Do Both: Feature & Skip
Survey Questions						
1 (N = 65)	26 (40%)	14 (22%)	12 (18%)	3 (5%)	8 (12%)	2 (3%)
2 (N = 95)	27 (28%)	14 (15%)	6 (6%)	19 (20%)	24 (25%)	5 (5%)

Note. Percentages are shown in parentheses

Table 9

Reasons for Not Using Hypothetical Google Think Feature

	Reasons				
	No Reason Provided	Don't Know the Answer ("Why Guessing?")	Fast Access to Information	No Need Felt to Remember Information	Do Both: Feature & Skip
Survey Questions					
1 (N = 109)	19 (17%)	32 (29%)	53 (49%)	2 (1.8%)	3 (2.8%)
2 (N = 90)	11 (12.2%)	48 (53.3%)	29 (32%)	0	2 (2.2%)

Note. Percentages are shown in parentheses

General Discussion

One goal of the present study was to examine the positive learning effects of thinking-before-googling with the provision of cue support. More specifically, we tested whether providing letter hints to learners when they attempted to come up with a potential answer to a general trivia question would affect its learning benefit as compared to searching the internet right away. In Experiment 1, participants were presented with one-letter cue support in thinking-before-googling trials whereas Experiment 2 and 3 offered two-letter and three letter-hints, respectively.

Based on prior research work on the pretesting effect in more traditional experimental paradigms; that is, generating an answer to a yet-to-learn question or topic prior to being presented with the information, we expected better memory for answers to trivia questions when those answers were self-produced prior to a Google search rather than googled immediately.

Additionally, we hypothesized two potential outcomes regarding the provision of cue support in thinking-before-googling trials. On one hand, the magnitude of cue support provided to learners (one-letter-, two-letter-, three-letter hints) may have little or no impact on the positive effect of thinking-before-googling on memory for googled information (Vaughn & Kornell, 2019). On the other hand, there is the possibility that the benefit of thinking-before-googling is greater under conditions that render the information less accessible at the time of the thinking-attempt. According to the elaborative processing view, for example, retrieval attempts that make it harder for the learner to come up with a potential answer may provide more room for elaborative retrieval, which in turn, may lead to better memory retention (Bjork & Whitten, 1974; Glover, 1989; Whitten & Leonard, 1980). With respect to the current study, then, fewer cue support in thinking-before-googling trials (i.e., one-letter hints) may elicit greater activation of relevant semantic knowledge, perhaps by broadening the search set for target item-specific information, and thus yield better memory retention (for more information on possible explanations for the elaborative processing view, see Carpenter & DeLosh, 2006).

In three experiments, we demonstrated that producing a potential answer to a question before consulting the internet led to better memory for the googled information than consulting the internet right away, thus replicated the thinking-before-googling effect (Giebl et al., 2021, 2022). Furthermore, the learning benefit of thinking-before-googling was not affected by the strength of cue support. Consistent with Vaughn and Kornell's (2019) findings, memory retention did not vary depending, as long as the answer was not too easily guessable, on whether participants received an initial one-letter hint versus a two-or three-letter hint support). Although we cannot rule out the possibility that the degree to which learners exerted effort or engaged in elaboration on what the potential answer might be is not important for the encoding of new information, it appears, though, that there is something unique about the thinking-before-googling attempt itself that underlies the enhanced retention of the information.

As suggested by Kornell and Vaughn's (2016) two-stage theoretical model of learning from retrieval, the act of querying one's own memory (aka retrieval) enhances learning when the learner attempts to generate the correct answer (Stage 1) and receives access to the correct answer through successful generation or corrective feedback (Stage 2). In the present study—and consistent with this model—best memory performance for trivia questions in the present study was demonstrated when participants attempted to generate the correct answer on their own (Retrieval Stage) and then received corrective feedback by searching for the answer on Google (Feedback Stage). In the thinking-before-googling learning trials, participants experienced a retrieval attempt followed by feedback, whereas in the googling-right-away trials, learners potentially missed the opportunity to engage in retrieve and/or generation processes known to enhance learning. It is important to point out that the benefits of thinking-before-googling were found regardless of (i) learners' rate of success in their attempt and despite of (ii) learners' potential differences in engagement as the strength of cue support was varied across experiments. Together, these findings suggest that coming up with an answer before consulting Google can enhance learning, while additional cue support did not provide additional benefits.

