# The Benefits of Saving on New Learning

Sean M. Stone and Benjamin C. Storm

University of California, Santa Cruz

## Abstract

Instead of personally remembering every piece of digital information that we come across, we tend to store information onto computers for later reference. This study investigates how human cognition is influenced by the ability to offload memory onto external devices such as computers. Specifically, it asks whether saving our digital material provides us with better resources to remember material that is encountered in the future. This question is explored in a series of three experiments that illustrate the impact of computer fallibility and varying list length on memory for lists of words learned after the *saving* and *not saving* of prior lists. Undergraduate psychology students were recruited and ran in a natural computer environment using normal computer materials. Experiment 1 results show that *saving* material before learning new material significantly improves memory for new material compared to when *not saving* before learning new material. Experiment 2 and 3 results show that perceiving the saving process as unreliable and limiting the size of saved material eliminates memory benefits for new material. These results suggest that saving exists as a convenient way to offload knowledge, making it easier for us to remember new information that we come across.

As an integrated part of our lives, computers have allowed us to access large amounts of information from all over the Internet with speed and ease. Storing this information within our personal computers has become second nature and continues to help us keep track of a seemingly unlimited supply of digital items that would otherwise be lost. While previous research has led to an understanding of strategies that people utilize when storing digital information, much less is known about how this storage influences memory and cognition. Computers, which allow both convenient access and storage of information, may be changing the way in which we perceive saved material. This change in perception could also be affecting how we obtain and encode future information within our computer environments.

The current study seeks to investigate whether saving information into a computer frees up the cognitive resources required to better remember information that is encountered in the future. Does saving into a computer incidentally change the amount effort used to encode and, subsequently recall new material? Similarly, are computers providing their users with an advantage to offload knowledge and extend the abilities of human memory? Background research may shed light onto how these questions could be addressed.

Due to the increased functionality and storing capacity of computers, humans are eager to save information into computers for later reference (Rodden & Wood, 2003). Research on both loss aversion and item attachment offer explanations as to why people tend to keep the things that they come across (Kahneman & Tversky, 1979; Rochberg-Halton, 1984). With the recent advent of computers, humans now have even greater access to information and more compact ways of storing that information. When faced with the decision to keep digital material, users generally indulge in the saving process because it is easier to keep a file and deal with it later, then to try and judge the importance of the file in the present (Bruce, 2005). Because users do not often know how or when information will be needed in the future, saving offers the perfect option to defer judgment to a later time. Although the saving process alleviates some pressure from decision making, the convenience that it offers comes at a cost. File systems tend to be incredibly large, complicating both the organization and retrieval of files from personal systems (Whittaker, Bergman & Clough, 2010). This often places a strain on memory for what our files contain and where they are stored. For these reasons, human cognition may be adjusting to life with technology in ways to alleviate the burden of remembering the contents of file systems. One area of cognitive psychology that is beginning to look at these adjustments is called *distributed cognition.*

Among other things, distributed cognition seeks to understand how and in what contexts humans rely on the real world to 'extend' cognition. Hutchins (1995) suggested that humans use features of the environment to represent thought and to externalize internal cognitive states. Similarly, Newell and Simon (1972) argued that items in one's visual field work in combination with internal memory states to aid working memory in problem solving tasks. Others confirm the idea that 'offloading' information onto the environment can increase the efficiency of working memory in spatial tasks (Maeda, 2013) and optimize the use of attention (Tversky, 2011). Many tools including paper and pen (McClelland, Rumelhart, & PDP, 1986), shopping lists, and calendars, have also been used to externalize thought and memory onto tangible resources. These records of information, stored conveniently within the real world, exist as external reminders to cue memory and guide future behavior. Dror and Harnad (2008) describe that in an effort to reduce the burden required to remember mass amounts of information, humans are beginning to offload memory onto various forms of technology. They argue that this 'cognitive offloading onto cognitive technology', exists as a way to increase cognitive efficiency by extending the abilities of the human mind. Clark & Chalmers (1998) claim that the demand to externalize information into the world is similar to the demands of the human memory system. They suggest that as long as information is available, accessible, and reliable, it can be sufficiently stored and retrieved from both the environment and from memory. Because computers are able to store information that is available and accessible in the future, they may exist as useful mediums in which to extend human memory.

Although little empirical research has explored the link between distributed cognition and memory, some evidence suggests that humans are taking advantage of certain tools in an effort to reduce memory load (*For a full review see*: Michaelian & Sutton, 2013). Sparrow, Liu, and Wegner (2011) found that subject memory for various facts was affected by whether subjects believed that the facts were saved by a computer. Significantly fewer facts were remembered when subjects were asked to recall those that had been ‘saved’ over those that had been ‘erased’. Henkel (2013) looked to investigate whether using a camera to take a picture of an item later affected memory for that item. For objects that were photographed, subjects recalled less of the objects overall, less details about the objects, and less information about the objects’ locations in comparison to objects that were not photographed. This *photo-taking-impairment* effect supports the idea that not only are we less inclined to remember photographed information, we may also be less adept at remembering *saved* information. If saving (whether into a camera or onto a computer) allows information to be accessible in the future, then maybe that information does not need to be remembered sufficiently by the individual who has saved it. This decision to offload memory onto technology for later reference may depend on how accessible information is perceived as being, and consequently, how important it is for the individual to remember the information themselves. How then does memory interact with the perceived importance of information? Prior *directed forgetting* research offers a relevant explanation.

