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Does access to external storage lead to less emphasis on learning?

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by

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ABSTRACT

Two experiments were conducted to examine the effects of having access to external memory storage on what students encode in internal memory. The accessibility of external information makes it very easy to get to without having to exert a lot of mental effort. I investigated how typing and saving notes about facts on a computer would impact internal memory if participants knew they would have access to their notes when tested on the facts. In Experiment 1 participants heard trivia facts and took notes on each one, which they saved to one of six folders. Half of the participants were told they would be able to access the folders during the test while the other half were told they would not. At test, participants were asked if they recognized a fact as one they had studied and into which folder they had saved notes about that fact. Although no participants actually were given access to their notes during the recognition test, fact memory was close to ceiling for both groups and was higher than folder memory, with no differences between access groups. Experiment 2 included easy and difficult facts and participants were given a cued recall test on both the facts and the folders. Access condition had no effect, but cued recall was higher for easy facts, and more folders were recalled than facts when the facts were hard. Performance also depended on the quality of notes that participants had taken, with higher quality notes for easier facts. Further investigation is needed to determine how information is prioritized for encoding internally when it is also available externally.

CHAPTER 1: INTRODUCTION

Information technology is becoming ubiquitous. College campuses abound with laptops and cellphones, which are a common sight in lecture halls where students might use them to take notes or catch up with their friends on social media. With the prevalence of digital technologies in learning environments it seems a worthwhile endeavor to investigate what impact technology usage might have on cognitive processes. A particularly relevant question, when it comes to technology use in a classroom, is whether having access to a virtually limitless store of information impacts the way a student learns. If all of the information necessary to pass a class can be found online or on a hard drive, there might be unintentional consequences on the perceived need to store information in internal memory. The goal of this thesis is to explore the impact that the availability of digital memory storage has on what information is stored internally.

A single human brain cannot hold all of the information the entire species has amassed over time. This is because while memory capacity might seem unlimited, there are limitations on how much information can be encoded at a given time. Craik, Govoni, Naveh-Benjamin, and Anderson (1996) examined the impact of dividing participants' attention on their abilities to encode information and found that attention is a limiting factor in encoding. They posited that the encoding of perceptual information requires conscious awareness, attention, and processing resources that are limited in scope and cannot be simultaneously allocated to multiple tasks. This puts a limitation on how much information a single person can encode over a lifetime.

While there is no known limit of human memory capacity, what is certain is that people have to make compromises when it comes to how much knowledge they retain (e.g., Marois & Ivanoff, 2005). Instead of relying purely on information available to one's self, one might look to

others as supplemental sources of memory. While one person might not be able to store all of the information one desires to have, one is able to rely on other people to supplement whatever one was unable to store. By relying on other people for information, one can potentially have access not only to all of one's own acquired knowledge but also to that of anyone else with whom one might come in contact. This also enables individuals to learn from the experiences of others without having to experience things for themselves, although other people may not be the most reliable stores of memory (Schacter, 1999). This form of memory outsourcing has likely existed since people learned to communicate and has been referred to by Hutchins (1995) as distributed cognition.

Having access to external memory storage does not seem to have had a particularly pernicious impact on whether people bother to learn anything at all. There is an obvious advantage to keeping information localized to one's own memory. It can be readily available at any time and does not depend on the availability of an artifact. It is unlikely that the distribution of cognition will ever completely replace learning. What it might affect, however, is the selection process of which information is worth the effort of encoding into internal memory. The quicker and easier it becomes to access information that has not been encoded, the less appealing it becomes to put in the effort required to encode it. A book could be used as a reference for information that has not been learned and that might only be needed in a very specific context. It takes some time and mental effort to find the desired information, but many people would likely prefer having an encyclopedia to learning all of the information contained within. Similarly, a handheld mobile device that can connect to the internet might require even less time and mental effort for locating needed information. This increased portability and ease of use might make it

more tempting to offload memory onto a digital device than to rely on a reference book. A shift may occur in favor of learning less and externalizing more.

The reason why the externalization of memory might be appealing can be described in terms of what Kahneman (2003, 2011) refers to as System 1 and System 2 thinking. He described these two systems as metaphorical characters who operate under different circumstances and are responsible for different aspects of human cognition. System 1 is responsible for quick and easy judgments, intuition, and overconfidence in knowledge (Tversky & Kahneman, 1974). It is characterized by cognitive ease and can be seen at work any time an answer comes easily to mind. The ease of System 1 processing, which is also known as fluency, is experienced as a pleasant feeling (e.g. Briñol, Petty, & Tormala, 2006). It leads to many biases including increased confidence that the item will be remembered (e.g., Begg, Duft, Lalonde, Melnick, & Sanvito, 1989). Additionally, the easier it is to initially process information, or the more easily it comes to mind, the more truthful or better or familiar it seems (see Atler & Oppenheimer, 2009, for a review). This fluency effect, according to Hertzog, Dunlosky, Robinson, and Kidder (2003), also functions as a cue in making judgments of learning. Fluency could also lead to less effort being devoted to encoding. For the average person it might not seem beneficial to expend a lot of effort on encoding information that seems to have been very easy to learn.

System 2 processing refers to a process that is both effortful and resource intensive. Kahneman (2003, 2011) described System 2 thinking as a slow and deliberate process, which takes into account the initial judgment of System 1 and adds to or reframes the information provided by it. The feeling of cognitive ease associated with System 1 is diminished by the

mental effort and potential for frustration of integrating new information and trying to make sense of it. System 2 processing is not always successful.

It is reasonable to conclude that people would likely feel comfortable processing simple information internally, but might be reluctant to take on something more complex or unfamiliar (e.g., De Neys, Rossi, & Houde, 2013). This is where the externalization of memory becomes appealing. Instead of exerting the extra effort of using System 2 to internally store difficult information, one might be tempted to rely on System 1 for initial judgments and then outsource further processing to an external object (or person), that is, one might be tempted to rely on distributed cognition.

Because of the effort required to use System 2, many people may be overly reliant on information available outside of their own internal memory. A study by Risko and Dunn (2015) provided evidence that people are more willing to use external memory than seems necessary. During one experiment, participants were read a string of letters, which they immediately recalled. Some participants had the option of writing down the letters as they were heard, and they were allowed to look at their written notes during recall. Risko and Dunn found that almost half of the participants wrote down letters even when they were asked to remember only two letters. That is, participants seemed to be willing to use external memory even when it was not likely to improve performance.

While System 1 can be employed to process familiar topics or simple information, a digital technology can act as a System 2 surrogate for storing details or complex webs of information. The externalization of memory storage may require fewer processing resources than recollection entirely from internal memory because reading information generally entails shallower processing than recalling the same information from memory (e.g., Roediger & Pyc,

2012). In addition to the internet, other digital technologies allow one to easily select and store information in external memory. Students can take advantage of the ease with which information can be stored on a computer by using laptops to take notes during class instead of writing them out by hand. Typing is generally faster than handwriting, which allows for more information to be transcribed.

Just as with reading in comparison to recalling, however, there is evidence that the efficiency of typing corresponds to shallower processing of the information (Mueller & Oppenheimer, 2014). Handwriting of notes forces students to determine what information is important to write down because it is unlikely that they would be able to write down all of the information delivered in a lecture. Taking notes on a laptop provides students the opportunity to write down every word without necessarily having to process it. This seems to entail bypassing System 2 processing of information and relying primarily on System 1 to simply translate auditory information into text on a screen. If System 2 is not required for storing information for later usage (which is the likely purpose of taking notes on a laptop), then it will probably not be used. In addition, lectures often employ visual information, which, alongside the spell-checking capabilities of text processors, helps to disambiguate the spelling of unfamiliar terms. This makes complex terminology easier to process by removing the need to truly learn the term and to establish associations with familiar terms.

While taking notes on a laptop might allow a student to rely mostly on System 1 processing, additional information will be needed in order to be able to access those notes in the future. Much like internal memory, external memory needs to be accessed in order to be used. This entails remembering where the information was stored. The process is fairly straightforward when looking for information online, where a search engine just requires a few keywords to

generate information on a topic. It is slightly more complicated when the information is stored locally on a hard drive. Students might save their notes in a specific location on a computer, which is likely within a labeled folder. The additional information that a student would need to process when saving one's notes is the name of the file and possibly the name and location of the folder.

According to Kahneman (1973), while there is a general limit as to how much processing effort can be devoted to attention and the processing of information, there are different levels of processing requirements depending on what is being encoded. Some processes, he argued, can happen automatically, with the minimal expenditure of energy. Hasher and Zacks (1979) expanded upon this idea by describing a spectrum of attentional requirements. Some information requires minimal attention, while other information is more demanding and prevents concurrent processing from occurring. The amount of extra information that gets processed automatically and that becomes part of a memory depends on the amount of attentional resources demanded by the target information, but it often includes useful contextual information, such as where an item is being stored in external memory.

Troyer, Winocur, Craik, and Moscovitch (1999) expanded upon this idea of automatic versus effortful encoding in the context of source memory. They described the distinction between source memory that is associated with an item directly (maybe a property of the item itself such as tone of voice) and source memory that is not closely related to the item. Contextual information that is associated with a target memory might be encoded without additional effort. Effortful System 2 processing is required to associate information to a target that is not directly related to it. When the contextual details of a memory are abstract, such as when the information is located on a webpage or in a folder on a computer, it likely requires additional System 2

processing. While folders that contain notes for a specific class might have sensible names, an association must still be created between the name of the folder and the information contained within.