That being said, there appears to be enjoyable or reassuring about receiving hints when trying to come up with an answer independently before resorting to the Internet. Vaughn and Kornell (2019), for example, showed that participants were much more likely to engage in self-testing when given hints compared to when no hints were provided. The authors attributed this result, in part, to the notion that when learners perceive a good chance of success (which hints, presumably, increase) generating an answer oneself may become more appealing than simply being presented with the information. Similarly, recent research work has demonstrated that learners are more motivated to produce an answer themselves when they are curious to learn the answer, which often occurs when they are in their *Region of Proximal Learning* or *RPL*—a mental state where they believe they almost know the answer; when the desired information is most amenable to learn (e.g., Metcalfe et al., 2017, for more information on RPL, see also Metcalfe, 2002 and Metcalfe et al., 2003).

In the recent paper titled "Curiosity and the desire for agency: wait, wait…don't tell me!" (Metcalfe et al., 2021), participants were presented with general knowledge questions (e.g., What is the last name of the male star of Casablanca?", "Bogart"), one by one, and asked to rate their level of curiosity. Subsequently, they were given the option to request hints or to receive the complete answer. At the end of the learning phase, participants were tested on all knowledge questions. The results revealed that when participants were curious to find out the answer, they were more willing to try to produce the answer to a question themselves, and even request hints to keep self-quizzing and delay the reveal of the correct answer. These findings provide further support for the notion that when people believe they have a good chance of knowing the answer, they are motivated to challenge themselves by querying their own memory instead of being provided with the correct answer outright. Moreover, it seems that the provision of cue support can encourage learners to continue guessing what the correct answer might be.

The aforementioned results hold significant relevance for the current study. It is noteworthy that, when presented with a hypothetical Google Think feature—prompting people to guess an answer before consulting the internet, a majority of people across Experiments 1-3 (74%, 73%, and 78%, respectively) expressed a preference to skip the Google Think feature and immediately search online. Even when participants were informed about the potential memory benefits associated with thinking-before-googling prior to deciding whether they would use the feature or skip it and search right away (Experiment 4), more than half (63%) still reported a tendency to turn to the internet without contemplating their own memory.

Interestingly, across Experiments 1- 4, participants cited two main reasons for skipping the Google Think feature in their own responses. Firstly, it appears that participants perceived searching the internet as a faster and less time-consuming approach compared to initially searching their own memory. Secondly, it seems that they believe that utilizing a search engine aligns better with its intended purpose. As one participant put it, “because if I knew the answer I would not use Google in the first place.”

A shift in reporting behavior, however, occurred when participants in Experiment 4 were informed that they hypothetical Google Think feature would be accompanied by a letter hint (i.e., Google Think + Hint). With the provision of hint support, only half (49%) of the participants reported a likelihood of skipping the Think feature, while the remaining half (51%) indicated a willingness to utilize the hypothetical Google Think feature.

This change in attitude aligns with the notion that when learners perceive a higher probability of guessing the correct answer, they are more inclined to engage in retrieval and generation processes compared to situations where the likelihood of arriving at the correct answer seems remote. For instance, one participant, when asked about their willingness to engage with a hypothetical Google Think + Hint feature mentioned “…at least now I have something to go off of rather than just doing it blindly.” Similarly, another person expressed their intention to use the Google Think + Hint feature because it adds an element of enjoyment, stating, “…because it makes almost fun and sometimes I have anxiety so I really only need a clue or hint if I’m stuck and have an answer on the edge of my tongue.”

As indicated by the latter participant, cue support not only seems to boost learners' confident in their ability to generate the correct answer, but it might also elicit enjoyment and engagement of the learning process. In fact, in Experiment 4, 20% of participants who expressed a willingness to use the hypothetical Google Think + Hint feature stated that they would do so because the hint added a gamification or fun aspect. For instance, one participant wrote, "…the letter hint makes it seem more like a game which is interesting", while another participant mentioned that the feature with the hint "feels more like a riddle…making it more fun". Interestingly, when participants were asked about the Google Think + Hint feature, references to the "gamification/fun aspect" occurred more frequently (20%) compared to when they were asked about the feature without hint support (5%).

Even though these self-reported data provide promising insights into understanding learners' motivation to engage in thinking-before-googling efforts, it is important to question why participants in Experiment 4, who expressed their preferences for a hypothetical tool they did not use, reported more enthusiasm for the Google Think feature with hints compared to the majority of participants across Experiment 1, 2, and 3 who generally indicated that they would not use such a feature in the post-experiment survey. This difference in likelihood towards a Google Think tool could potentially be attributed to post-experiment fatigue. Specifically, in Experiment 4, survey takers only responded to two questions about the Google Think tool reported here before being thanked for their participation, whereas individuals in Experiment 1-3 first went through a relatively long and challenging study before answering a question about a hypothetical Google Think tool. It is possible that by the time participants in Experiment 1-3 reached the post-experiment question, they may have already felt tired and less enthusiastic about the hypothetical Google Think tool compared to individuals in Experiment 4. Additionally, we deliberatively included nearly impossible trivia as stimuli in Experiment 1-3, which might have reduced participants' feelings of confidence in successfully retrieving or generating answers using the hypothetical tool in daily life scenarios.

In summary, our data yield three main outcomes: (a) the replication of the Thinking-before-googling effect, (b) regardless of letter hints as long as the answer is not too easy to guess, and (c) hints may encourage learners' willingness to query their memory, although caution is required when making strong claims based on the post-experiment responses in Experiment 1-3.

CHAPTER 5: SUMMARY AND DISCUSSION

The internet has inarguably become our main source of information and memory repository, providing instant access to an ocean of knowledge in mere seconds. One possible drawback to this convenience, however, is that there might be a reduced need to fully encode and retain information internally, thus undermining effortful processing and potentially resulting in suboptimal performance and learning outcomes when the internet is not available (Giebl et al., 2021, 2022). Consequently, it is increasingly important for learners to establish a more balanced partnership with the internet in terms of learning and memory.

The aim of this dissertation was to examine ways in which the internet can be utilized more effectively for learning. More specifically, we were interested in whether prompting our own memory for answers before turning to the internet (akin to a traditional pretest paradigm) would lead to greater learning outcomes than simply googling the information. Moreover, we wanted to see whether the act of thinking-before-googling may have the potential to enhance the learning of new information–as suggested by the traditional pretesting effect, as well as strengthen the memory representation and traces of related information learned prior to the internet search (see Chapter 2 & Chapter 3). Lastly, the current research work investigated the role of hint support in facilitating learning from thinking-before-googling attempts and explored ways to make the process of querying one's memory prior to a Google search more appealing by incorporating hints (see Chapter 4).

Overall, results revealed that thinking before searching the internet aka thinking-before-googling can yield better memory retention of googled information than googling the information right-away, thus replicating the traditional pretesting effect in the context of learning new information via the internet. Moreover, as seen in Chapter 2, attempting to solve a complex problem before using Google resulted in better retention and transfer of knowledge not only for searched-for information on the internet but also for relevant information learned prior to the Google search, specifically in learners with some content knowledge. In Chapter 3, I found that the benefits of thinking-before-googling also extended from complex learning material to fact-type information such as general knowledge questions. That is, across four experiments, engaging in thinking-before-googling attempts led to better memory retention of searched-for trivia answers found online compared to immediately searching for answers on Google.

Additionally, the act of googling-right-away resulted in similar memory performance for trivia questions as merely reading the question-answer trivia pairs. This finding is surprising given most participants' self-reported tendency to rely on internet searches without an initial contemplation, thus emphasizing the significance of retrieval and generation processes in optimizing the way we learn from the internet. Finally, producing a potential answer prior to a Google search, i.e., pretesting in the context of internet-based learning, also led to better retention than contemplating an answer before being presented with the correct information (i.e., traditional pretesting set-up), perhaps highlighting the importance of agency in the learning process.

Chapter 4 provided additional evidence supporting the idea that thinking-before-googling can enhance memory for googled information compared to immediately consulting the internet. Interestingly, this thinking-before-googling effect persisted even when participants were provided with hints. It is noteworthy that the level of hint support provided did not have an impact on the learning advantages of thinking-before-googling. Furthermore, when asked about a hypothetical Google feature that encourages contemplation prior to a search, most people expressed a preference for skipping the Google Think feature and immediately searching the internet for answers. Even after being informed about the memory benefits of engaging in thinking-before-googling attempts, more than half (63%) of the respondents still reported a preference for skipping the prompt. However, when hint support was mentioned, half (51%) of the learners expressed willingness to engage with the hypothetical Google Think feature before searching the internet for answers.