As already noted, typing information into a computer can be done relatively automatically (i.e., with System 1) leaving resources available for encoding additional details such as contextual information about where that information is stored. This additional processing requires some System 2 involvement because attentional resources are required. It is not clear, however, if the recruitment of System 2 to connect information with its contextual details is preferable to the processing required to encode more complex or detailed information. An interesting question becomes whether having access to information stored externally alters which information is preferentially selected for processing and encoding internally. The goal of this thesis is to investigate what information is encoded when participants are led to believe they will have access to digitally stored information, but only if they can remember where it has been stored.

Sparrow, Liu, and Wegner (2011) asked a similar question. They examined whether participants would rely more on external memory when they knew that the information they were looking for would be stored on a computer. Participants were presented with facts, which they typed into a computer. Their memory for the facts was tested. Over the course of four experiments Sparrow et al. found that participants recalled fewer facts when they were told that the fact would be saved on a computer than when they were told the fact would be erased. Two of those experiments motivated the current experiment and are discussed in more detail below.

Sparrow et al. (2011, Experiment 3) wanted to know whether participants would recall more facts when the facts were erased and participants knew they would not have access to them.

Participants were given a list of 30 memorable trivia facts, presented one at a time, and were asked to type each one into a computer. Through a practice recall trial at the beginning of the experiment, participants were lead to believe that they would be able to access the information that they were told had been saved. For one third of the facts participants were informed that the entry was saved, for another third of the facts they were informed that the entry was saved into a specific folder (folders had generic names such as FACTS, DATA, INFO, etc. and facts had been previously randomly assigned to these folders), and for the remaining third of the facts participants were told their entries were erased. Participants were then given a recognition task wherein they saw all 30 of the facts, half of which had been slightly altered, and were asked to make a judgment about whether they had seen the exact fact before. They were also asked to either indicate to which folder the fact had been assigned or whether it had been erased. The results showed that while participants performed very well on the recognition task, their memory was best for facts they believed were erased compared to facts they believed had been saved.

Experiment 4 of Sparrow et al. (2011) further expanded upon these results by using a recall test rather than a recognition test. As in Experiment 3, participants typed in trivia facts and were told in which folder the facts would be saved (using the same folder names as Experiment 3). Participants also completed a pretend practice trial that made it seem like they would have access to folders during the recall test, but no access was actually allowed. After typing in the facts, participants were given 10 minutes to recall as many of the facts as they could. They were then given a keyword from each fact and asked to indicate in which folder that fact had been saved by typing in the folder names, which had not been displayed except for when participants were saving the facts. Participants were better at remembering the folders where facts were stored than they were at remembering the facts themselves, although they performed poorly on

both tasks. They were able to remember the fact and the folder together better than just the fact alone. They also were able to remember the folder when they did not remember the fact about as often as they forgot it. Sparrow et al. suggested that when given the opportunity, people might prefer to know where they can find the information that they need rather than to try to encode that information, and they make this process easier by encoding where that information had been stored on a computer. Sparrow et al. also indicated that a potential explanation for participants recalling more folders was that there were only 6 folders for them to remember whereas there were 30 facts.

The relationship between external memory availability and encoding for internal storage was further investigated in the present study by slightly altering the methods used by Sparrow et al. (2011). Two experiments were conducted to ascertain whether or not participants would prioritize encoding where information might be found over detailed encoding of that information when they believed they would have access to the location when they needed it. It was hypothesized that participants who believed they would have access to external information would rely on System 1 processing to encode easy to process aspects and only recruit System 2 to encode where they had stored it. Additionally, those who believed they would not be able to access the information they needed to remember were expected to recruit System 2 to encode the information in its entirety instead of encoding where it was stored.

CHAPTER 2: EXPERIMENT 1

Experiment 1 was conducted to investigate how System 2 might be employed when digital storage is available for information that must be learned. A simple trivia statement might elicit predominantly System 1 activity, which can easily be integrated with information already existing in memory. System 2 might be used either to add details to information made readily available by System 1 or to encode where that information could be found externally. When participants believe they might have access to notes that they stored on a computer, System 2 might be recruited for the latter. Instead of forming new associations and storing details, it might be employed in associating the information processed by System 1 with the name of the folder where that information is located.

In order to more closely mirror a learning environment, such as a college classroom, participants were asked to listen to a series of facts and to take notes on them using a computer. This resembles what students might do during a lecture, which is a commonly employed teaching method. The purpose was to expand upon the ecological validity of the Sparrow et al. (2011) experiments while also testing the robustness of the effect they described. The question was whether participants who are told that they will be able to access information will devote System 2 processing to storing the location of the information rather than the details.

Participants were instructed to save the notes that they had taken in a folder of their choice, but their options were limited to six available folders named after the colors of the rainbow. This simplified the process and created a plausible reason for using System 2, as the association between a fact and a folder needed to be derived by the participant. Half of participants were told they would have access to the folders during a test on the trivia facts, while the other half were told they would not have access. A recognition test, similar to the one used in Experiment 3 of Sparrow et al. (2011), followed the study phase. Participants were first asked if

they had heard a specific fact during study; they were then asked to select the folder where the fact had been stored.

Based on the findings of Sparrow et al. (2011), it was expected that the participants who were told they would have access to the folders would recruit System 2 to form associations between facts and folders and would remember the folders better than the fact details. In contrast, it was expected that when participants were told they would not be able to access their notes, System 2 would be employed for encoding fact details rather than associating facts with folders so that memory for facts would be higher than memory for folders.

Method

Participants and design

There were 28 undergraduate participants from Iowa State University. They completed the study for course credit. There were 13 males and15 females with an average age of 19.6 years (*SD* = 0.31). Half of the participants were assigned to the Access group and half to the No Access group. The IRB approval for this study can be found in *Appendix A*.

Stimuli and materials

Participants completed the task on a computer using a monitor and keyboard throughout the entire task and a pair of headphones to listen to the trivia during the study phase of the task. The task was programmed and presented using E-Prime 2.0 software (Psychology Software Tools, Pittsburgh, PA). Participants were provided with written instructions presented in black size 24 Arial font centered on a white background on the computer monitor.

Stimuli were 36 trivia facts, some taken from Sparrow et al. (2011) and others gathered through numerous Google searches for trivia. An example trivia fact is ‘The king of hearts is the

only king without a moustache." Categories covered by the facts included geography, biology, history, pop culture, and others.

Audio stimuli were created using the Microsoft Windows Text-to-Speech program on a laptop running a Windows 8.1 operating system and were recorded using Audacity software (Audacity Team, 2012. Audacity® Version 2.0.0). The automated voice used to play the trivia facts that were recorded was Microsoft David Desktop - English (United States) reading each fact at normal speed. Participants heard the trivia facts through a pair of over-ear headphones; they were not provided with written versions of the trivia.

Two versions of the recognition test were created in which half of the facts included single-noun changes from the trivia facts that were heard during the study phase. Facts that did not include changes in version A of the recognition test were changed in version B of the recognition test and vice versa. An example of an incorrect fact provided during the recognition test is: "The king of spades is the only king without a moustache." All trivia facts are presented in *Appendix B* along with their incorrect version for half of the recognition tests.

Procedure

All testing was done individually on a computer. Participants were seated in a cubicle that contained a single table and chair. The door to the cubicle was closed during data collection. Participants were allowed to adjust the location of the monitor and keyboard so that they were comfortable. Participants were assigned to one of four counterbalance conditions based on order of arrival. The four conditions encompassed the two versions of the recognition test and the two access conditions. All participants were instructed that during the study phase they would listen to trivia facts, one at a time, each fact played only once and that after hearing a fact they should use the computer keyboard to type notes that they thought would help them remember the fact.

After participants typed a note and hit the enter key, they were prompted with a message on the screen to select a folder in which to save the note they just typed. The available folder choices were: 1. Red, 2. Orange, 3. Yellow, 4. Green, 5. Blue, 6. Purple, and participants were instructed to press the number on the keyboard that corresponded to the folder of their choice. Upon pressing a number, participants were provided with a screen indicating into which folder they had selected to save the notes. Participants were instructed to spread the facts evenly among the folders.

During initial instructions, participants were informed that some participants would be allowed to access folders during the test phase of the experiment. For half of the participants, the instructions further indicated that they were in the Access group and that during the test phase they would be allowed to view a folder into which they had saved notes. They were informed that for each test item they would have access to the first six items in the folder of their choice. For the remaining half of the participants the instructions further indicated that they were in the No Access group and they would not have access to any folders during the test phase. Half of the participants in each access group were given recognition test A and the other half were given recognition test B.

Participants were given one practice trial after which they were allowed to ask the research assistant to clarify any instructions if necessary. After the practice trial, participants completed 36 trials of listening to facts, typing in notes, and selecting into which folders to save the notes. Upon completion of the study phase, participants were provided with instructions about the recognition phase, which were the same across all participants. The instructions began by informing participants that no participants would have access to folders during the recognition test. The instructions continued by describing the two questions on each trial. On each

recognition trial, the instructions asked participants to indicate via key press (z for no and m for yes) if they had heard the exact same fact as what was displayed on the screen. When the participants responded, a new screen appeared asking participants in which folder they remembered storing the fact or a variation of the fact being displayed. The choices were the same as the study phase (i.e., 1. Red, 2. Orange, 3. Yellow, 4. Green, 5. Blue, and 6. Purple) and they were displayed with the fact being tested. Participants made a selection by pressing the number key associated with the color of their choice.