Thinking-Before-Googling and the 2-for-1 Memory Benefit

Considerable work has shown that contemplating a potential answer or solution to a problem prior to being presented with it has the potential to promote better subsequent encoding of the to-be-learned information than simply being presented with the answer, known as the pretesting effect. Little is known, however, as to whether pretesting could result in memory benefits when acquiring new information through the internet, and whether considering a possible answer before googling the correct response could also potentiate one's understanding of previously related learned information.

In Chapter 2, Giebl et al., (2020) found that when learners were asked to generate a solution to a challenging task related to computer programming that they had not yet received sufficient information to solve the problem, memory retention and transfer of knowledge related to the googled information was better on a final test than when learners were told to google the missing information right-away. Interestingly, searching one's own memory for potential solutions also enhanced the learning of relevant information studied before the programming task. Thus, attempting to solve a problem, even if unsuccessful, appears to benefit learning both retroactively and proactively.

One possible explanation for this 2-for-1 learning benefit, perhaps, is that the act of attempting to solve a problem without sufficient knowledge may have the potential to modify and strengthen existing memory traces and enhance the semantic activation and elaboration of new information, facilitating a deeper conceptual understanding of the to-be-learned information overall. Consequently, internet users could have improved retention of the information they searched for and be able to apply it in new learning contexts. Such reasoning would be consistent with findings from the traditional pretesting literature such that thinking ahead about how to solve a problem can arouse curiosity and interest in the task at hand (Berlyne, 1954), which might have helped learners in this experiment to better focus —via increased attentional processes—on the pretested information that was subsequently presented on Google, thus leading to its enhanced retrieval and transfer of information on the final exam. Another possibility is that better performance and learning outcomes on a final transfer test may not only be attributed to heightened curiosity and increased attentional processes, but also to more effective and efficient processing of the material found on Google. It seems reasonable that attempting to solve a problem initially may have led to a deeper and more elaborate processing of the task-related information subsequently found on Google, thus leading to better retention and transfer of knowledge compared to googling the information right-away.

Contemplating a task before googling the answer may have also prompted learners to reflect on relevant information previously and apply the retrieved information to come up with potential solutions for the programming task. This process of applying the retrieved information in a new learning context can activate and strengthen different retrieval routes to the representation of the learned information. Consequently, the retrieved information may become more memorable and accessible in the future (Carpenter, 2012; Karpicke, in press) relative to task-related information that was merely searched on Google without potentially engaging in retrieval practice.

A final point worth noting is that attempting to solve a task before searching Google for a solution appeared to be particularly beneficial for participants with some degree of programming experience and background knowledge. Consistent with the idea that prior knowledge can aid learners in integrating new information and enhance comprehension (see Huelser & Metcalfe, 2012; see also, Carpenter et al., 2016), it is possible that participants' background knowledge on fundamental programming principles helped them to better remember information learned before programming task and integrate the retrieved information with task-related information found on Google, Therefore, prior knowledge may serve as additional cue support to reinforce the learning of both old and new information. In comparison, participants with no prior experience in computer programming, may have had difficulty forming important connections between the task requirements and previously learned information, which could have resulted in a poor conceptual understanding of both the previously learned information and new information sought out on Google.

Comparing the Benefits of Thinking-before-googling to Other Ways of Learning without the Internet