Upon completion of the testing phase participants were asked two follow up questions and were debriefed. The first question was a manipulation check. Participants were asked to which Access group they had been assigned. They could select among the following options: 1. I would have access, 2. I would not have access, and 3. I don't remember. The second question was about strategy. Participants were asked to type a description of the strategy they had used to select which folder to use for a given note. During the debriefing, the general question being examined was explained, including the reason why no one actually had access to the folders at time of test.

Results and Discussion

Of the 28 participants who completed the experiment, 6 participants did not correctly answer the manipulation check question at the end of the experiment assessing whether they were assigned to the access or no access group. Because the focus of the research was on the differences as a function of whether participants believed they had access, these participants

were excluded from further analysis. Of the 22 remaining participants, 12 were in the access group and 10 were in the no access group.

Recognition

Proportion correct recognition was examined with a 2 (Access Group: access or no access) x 2 (Test Content: fact or folder) analysis of variance (ANOVA). The means are shown in Figure 1. There was a main effect of test content, $F(1, 20) = 36.11$, $MSe = 0.038$, $p < 0.0001$. Recognition was higher for facts ($M = 0.86$, $SE = 0.01$) than folders ($M = 0.51$, $SE = 0.06$). There was no main effect of access nor was there a significant interaction.

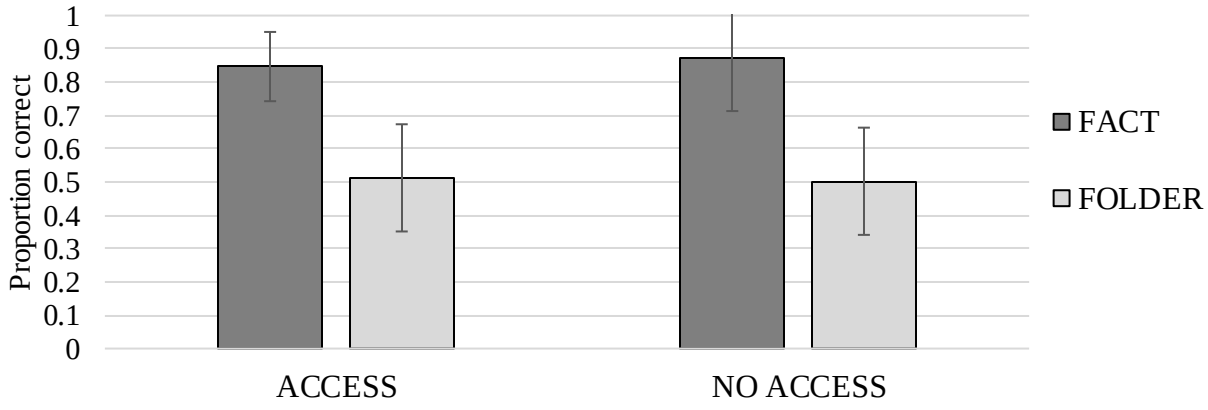

Figure 1. Proportion of facts and folders recognized for each access group. Error bars represent 95% confidence intervals.

The access manipulation did not affect performance. Participants who were told they would have access to their notes did not remember more folders than facts relative to those who were told they would not have access. However, because all participants performed close to ceiling with fact recognition, it is not possible to determine whether or not participants employed System 2 for different purposes (or at all) based on whether they believed they would have

access to their notes. Encoding of the facts may have been so effortless that there were processing resources leftover to encode folders as well. It may also have been that participants found it unnecessary to encode folders when the facts were memorable enough for them to rely on System 1 and feel confident that they would be remembered. Participants may have recognized more facts than folders because the recognition test for facts was easier than for folders. While there was a 50% chance that participants could guess the fact recognition correctly, there was only a 17% chance of guessing the folder. This could account for at least part of the difference between fact and folder recognition. Another possibility is that the facts were memorable because they were so interesting.

Strategies

At the end of the test phase participants were asked to describe the strategy used during the study phase to select which notes would go in which folders. These strategies could be taken as an indicator of System 2 effort in associating facts with folders. I categorized the strategies by whether or not they involved associating facts with folders. Some strategies included determining the folder based on associating the color of the folder with the fact while others involved assigning categories to folders and allocating notes on that basis. In both access groups the majority (58% of the access group and 70% of the no access group) of participants indicated they had used a strategy to associate facts with folder names.

Participant strategies indicate that participants in the access group behaved similarly to participants in the no access group when it came to employing System 2 to associate facts with folders. A possible explanation for this is that the access manipulation was weak so all participants might have believed they would have access to their notes. Alternatively, as already

noted, it could be that the facts were so interesting and memorable that participants, potentially experiencing the fluency effect, could have felt confident enough in remembering the facts that they did not think it necessary to recruit additional System 2 resources to encode the folders regardless of access condition. Finally, all participants had to designate folders for each fact and this might have had the unintended consequence of directing their attention to the folders and unintentionally leading to similar levels of System 2 processing in both groups.

No support was found for the prediction, based on the findings of Sparrow et al. (2011), that participants who were told they would have access to folders would recruit System 2 for different purposes than those who were told they would not have access. There was no difference between the two groups in terms of how many participants used strategies to determine which notes went into which folders, so it is unlikely that the strategies participants employed were based on access group. It is possible that all participants believed they would have access to folders on the basis of having to choose where to store their notes or that the act of choosing where to store each note established a fact to folder association that was similar in both access groups.

The trivia facts used in Experiment 1 were interesting and dealt with subjects familiar to the participants. As a result, they were easy to remember and likely appealed to reliance on System 1. The facts were generally not very detailed, which could have reduced the level of processing required to encode them. This might have made recruiting System 2 to encode details superfluous. The only need to use System 2 was to choose the folder. As a result, both access

groups processed the facts and folders in the same way leading to similar performance on the recognition test.

Trivia facts could be easy to remember because they deal with more general knowledge that does not require an understanding of any unknown concepts. The information might also be interesting in its own right. Memory for more difficult and esoteric facts about very specific items might require more effort to encode and require the use of System 2, particularly if the participant is unfamiliar with the underlying concepts or terminology. This possibility was examined in Experiment 2.

CHAPTER 3: EXPERIMENT 2

In Experiment 2, a procedure similar to that of Experiment 1 was used. The study phase involved participants' listening to facts and typing notes about those facts to be stored in folders selected by the participants. The facts included some trivia from Experiment 1 as well as more esoteric facts that were judged by seven undergraduate research assistants to be more difficult to encode. The instructions were generally the same between the two experiments but the instructions for Experiment 2 included more details as well as an example of how folder access would work during the test phase.

In Experiment 1, which used a recognition task, performance was near the ceiling. Sparrow et al. (2011, Experiment 4) used a recall task and participants seemed to perform close to floor, which presents a similar problem. If participants struggle to remember either the facts or the folders, then it is difficult to ascertain what might be happening during encoding. In Sparrow et al., participants remembered more folders than facts. This could be because memory for the folders was assessed with a cued recall test while memory for the items was assessed with free recall. Participants, when prompted with a cue, might also have been able to remember the fact associated with the cue, but they were not given the chance to do so.

A cued recall test can be considered an intermediary between recognition and free recall in terms of difficulty. While not providing a full answer, like recognition provides, there is a clue as to where an item might be located in memory, which is more information than free recall provides. Cued recall more closely resembles what a student might use to look for notes on a computer. It is likely that when students are looking for something in their notes, they have an idea of what they are looking for and can use that as a cue to locate it.

The trivia facts used in Experiment 1 were very interesting and thus very memorable. It could also be that the nature of the information affects the type of encoding strategy used. For

more difficult to remember information, rather than using System 2 to fully understand and internally store the information, participants might be more tempted to use System 1 to store the general subject and then turn to System 2 to associate the subject with a folder for future access. This would lead to better association of cues with folders than to memory for fully detailed facts. For easier to remember information, participants might rely on System 1 for encoding the information deemed important and might only use System 2 to make the choice of the folder with no additional attempt to associate the fact and the folder. By varying difficulty levels of the facts it might be possible to determine when System 2 is recruited and for what it is used.

Six participants failed the manipulation check in Experiment 1, suggesting that simply telling participants that they will or will not have access while also explaining the nature of the task is not a sufficiently strong manipulation. In the current experiment, steps were taken to make sure participants understood the group to which they had been assigned and what that assignment would mean when it came to the test. All participants were presented an example of what the test situation would be like for both the access group and no access group before they were informed of their group assignment. In addition, before the start of the study phase, a research assistant asked participants about whether they would have access to folders during the test phase of the task. Participants who answered correctly were allowed to begin the study phase without further instructions and those who answered incorrectly were given further instructions about whether or not they would have access to folders.

During the test phase participants were asked to recall facts associated with cues. Each cue was part of the grammatical subject of a studied fact. The task was to recall the details from the studied fact named by the cue. For example, "What is the statement you heard about hermeneutics" was the recall cue for the fact "Hermeneutics is the theory and methodology of

text interpretation." Participants had to type the facts about the cues as best as they could remember them. After recalling the facts, using the same cue, participants were asked to type the color or number of the folder in which the associated fact was stored.

In Experiment 1, the participants did the recognition test immediately after the study phase. This likely contributed to the near ceiling performance, so a distractor task was inserted between study and test in Experiment 2. Putting a delay between the study and recall phases would decrease the likelihood that participants could rehearse some of the facts. A distractor task requires participants to attend to the task rather than attempt to further think about studied materials.

Given the inclusion of more difficult facts, the change to a cued recall test, and the addition of a distractor task, it was predicted that overall performance would be lower than in Experiment 1. Based on the findings of Sparrow et al. (2011, Experiment 4), participants in the access group were expected to remember more folders where notes were stored than the facts themselves. This prediction was based in part on the assumption that participants in the access group would use System 2 in order to remember where they put their notes so they could use them for recall. Conversely, the no access group was expected to use System 2 to encode more details from the facts because they would not have access to the folder during the recall test. For facts that were easy, participants were expected to rely predominantly on System 1 for encoding but there would be some memory for the folder as was found in Experiment 1. This was expected of all participants regardless of group assignment because every participant was asked to designate a folder in which to store their notes and therefore every participant used System 2 to associate the fact and folder. For the difficult facts, participants in the access group were

expected to recall more folders than facts and participants in the no access group were expected to recall more facts than folders.

Method

Participants and design

There were 44 participants from Iowa State University who completed the study for credit. There were 27 females and 17 males. The average age of the participants was 19.4 years (*SD* = 1.14). Half of the participants were assigned to the access group and half were assigned to the no access group. The IRB approval for this study can be found in *Appendix A*.

Stimuli and materials

Participants completed the task on a computer using a monitor and keyboard throughout the entire task and a pair of headphones to listen to the facts during the study phase of the task. The task was programmed and presented in the same manner as Experiment 1. Participants were provided with written instructions presented in black size 24 Arial font centered on a white background on the computer monitor.

Undergraduate research assistants judged 48 facts, 24 of which were taken from Experiment 1, on how memorable and interesting they were. The 18 facts judged as most interesting and memorable were included as easy facts. An example of an easy fact is "The collective term for a group of owls is a parliament." The 18 facts rated the least interesting and least memorable were included as the difficult facts. An example of a difficult fact is "Korsakoff's syndrome occurs as a result of thiamine deficiency." The difficult facts came from random pages on Wikipedia as well as the memory of the researcher. The higher difficulty facts included topic-specific vocabulary that might not be familiar to the participants such as 'furlong,' 'numismatics,' 'hermeneutics,' and 'Tardive dyskinesia.' All 36 facts are provided in *Appendix*

C. Categories covered by these facts included physics, cognitive psychology, genetics, and others. Audio stimuli were created using the same method as was used in Experiment 1.

The cues used in the test phase were derived from the grammatical subjects of the facts presented during the study phase. All cues started with the phrase "What is the statement about" and included the cues provided in *Appendix C*. Test materials were the same for all participants.

Procedure

The instructions during the study phase were similar to those given in Experiment 1, but participants were provided with an example of how notes could be accessed during the test phase for those put in the access group. All participants saw the example before they were informed about the group to which they had been assigned. Before participants began the study phase, a research assistant asked the participant to which group he or she was assigned. Participants who answered correctly were allowed to move on to the study phase without further instructions. Participants who answered incorrectly were given further instructions to clarify their group assignment before they were allowed to continue.

The procedure of the study phase was the same as in Experiment 1. Participants listened to facts, one at a time, each fact played only once. They took notes on a computer and chose in which folder they would like to save the notes. The folder choices were: 1. Red, 2. Orange, 3. Yellow, 4. Green, 5. Blue, 6. Purple. Participants were instructed to distribute their notes as equally as possible. To make this task easier, participants were provided with a count of how many facts were already in each folder every time a folder was chosen.

In the initial instructions, all participants were informed that some participants would be allowed to access folders during the test phase of the experiment. The instructions to participants in the access group indicated that during the test phase for each item they would be allowed to

view a selected folder in which they believed they had saved the notes that they typed during the study phase. The participants in the no access group were told that they would not have access to any folders during the test phase.

Upon completion of the study phase, participants were given a short (5 minute) speeded distractor task during which they had to identify which letter (S or T) appeared on the left or right side of a fixation cross in the middle of the screen. The purpose of the distractor task was to put some time between the study and test phase. After the distractor task participants were provided with test instructions, which were the same across all participants. Prior to receiving these instructions, participants were informed that no participants would have access to folders during this phase of the experiment. The instructions were to type in the fact associated with the cue presented on the screen. Upon pressing enter to submit a response, participants were asked to recall in which folder the note about the fact associated with the cue was saved during the study phase. They could enter their responses as either the color or the number of the remembered folder.

Upon completion of the test phase, participants were asked follow up questions and debriefed. As in Experiment 1, the first question asked whether the participant had been assigned to the access or no access group. The second question asked participants to describe the strategy they had used to assign notes to folders. A third question asked: "Do you think that being told that you would have access to the folders would affect how well you remembered which folder went with which trivia fact?" with response options: "yes, I probably would remember better" and "no, it would have no impact on my memory." A fourth question asked "If you had the opportunity to access a folder during the test phase, would you have used it or would you try to

recall the information from memory?" with response options "I would have used the folder" and "I would recall the information from memory."

Results and Discussion

Out of 44 participants who completed the study, data from six participants were discarded. Three participants were removed for not following directions, either putting all notes into one folder or not giving responses to the questions about folders. The other three participants were removed for not even attempting to recall more than 50% of the facts and not recalling correctly any that were attempted. Of the remaining 38 participants, who were included in the analysis, 19 were in the access group and 19 were in the no access group. No participants failed the manipulation check.

Scoring

Each cued recall response for the facts was scored in a binary fashion as correct or incorrect. A general rule was that all relevant details needed to be included for the response to be considered correct. This rule was standardized across participants through the creation of idea-units (e.g., Dunlosky, Hartwig, Rawson, & Lipko 2011), which represented the noun phrases, adjectives, and verbs that contributed to the meaning of the statement. Redundant terms as well as terms contributing only to the grammatical structure of the statement were excluded. The idea units for each fact are shown in *Appendix C*.

Only responses containing all of the relevant idea-units (or variations of those units) were marked as correct. The response did not have to repeat the information included in the cue. Responses that were missing any idea-units were marked as incorrect. For example, "What is the statement you heard about signal detection theory" was the cue to the studied statement "Signal detection theory quantifies the ability to distinguish signal from noise." To be correct, the

response would have to include quantification as well as the ability to distinguish signal from noise. An incorrect recollection might say "it is the ability to distinguish signal from noise." The response is incorrect because the theory entails quantification of the ability. That is, incorrect recollections were missing any idea unit within the fact without which the fact would not be true. Many of the easier facts did not require detailed responses to be correct. For instance, "owls = parliament" was considered correct for the fact "The collective term for a group of owls is a parliament" because the meaning of the fact was conveyed and details were extraneous. Folders were marked as correct when the color or number of the folder where the note on a fact was stored was correctly typed, and misspellings were accepted.

Cued recall

Proportion correct cued recall was examined with a 2 (Access Group) x 2 (Fact Difficulty) x 2 (Test Content) ANOVA.[1] The means are shown in Figure 2. There was a main effect of test content, F (1, 36) = 7.16, MSE = .052, $p < 0.0001$. Recall was lower for folders (M = 0.50, SE = 0.03) than facts (M = 0.40, SE = 0.03). There was a main effect of fact difficulty F (1, 36) = 140.63, MSE = 0.052, $p < 0.0001$. Recall was higher for easy facts (M = .60, SE = 0.04) than hard facts (M = .20, SE = 0.03). There was an interaction between difficulty and test content, F (1, 36) = 24.45, MSE = 0.023, $p < 0.0001$. There was no main effect of access group nor were there any other significant interactions.

[1] In an attempt to make performance on the easy and hard facts more comparable, the data were rescored to get a proportion of idea units recalled. This analysis is included in *Appendix D*. The pattern of results was the same.

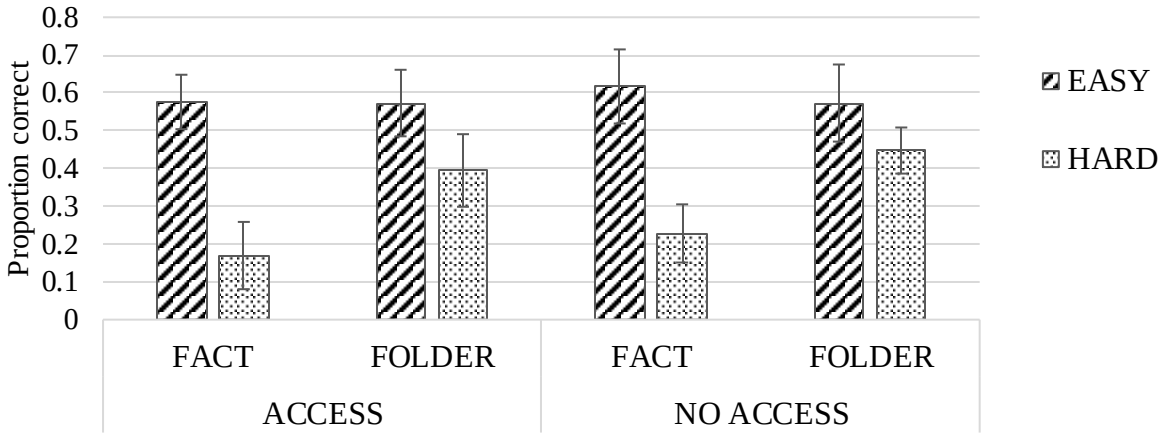

Figure 2. Proportion of easy and hard facts and folders recalled for each access group. Error bars are 95% confidence intervals.