In the experiment reported in Chapter 2, participants who attempted to solve a complex programming task prior to consulting the internet for answers performed better on a final test of retention and transfer of knowledge compared to participants who immediately searched the internet for answers. Such potentiating memory benefit of thinking-before-googling attempts seems to extend also to the learning of fact-specific information. Indeed, across four experiments in Chapter 3, Giebl et al., (2022) demonstrated that trying to come up with a potential answer to a general knowledge trivia question prior to a Google search led to better memory for the googled answer later on than immediately searching the internet for the answer. This result, provides additional evidence in support of the thinking-before-googling effect, as seen in Chapter 1 (Giebl et al., 2021). Moreover, it should be noted that although Storm et al., (2020) have shown that searching the internet for answers in itself can be a positive learning event compared to simply being presented with the correct answer, consulting the internet for immediate answers, aka googling-right-away, in our study, did not result in superior memory compared to being given the correct answer outright (see Experiments 2a and 2b in Chapter 3). Of course, our findings cannot rule out the possibility that the act of searching the internet may engage cognitive processes that could be beneficial for learning, such as actively considering a variety of possible search terms and evaluating one's knowledge gaps through retrieval practice, which may facilitate the learning and recollection of sought-out information found on the internet. If, however, as indicated by participants' self-reported responses to our metacognitive questions, our inclination is to search for the desired information right away, without considering first what the correct answer might be, the potential benefits of the search process itself might be relatively limited, and thus the extent to which one may benefit from thinking-before-googling attempts.

Another noteworthy result is that engaging in thinking-before-googling not only yielded better recall of information searched online compared to when participants googled the information right away, but also resulting in better memory in comparison to when learners were required to come up with a potential answer before receiving the correct information, which is akin to a traditional pretesting set-up. This finding indicates the importance of agency in the learning process. When individuals turn to the internet, they are actively seeking knowledge, whereas if the answer is readily available without effort, the learning process may become more passive. Thus, contemplating a potential answer before conducting a Google search could instill a greater sense of agency in the learning process than when learners are solely given the correct answer after a pretest without any further active involvement on their part.

The Role of Hints in Thinking-Before-Googling Attempts

Attempting to generate a potential answer to a question before consulting the internet, aka thinking-before-googling, can promote better memory for both simple and complex learning materials than simply googling the answer right away (Chapter 2 & 3, see Giebl et al., 2021, 2022). Yet, when asked about daily interactions with the internet, people overwhelmingly indicated that they typically turn to the internet for immediate access to answers rather than attempting to recall the answer first (Chapter 3, see Giebl, 2022). As a means of finding a way to motivate learners to engage more frequently in thinking-before-googling attempts, one goal of the experiments reported in Chapter 4 was to investigate if the provision of hint support could lessen people's tendency to google the answer right away. A second goal was to examine if the strength of the thinking-before-googling effect would be reduced as the "strength" of the hint increased.

In all three experiments, the strength of the hint provided; that is, the number of letters participants in our study received when engaging in thinking-before-googling efforts, did not change the degree to which memory benefitted from such attempts, as long as the answer was not too easily guessable. Although it cannot be dismissed that the degree of effort or engagement in thinking-before-googling trials as triggered by the level of cue support, may not impact the quality in which one encodes new information, perhaps there is something unique about the act of thinking before searching on Google itself that can enhance information retention.

In line with Kornell and Vaughn (2016) two-stage retrieval model, participants demonstrated better memory for googled information when they first attempted to query their own memory for an answer (Stage 1: Retrieval/Generation attempt) before searching the internet for the correct answer (Stage 2: Feedback). In contrast, when participants immediately searched the internet for answers, they may have bypassed the opportunity to engage in retrieval/generation processes known to promote learning. Taking together, the results of all three experiments suggest that contemplating the right answer before conducting a Google search can enhance learning, regardless of the level of cue support.

Although our study found that cue support did not appear to impact the learning advantage of thinking-before-googling, people expressed a greater willingness to utilize a hypothetical Google Think Feature with the provision of hints, even more so than when they were informed about the memory benefits of thinking-before-googling. Participants' open-ended responses suggest that people might enjoy the process of guessing when hints are present, as it may trigger their curiosity about what the correct answer might be and motivates them to find out the answer themselves as opposed to rushing to the internet for answers. This enjoyment of the guessing process could be related to the role of agency in thinking-before-googling with hint support, as people feel more inclined to generate the answer themselves when they feel closer to figuring it out the right answer (Vaughn & Nate, 2019; Metcalfe et al., 2021). Therefore, providing hint support could be an effective way to encourage learners to engage in thinking-before-googling attempts and take an active role in the learning process.

Concluding Comments

As much as human seek out convenience and easiness in various aspects of our lives, we found that similar to the saying "A Tiny Good Deed Can Go a Long Way", a tiny effort to *thinking-before-googling* can grow into lasting memories. Plus, the support of hints may make that journey more enjoyable.

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