The Fact Difficulty x Test Content interaction is easily seen in Figure 2. Simple main effects tests showed that there was no difference in folder and fact memory for easy facts, F (1, 36) = 0.21, p = 0.65, but folder memory was higher than fact memory for hard facts F (1, 36) = 24.33, $p < 0.0001$.

While no recall differences were found between participants in the access and no access group, there was an effect of difficulty on recall for both facts and folders. Participants recalled more facts and folders when the facts were easy than when the facts were hard. When the facts were easy, participants recalled facts and folders at a similar rate. When the facts were hard, recall of the facts was especially low and participants recalled more folders than facts. A potential explanation for better folder than fact memory was brought up by Sparrow et al. (2011) when discussing the limitations of their experiments. There were far fewer folders (6) than facts (36), which makes recalling folders easier than recalling facts. However, as just noted, when the facts were easy, participants recalled just as many facts as folders and when the facts were hard

participants were performing above chance in folder memory. If participants guessed on all of the folders they would have been correct about 17% of the time. Their performance was higher, indicating that they were not just guessing the folders. It may be that the hard facts were so unfamiliar to System 1 that they could not be accurately encoded and only the general topic or category was available to System 2. System 2 used the partial information to determine the folder and the association between the partial information and the folder was available on the folder recall test.

Strategies

Participants described the strategies that they employed for determining in which folder each note was stored. Just as in Experiment 1, strategies were split into two categories: strategies that related the facts to the folders and strategies that were unrelated to the facts. Overall there was no difference between the strategies used by participants in the access group and participants in the no access group. In both access groups, 79% of participants responded that they used a strategy that related the subject of the fact to the color or number of the folder where they assigned it.

There also was no real difference in responses between the access and no access group in the other two questions asked at the end of the experiment. The percentage responding that they would probably better remember which folder went with which fact if they were in the access group was 84% for the access group and 79% for the no access group. The percentage responding that they would have used the folders if they had the opportunity to access them during the test phase was 84% for the access group and 100% for the no access group.

Just as with Experiment 1, access group had no effect on memory as reflected in cued recall. Just as in Experiment 1, participants in both access groups reported using strategies to

determine which facts went into which folders. There was no difference between the groups in how often participants used strategies that depended on associating a fact with a color either by category or by imagery. It could be that participants in the no access group did not believe that they would not be given access to folders because they had to take notes and save them to folders. The act of taking notes on a computer and then choosing where the notes would be stored might have provided them with contradictory evidence. The very act of choosing folders with names unrelated to the contents of the facts likely guided participants towards using System 2 to make associations between facts and folders. While it is also possible that participants in the access group did not believe that they would actually have access to the folders at time of test, this is unlikely because most of the participants indicated that they used strategies to associate facts with folders as a method for encoding where they could find the facts if they needed them. Most participants also agreed that they would have used their notes if they were given the chance to access the folders during test. Considering the recall and strategy data together, it seems that requiring participants to decide where to store a fact leads to a decision to strategically map the content of the fact onto folders. The need to make a folder decision produces a natural association between the fact and its folder regardless of the access condition.

Notes

Participants in Experiment 1 performed close to ceiling on the recognition test, so there was no need to examine note quality either as an indication of successful fact encoding or as a driver of memory accuracy. Because participants in Experiment 2 were not performing close to ceiling, the quality of their notes was examined. Participants' notes were rated based on how helpful the notes would have been if they were available during the recall test. Notes that were unrelated, incomplete, or misinterpretations of the facts were rated as poor notes. Notes from

which the facts could be reproduced either in full or with the same meaning as the original were rated as good notes. Because hard facts contained more detail, notes were more likely to be scored as good for easy facts than hard facts. Good notes for hard facts often required verbatim or close to verbatim notes. Two raters categorized all participants' notes as either good or poor.[2] The agreement between the raters, measured as Cronbach's α, was 0.97, so the ratings were considered reliable.

An exploratory analysis of note quality showed differences between the easy and hard facts. Proportion of good notes was examined with a 2 (Access Group) x 2 (Fact Difficulty) ANOVA.[3] Just as would be expected given the recall data, there was no main effect of access group and no interaction. There was a main effect of fact difficulty, $F(1, 36) = 159.58$, $MSE = 0.02$, $p < 0.0001$. The proportion of good notes for easy facts ($M = .72$, $SE = 0.04$) was greater than the proportion of good notes for hard facts ($M = .32$, $SE = 0.04$).

Proportion of correct recall was examined with a 2 (Note Quality: good or poor) x 2 (Test Content: fact or folder) analysis of variance (ANOVA). There was a main effect of note quality, $F(1, 36) = 21.10$, $MSE = 0.06$, $p < 0.001$. Recall was higher for facts and folders with good notes ($M = 0.31$, $SE = 0.02$) than with poor notes ($M = 0.13$, $SE = 0.01$). There was an interaction between note quality and test content, $F(1, 36) = 32.94$, $MSE = 0.01$, $p < 0.001$. The interaction is shown in Figure 3. Simple main effects tests showed that there was no difference between proportion of facts and folders recalled when notes were good, $F(1, 36) = 0.05$, $p = 0.83$, but

[2] An initial attempt to create a more precise rating system was unsuccessful as there was no obvious way to determine graded boundaries between the good or poor categories.
[3] Correlations corresponding to the notes analyses in this section are shown in *Appendix E*.

folder memory was higher than fact memory when notes were poor, F (1, 36) = 35.15, p < 0.0001.

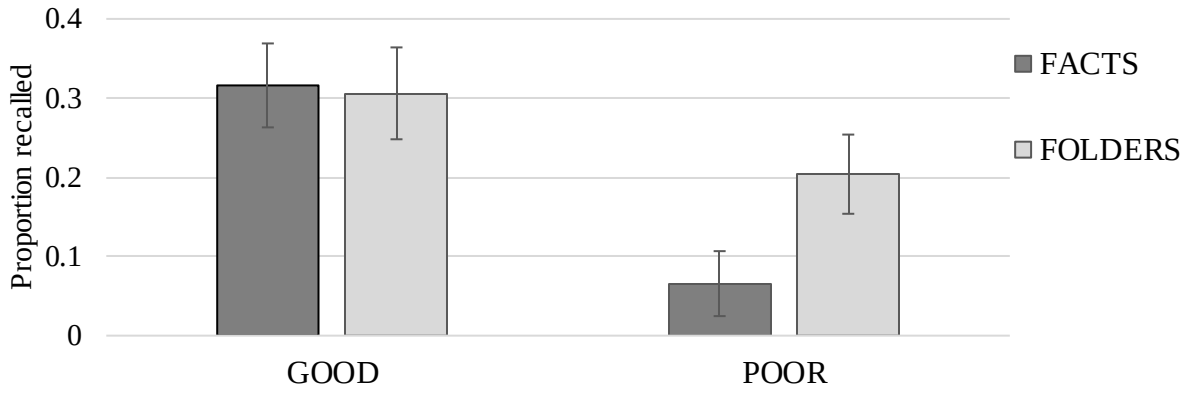

Figure 3. The proportion of facts and folders recalled when notes were good or poor. Error bars are 95% confidence intervals.

The notes analysis supports the possibility that recall of hard facts is poor at least in part because the hard facts are not well encoded to begin with. This is evidenced by the paucity of good notes taken for hard facts. The notes were taken after the fact was heard in its entirety, so in order to take good notes the fact must have been kept in working memory for the time between when the fact was finished and when the note was completely entered. It is likely that System 1 was able to encode and maintain familiar terms in working memory. However, because good notes were taken for hard facts on only about a third of the trials, it appears that System 1 was not able to do that with less familiar terms. This might produce a situation in which participants are unable to rely on System 2 processing of the fact itself because System 1 fails to provide sufficient input. However, when the facts were hard, participants remembered more folders than facts suggesting that even though the participants had a hard time encoding the hard facts (as evidenced by the small number of good notes and lack of facts recalled), they were able to encode some of the folders in association with the facts. It appears that for hard facts only

partially encoded by System 1, the use of System 2 to choose a folder establishes enough of an association that it can sometimes be used to recover the folder during the recall test.

CHAPTER 4: GENERAL DISCUSSION

In Experiment 1, memory for facts and their locations in external memory was examined by comparing the performance of participants who were told they would have access to information with those who were told they would not. A prediction was made, based on the findings of Sparrow et al. (2011), that participants who believed they would have external access to information would prioritize encoding where that information could be found over the details of the information. The manipulation did not have an effect and participants performed near ceiling on a recognition test in Experiment 1. Experiment 2 strengthened the access manipulation, included facts of variable difficulty, and used cued recall tests instead of recognition to bring performance down from ceiling. As in Experiment 1, the access manipulation did not have the effect predicted from the results of Sparrow et al. Access group had no impact on performance, but fact difficulty did.

Sparrow et al. (2011, Experiment 3) had participants read facts from a list and use a keyboard to type them into a computer. The participants were told that they would be able to access the facts during a test if they could remember where they were stored. After typing in each fact the participants were informed where it was saved if it was saved at all. A third of the facts were saved in a specific folder with a generic label such as FACTS, DATA, or INFO. Another third were saved in an unspecified folder. The remaining facts were not saved at all. This experimental approach examined not just participants' memory for facts and folders when facts were saved, but also what happened to fact memory when facts were erased or saved in an unspecified location. Each participant saw facts that they were lead to believe they would have access to as well as facts that they were lead to believe they would not. The within-subjects nature of this design was not employed in the current experiments in which some participants

were lead to believe they would have access to all of the information they saved while others were lead to believe they would not.

The procedure of the current experiments more closely mirrored Sparrow et al.'s (2011) Experiment 4 in which all of the facts that participants typed were saved into a folder randomly designated by the experimenter. Participants were not given any practice trials and their attention was never explicitly directed to the names of the folders or how many there were. In contrast, participants in the current experiments were made explicitly aware of the names of the folders as well as how many there were thereby directing their attention to the folders regardless of whether or not they would be able to use them. Participants in Experiment 1 were shown the names of all of the folders each time they were asked to select where a fact would be saved. Participants in Experiment 2 were shown the names of the folders when they made their selection as well as the number of notes saved to each folder after the selection was made thereby making both the names of the folders and their quantity salient during each trial.

Expanding upon the findings of Sparrow et al. (2011), Experiments 1 and 2 incorporated more ecologically valid manipulations in terms of how folders were assigned to facts and how the information was presented. In Sparrow et al., the assignment of folders to facts was arbitrary and was determined by the experimenter. In the current experiments, an attempt was made to more closely reflect how students might use external storage devices, such as laptops, to save information from lectures. When using a laptop during a lecture to type notes, students determine for themselves where their notes will be saved.

Determining where notes should be saved seemed to have more of an impact on participants' memory than whether or not they would have access to these notes. This agency was absent from the Sparrow et al. (2011) experiments but was a major component of both of the

current experiments. While the names of the folders were chosen by the experimenter to not be associated with the facts, participants were able to form these associations themselves as indicated by their use of strategies. Experiment 4 of Sparrow et al. provided participants with information about where their notes were stored, but this was a passive process and might not have motivated the creation of associations between facts and folders. Moreover, the generic quality of the names used in Sparrow et al. might have made it more difficult to form these associations had the motivation arisen. The names of the folders were DATA, FACTS, INFO, NAMES, ITEMS, and POINTS. It is difficult enough to distinguish between these terms as they are synonymous, which would make forming associations between the facts and these folder names counterintuitive. The current experiments provided participants with folder choices that were not interchangeable and could easily lend themselves to associations. This increased the likelihood that participants, regardless of access condition, would be able to encode the folder names alongside the facts. This is a likely explanation for why no difference was found between participants in the access and no access condition.

In Sparrow et al. (2011), participants simply typed verbatim statements that they saw on the screen. In the current experiments, the information was heard and students were instructed to take notes that might help them. This more closely resembles a typical classroom situation in which student notes are likely to come from a lecture delivered verbally and maybe through the use of a projector and slides. Participants in Sparrow et al. were also not limited in the amount of time they spent looking at the statements. Presenting the information auditorily in the current experiments forced a time limit on how long participants were exposed to each fact. If a participant was distracted or otherwise unable to keep a fact in working memory he or she would not have had the opportunity to verify the accuracy of the notes that he or she typed.

Additionally, the unfamiliarity of terminology used in the hard facts of Experiment 2 might have adversely impacted participants' ability to retain any of the information presented long enough to take notes.

Requiring participants to designate the folder in which their notes would be saved produced System 2 usage for associating facts with folders regardless of whether participants believed the folders would be available to them. The association was established even when there was insufficient input from System 1 to fully encode the fact as with the difficult facts. It could be that it is easier to use System 2 to associate a general category (like science or geography) with a color than it is to use System 2 processing to create a framework for an entirely unfamiliar fact. Participants may have simply adapted their System 2 processing to forming associations rather than encoding details. Since the easy facts did not require very many details to be recalled, System 1 might have been sufficient to generate a correct response leaving System 2 the option of associating the facts with folders.

The results do not support any definitive statement about how System 2 processing might be employed when participants believe they will have access to externally saved information, but some general inferences can be made. Participants seemed to use System 2 more frequently to encode associations between facts and folders than the details of the facts. When System 2 was guided by the instructions towards forming associations between facts and folders, it frequently was able to create those associations.

The difficult facts in Experiment 2 were difficult in two ways. The first was the inclusion of esoteric terminology that may not have been familiar to most of the participants. The second was the inclusion of more idea units than were present in the easy facts. This combination of factors could have made the difficult facts more difficult than necessary thereby making it

unlikely for participants to be able to remember them. One way to mitigate the problem of overly-difficult facts might be to focus on more detailed facts instead of combining details and esoteric terminology. The terminology might have caused the participants to give up before they even had a chance to take notes. Facts that include a lot of details could be compared with simpler facts in a more straightforward fashion. Future studies might examine encoding strategies for simple and complex facts when participant are allowed to save their notes on a computer. Instead of including unfamiliar terminology, the complex facts would either have uncommon grammatical structures or more idea units than the simple facts.

Humans are often required to retain information that is not personally relevant or interesting. This is especially apparent in the realm of education where students are taught a much broader curriculum than they believe is required for employment. The content of the information being taught can be highly specific to the subject and employ terminology that is not part of the common vernacular. When faced with complex information that needs to be remembered and given the option of having that information available in a digital form, it seems that this could be a very appealing option. When students are faced with particularly pernicious terms and definitions they might be tempted to offload the effort of retaining a complete definition in favor of having it saved somewhere on their computers. Using System 2 to ensure future access to information might be more appealing than using it to store information internally. This could be occurring when students take notes on their laptops in class and rely on being able to find the information they saved rather than devoting the processing resources required to encode that information internally. The availability of external memory may drive people to use it, as was demonstrated by Risko and Dunn (2015). When faced with a situation where information must be integrated and applied, this dependence upon external memory might

prove to be more cumbersome than helpful. Offloading memory to an external source might entail relying more on System 1 and surface level processing, which makes it unlikely that the information could be integrated into a broader framework. This not only reduces the chances of being able to recall the information but also decreases the opportunity to use the information in a meaningful way.

While college students often encounter complex and subject-specific terminology in their coursework, it is usually presented visually as well as auditorily, which allows students to write down the exact term rather than guessing what it might be. This could lead to superficial processing (which can be done by System 1). In addition, the material is organized rather than just a series of unrelated facts. A potential follow-up study might look at related statements presented both visually and auditorily.

The promise of external memory seemingly has an impact on how participants process information, as indicated by the majority of participants in both experiments using strategies to associate their notes with the folders where they were saved. That impact is likely stronger for more difficult facts, which might provide participants with an opportunity to obtain information without exerting a lot of effort in processing it by simply remembering where to find that information when needed. Further investigations into the relationship between internal and external memory might hone in on which circumstances lead to different types of System 2 processing.

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APPENDIX A: IRB APPROVAL

IOWA STATE UNIVERSITY
OF SCIENCE AND TECHNOLOGY

Institutional Review Board
Office for Responsible Research
Vice President for Research
1138 Pearson Hall
Ames, Iowa 50011-2207
515 294-4566
FAX 515 294-4267

Date: 2/24/2016

To: Anna Slavina
W112 Lagomarcino Hall

CC: Dr. Veronica Dark
W112 Lagomarcino Hall

From: Office for Responsible Research

Title: External vs Internal Memory

IRB ID: 16-023

Approval Date:	2/24/2016	**Date for Continuing Review:**	2/23/2018
Submission Type:	New	**Review Type:**	Expedited

The project referenced above has received approval from the Institutional Review Board (IRB) at Iowa State University according to the dates shown above. Please refer to the IRB ID number shown above in all correspondence regarding this study.

To ensure compliance with federal regulations (45 CFR 46 & 21 CFR 56), please be sure to:

- **Use only the approved study materials** in your research, **including the recruitment materials and informed consent documents that have the IRB approval stamp**.
- **Retain signed informed consent documents for 3 years after the close of the study**, when documented consent is required.
- **Obtain IRB approval prior to implementing any changes** to the study by submitting a Modification Form for Non-Exempt Research or Amendment for Personnel Changes form, as necessary.
- **Immediately inform the IRB of** (1) **all serious and/or unexpected adverse experiences** involving risks to subjects or others; and (2) **any other unanticipated problems involving risks** to subjects or others.
- **Stop all research activity if IRB approval lapses**, unless continuation is necessary to prevent harm to research participants. Research activity can resume once IRB approval is reestablished.
- **Complete a new continuing review form** at least three to four weeks prior to the **date for continuing review** as noted above to provide sufficient time for the IRB to review and approve continuation of the study. We will send a courtesy reminder as this date approaches.

Please be aware that IRB approval means that you have met the requirements of federal regulations and ISU policies governing human subjects research. **Approval from other entities may also be needed.** For example, access to data from private records (e.g. student, medical, or employment records, etc.) that are protected by FERPA, HIPAA, or other confidentiality policies requires permission from the holders of those records. Similarly, for research conducted in institutions other than ISU (e.g., schools, other colleges or universities, medical facilities, companies, etc.), investigators must obtain permission from the institution(s) as required by their policies. **IRB approval in no way implies or guarantees that permission from these other entities will be granted.**

Upon completion of the project, please submit a Project Closure Form to the Office for Responsible Research, 1138 Pearson Hall, to officially close the project.

Please don't hesitate to contact us if you have questions or concerns at 515-294-4566 or IRB@iastate.edu.

APPENDIX B: EXPERIMENT 1 STIMULI

Table A1. Trivia Facts Used in Experiment 1 Along with their False Versions

Statement	**Test**	**True or False**
1a. Al Capone's business card said he was a used furniture dealer.	B	True
b. Al Capone's business card said he was a used car dealer.	A	False
2a. The international telephone dialing code for Antarctica is 672.	A	True
b. The international telephone dialing code for Australia is 672.	B	False
3a. The king of hearts is the only king without a moustache.	B	True
b. The king of spades is the only king without a moustache.	A	False
4a. Every year about 98% of the atoms in your body are replaced.	A	True
b. Every day about 98% of the atoms in your body are replaced.	B	False
5a. Bluebirds cannot see the color blue.	B	True
b. Bluebirds cannot see the color red.	A	False
6a. A person burns more calories when sleeping than when watching television.	B	True
b. A person burns more calories when watching television than when sleeping.	A	False
7a. In Chinese script, there are more than 40,000 characters.	B	True
b. In Japanese script, there are more than 40,000 characters.	A	False
8a. The longest classical composition would take 639 years to perform.	B	True
b. The longest modern composition would take 639 years to perform.	A	False
9a. A cow produces nearly 200,000 glasses of milk in her lifetime.	A	True
b. A cow produced nearly 200,000 gallons of milk in her lifetime.	B	False

Statement	**Test**	**True or False**
10a. Europe is the only continent without a desert.	A	True
b. Antarctica is the only continent without a desert.	B	False
11a. Elephants are the only mammals that can't jump.	B	True
b. Giraffes are the only mammals that can't jump.	A	False
12a. Peanuts are an ingredient in dynamite.	A	True
b. Almonds are an ingredient in dynamite.	B	False
13a. Mary Stuart became Queen of Scotland when she was six days old.	B	True
b. Mary Stuart became Queen of Ireland when she was six days old.	A	False
14a. French fries are originally from Belgium, not France.	B	True
b. French fries are originally from Germany, not France.	A	False
15a. Greenland is the world's largest island by area.	A	True
b. Iceland is the world's largest island by area.	B	False
16a. A lion's roar can be heard from 5 miles away.	A	True
b. A tiger's roar can be heard from 5 miles away.	B	False
17a. The highest point in Pennsylvania is lower than the lowest point in Colorado.	A	True
b. The highest point in West Virginia is lower than the lowest point in Colorado.	B	False
18a. The Baby Ruth candy bar was actually named after Grover Cleveland's baby daughter, Ruth.	B	True
b. The Baby Ruth candy bar was actually named after Chester A Arthur's baby daughter, Ruth.	A	False
19a. Minus 40 degrees Celsius is exactly the same as minus 40 degrees Fahrenheit.	B	True
b. Minus 32 degrees Celsius is exactly the same as minus 32 degrees Fahrenheit.	A	False

Statement	**Test**	**True or False**
20a. The great Pyramids of Giza are the only one of the Seven Wonders of the Ancient World that still exist.	A	True
b. The Hanging Gardens of Babylon are the only one of the Seven Wonders of the Ancient World that still exist.	B	False
21a. A quarter has 119 grooves around the edge.	B	True
b. A nickel has 119 grooves around the edge.	A	False
22a. The Atlantic ocean is more salty than the Pacific ocean.	A	True
b. The Pacific ocean is more salty than the Atlantic ocean.	B	False
23a. There are an average of 178 sesame seeds on a McDonald's Big Mac bun.	A	True
b. There are an average of 178 sesame seeds on a Burger King Whopper bun.	B	False
24a. A person will shed over 40 pounds of skin in their lifetime.	A	True
b. A person will shed over 40 kilograms of skin in their lifetime.	B	False
25a. Only two countries border three oceans, the United States and Canada.	B	True
b. Only two countries border three oceans, the United States and Mexico.	A	False
26a. The fastest flying insect is the dragonfly.	A	True
b. The fastest flying insect is the butterfly.	B	False
27a. The largest land-locked country in the world is Mongolia.	A	True
b. The largest land-locked country in the world is China.	B	False
28a. Panama hats originated in Ecuador.	B	True
b. Panama hats originated in Bolivia.	A	False
29a. Damascus is the oldest continuously inhabited city in the world.	B	True
b. Jerusalem is the oldest continuously inhabited city in the world.	A	False
30a. The earth is struck by lightning 100 times every second.	B	True
b. The earth is struck by lightning 100 times every minute.	A	False

Statement	**Test**	**True or False**
31a. The average human body contains enough iron to make a 3 inch nail.	B	True
b. The average human body contains enough iron to make a 5 inch nail.	A	False
32a. Every continent in the world contains a city called Rome.	A	True
b. Every continent in the world contains a city called Athens.	B	False
33a. North Dakota is the only state that has never had an earthquake.	A	True
b. North Carolina is the only state that has never had an earthquake.	B	False
34a. Poison oak and poison ivy are members of the cashew family.	A	True
b. Poison oak and poison ivy are members of the nutmeg family.	B	False
35a. The dial tone of a normal telephone is in the key of 'F'.	A	True
b. The dial tone of a normal telephone is in the key of 'G'.	B	False
36a. Giraffes have the highest blood pressure of any animal.	B	True
b. The blue whale has the highest blood pressure of any animal.	A	False

APPENDIX C: EXPERIMENT 2 STIMULI

Table B1. Easy and Hard Trivia Statements with Recall Cues and Idea-units in Experiment 2*.

HARD		
Statement	**Recall Cue**	**Idea-units**
1. Signal detection theory quantifies the ability to distinguish signal from noise.	Signal detection theory	Quantified. Ability. Distinguish signal from noise.
2. A furlong is a measure of distance equal to 220 yards.	Furlong	Equal to 220 yards.
3. The prime minister of Canada is appointed by the governor general on behalf of the monarch.	Canada	Prime minister. Appointed by governor general. On behalf of monarch.
4. The Northern flicker is the state bird of Alabama.	Northern flicker	State bird. Alabama.
5. Numismatics is the study or collection of currency.	Numismatics	Study or collection. Currency.
6. Quantitative genetics is a branch that deals with phenotypes that vary continuously.	Quantitative genetics	Phenotypes. Vary continuously.
7. Hermeneutics is the theory and methodology of text interpretation.	Hermeneutics	Theory. Methodology. Text interpretation.
8. Electrolysis is a technique that drives otherwise non-spontaneous chemical reactions.	Electrolysis	Drives. Non-spontaneous. Reactions.
9. Metcalfe's law allows you to calculate the value of a telecommunications system.	Metcalfe's law	Allows. Calculate. Value of telecommunications system.
10. URL stands for uniform resource locator.	URL	Uniform. Resource. Locator.
11. Brady disclosure consists of evidence that is relevant to the guilt or innocence of a defendant.	Brady disclosure	Evidence. Relevant to guilt or innocence.
12. Gamma spectroscopy is the study of the energetic transitions in atomic nuclei.	Gamma spectroscopy	Study of. Energetic transitions. Atomic nuclei.
13. Parkinson's disease involves major loss of dopaminergic cells in the substantia nigra.	Parkinson's disease	Major loss. Dopaminergic cells. Substantia nigra.
14. Tardive dyskinesia is characterized by repetitive, involuntary, purposeless movements.	Tardive dyskinesia	Repetitive/involuntary/purposeless. Movements.
15. Korsakoff's syndrome occurs as a result of thiamine deficiency.	Korsakoff's syndrome	Occur as result. Thiamine deficiency.

Statement	Recall Cue	Idea-units
16. In the endothermic process, the system absorbs energy from its surroundings usually in the form of heat.	Endothermic process	System. Absorbs energy. Heat.
17. Mass spectrometry is a technique that helps identify the amount of chemicals present in a sample.	Mass spectrometry	Identify. Amount of chemicals. In sample.
18. Thermal ionization is the process by which atoms are spontaneously ionized from a hot surface.	Thermal ionization	Atoms. Spontaneously ionized. Hot surface.
	EASY	
Statement	**Recall Cue**	**Idea-units**
19. The collective term for a group of owls is a parliament.	Owls	Parliament.
20. The collective term for a group of alligators is a congregation.	Alligators	Congregation.
21. Al Capone's business card said he was a used furniture dealer.	Al Capone	Business card. Furniture dealer.
22. The king of hearts is the only king without a moustache.	King of hearts	Only king. No mustache.
23. Every year about 98% of the atoms in your body are replaced.	Atoms	98% atoms. Replaced each year. Body.
24. Elephants are the only mammals that can't jump.	Elephants	Only mammal. Can't jump.
25. A lion's roar can be heard from 5 miles away.	Lions	Roar heard. 5mi away.
26. The Baby Ruth candy bar was actually named after Grover Cleveland's baby daughter, Ruth.	Baby Ruth	Named after. Grover Cleveland's daughter.
27. Minus 40 degrees Celsius is exactly the same as minus 40 degrees Fahrenheit.	Temperature	-40deg equal.
28. The great Pyramids of Giza are the only one of the Seven Wonders of the Ancient World that still exist.	Pyramids	Only wonder. Still exists.
29. The Atlantic ocean is more salty than the Pacific ocean.	Atlantic ocean	Saltier than. Pacific.
30. A person will shed over 40 pounds of skin in their lifetime.	Skin	Shed. Over 40lb. In lifetime.
31. Only two countries border three oceans, the United States and Canada.	The US and Canada	Only countries. Border 3 oceans.
32. Damascus is the oldest continuously inhabited city in the world.	Damascus	Oldest. Continuously inhabited city.

Statement	**Recall Cue**	**Idea-unit**
33. Every continent in the world contains a city called Rome.	Rome	Every continent. Has city called.
34. North Dakota is the only state that has never had an earthquake.	North Dakota	Only state. No earthquake.
35. Poison oak and poison ivy are members of the cashew family.	Poison oak	Members of. Cashew family.
36. The giraffe has the highest blood pressure of any animal.	Giraffes	Highest blood pressure.

* The recall cues were presented in the frame "What is the statement you heard about _____"

APPENDIX D: REANALYSIS OF EXPERIMENT 2 RECALL WITH PARTIAL CREDIT

In this analysis, the dependent variable was the proportion of idea units correctly recalled rather than the binary correct (all idea units present) versus incorrect (at least one idea unit missing) analysis reported in the main text. Proportion of idea units recalled was examined with a 2 (Access Group) x 2 (Fact Difficulty) x 2 (Test Content) ANOVA. The means are shown in Figure C1. There was no main effect of test content, $F(1, 36) = 3.58$, $MSe = .043$, $p = 0.07$. There was a main effect of fact difficulty $F(1, 36) = 187.48$, $MSe = 0.018$, $p < 0.0001$. Recall was higher for easy facts ($M = .66$, $SE = 0.03$) than hard facts ($M = .21$, $SE = 0.03$). There was an interaction between difficulty and test content $F(1, 36) = 50.62$, $MSe = 0.017$, $p < 0.0001$. The interaction is shown in Figure C2. Simple main effects tests showed that there was no difference in folder and fact memory for easy facts, $F(1, 36) = 3.19$, $p = 0.08$, but folder memory was higher than fact memory for hard facts $F(1, 36) = 26.80$, $p < 0.0001$. There was no main effect of access group nor were there any other significant interactions.

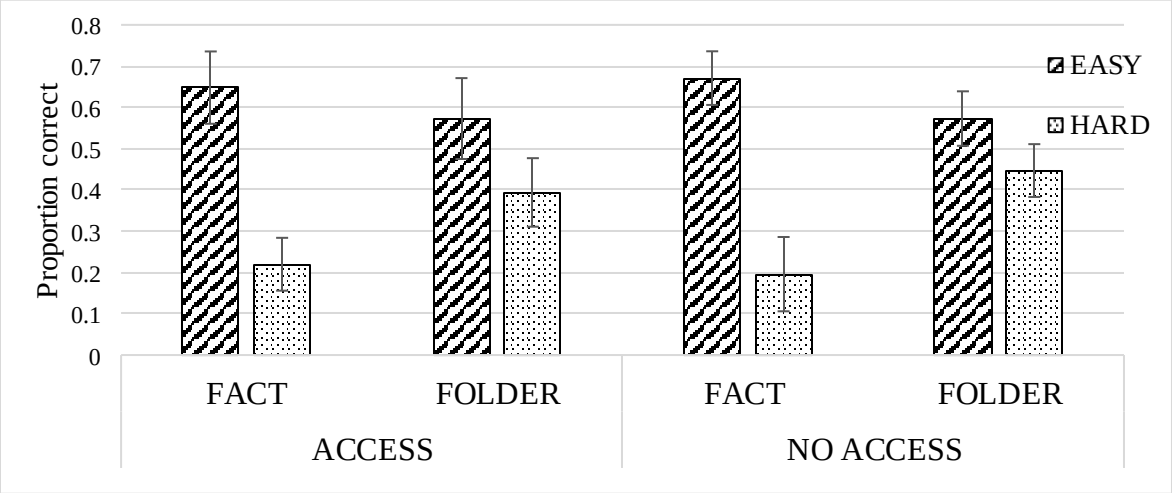

Figure C1. Proportion correct idea units recalled as a function of access condition, test content, and fact difficulty. Error bars represent 95% confidence intervals.

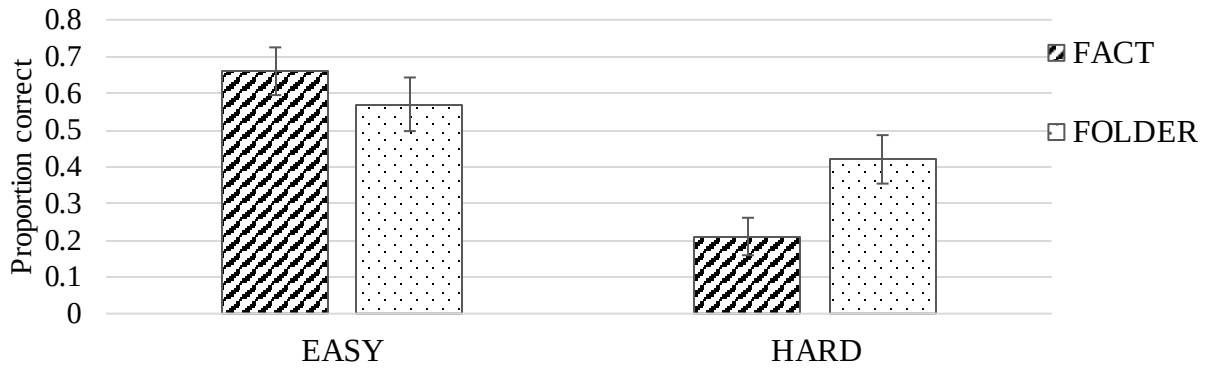

Figure C2. Rescored proportion correct facts and folders recalled as a function of difficulty. Error bars represent 95% confidence intervals.

A comparison between the original scoring method and the partial credit method is shown in Figure C3.

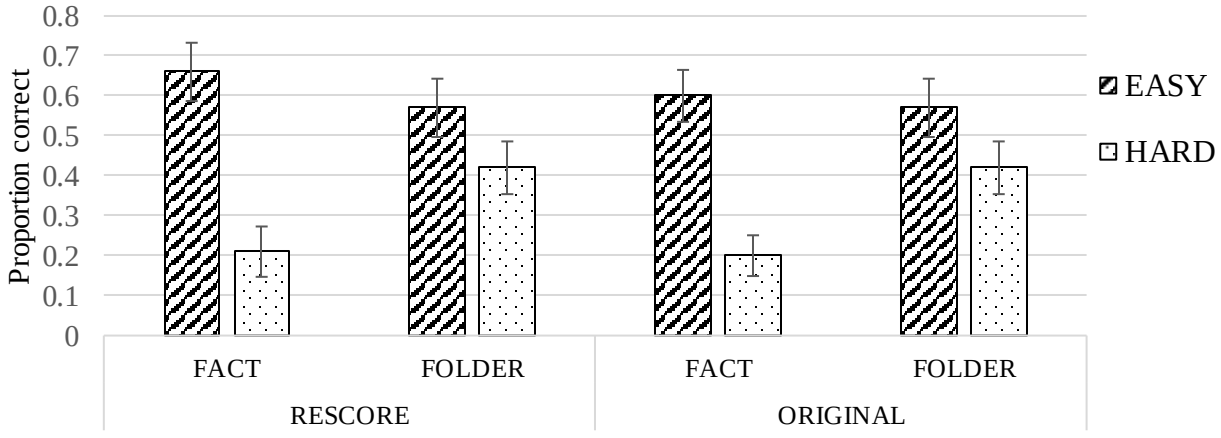

Figure C3. A comparison between recall with the original scoring method and the idea units method. Error bars represent 95% confidence intervals.

APPENDIX E: CORRELATIONS

Table D1. Pearson correlations between note quality, difficulty, content, and access condition with associated p values.

	Good notes easy	**Good notes hard**	**Facts correct**	**Folders correct**	**Access condition**	**Good notes total**
Good notes easy	r = 1	-	-	-	-	-
Good notes hard	r = .586 p < .001	r = 1	-	-	-	-
Facts correct	r = .646 p < .001	r = .519 p < .001	r = 1	-	-	-
Folders correct	r = .345 p = .034	r = .265 p = .108	r = .246 p = .137	r = 1	-	-
Access condition	r = .159 p = .341	r = .079 p = .636	r = .120 p = .474	r = .057 p = .735	r = 1	-
Good notes total	r = .890 p < .001	r = .891 p < .001	r = .654 p < .001	r = .343 p = .035	r = .079 p = .636	r = .1

Reliable associations were found between the proportion of good notes taken and the number of facts and folders correct. There were no reliable associations between Access condition and anything. The relationship between note quality and recall is apparent for both difficulty levels.