Directed forgetting (DF) has consistently shown that information believed as not needed is subsequently more difficult to recall than information that is believed as needed. Bjork (1972) showed this effect by comparing student memory for information that was perceived as either needed or not needed for a later exam. Memory for the latter was recalled to a lesser degree, suggesting that students assumed they could forget the unimportant information. In a classic list-method directed forgetting paradigm used by Bjork and colleagues, subjects who are told to study and then *forget List 1* before studying *List 2* are less likely to remember items from *List 1* than those who are told to study and *remember List 1* before studying *List 2.* This phenomenon, explained as the *costs* of directed forgetting, seems to be a possible explanation as to why Sparrow, Liu, and Wegner (2011) and Henkel (2013) found deficits in subject memory for information that was 'saved' by different forms of technology (for directed forgetting *costs* see: Liu, Bjork, & Wickens, 1999; Reitman, Malin, Bjork, & Higman, 1973). It seems as though subjects are choosing which information will be beneficial to remember and which information can be dismissed from memory. Subjects could be allowing themselves to forget information that is saved by technology, causing a self-imposed form of directed forgetting to occur.

Along with the *costs* of forgetting, DF research has shown that there are substantial *benefits* to forgetting as well. Subjects who are told to *forget List 1* before study of *List 2*, recall *List 2* items more successfully than those who are told to *remember List 1* before studying *List 2* (for directed forgetting *benefits* see: Bäuml, 2008; Bjork, Bjork, & Anderson, 1998; MacLeod, 1998). Attempts at explaining the reasons behind this phenomenon have illustrated an interesting, yet debated picture. One explanation, put forth by of Bjork (1970), was that of a *selective rehearsal account,* where subjects discontinue rehearsal of *List 1* before *List 2* study in order to prepare for the rehearsal of *List 2* (Sahakyan, Delaney, Foster & Abushanab, 2014). Later research suggested that *inhibition* of *List 1* is more responsible for the *costs* of *List 1* and the *benefits* of *List 2* (Bjork, 1989; Geiselman, Bjork & Fishman, 1983). Active suppression of *List 1* during study and recall of *List 2* provided an explanation as to why subjects were more able to recall *List 2* over *List 1*. Others provide evidence for a *context-shift hypothesis*, arguing that a *forget* cue causes subjects to consider the mental context present at *List 1* study as distinct from the mental context present at *List 2* study (Sahakyan & Kelley, 2002). This strategy aims to reduce proactive interference of *List 1* on *List 2* by discontinuing the presence of similar mental cues at study and recall of *List 1* (*costs*) and creating continuity between the mental cues present at study and recall of List 2 (*benefits*). This proactive interference works to benefit future learning by distancing irrelevant cues from relevant and more accessible cues.

Given this background, it would be interesting to extend directed forgetting research and investigate whether saving digital information is able to predict *benefits* on memory for information that is learned after the saving process. If subjects perceive saved material as accessible and therefore unimportant to personally remember, will there be improved encoding of new material similar to that observed in directed forgetting research?

Evidence suggests that human psychology is changing under the influence of modern technology. It seems that attention can be manipulated within technological environments to produce varying effects on memory for items encoded as ‘saved’ or ‘not saved’ by external sources. A possible explanation for these findings is that choosing to remember material specifically depends on how important that material seems to be by the person who is encoding it. When told to forget information, memory recall suffers because the information is perceived as unimportant. Interestingly, this forgetting also causes attention to be better allocated towards encoding subsequent items of interest. As described in directed forgetting, the saving process may permit the individual to forget saved information because it is perceived as not being required for personal remembrance (Golding & MacLeod, 1998). Individuals may be offloading information onto external memory sources and perceiving the information that they offload as 'unimportant' because it can be later retrieved from the computer. This negligence towards remembering saved information may ultimately benefit the user by opening up useful resources for learning new information.

The current study seeks to answer these questions by testing subject memory for file content that is studied after the *saving* of prior material. Does saving digital information influence how new digital information is encoded after the saving process? We believe the question of whether our organic memories are being influenced by access to computers should be further explored in the scientific literature. Research on this topic may say something interesting about how people are remembering the contents of their digital files as well as how technology is changing human cognition.

This study will have subjects both *save* and *not save* groups of files during several study and test trials. One variable, *Instruction*, will be manipulated to see whether a larger amount of words from a later studied list are recalled after the saving of an earlier studied list. We hypothesize that a list studied after a *save* cue of a previous list will be remembered better than a list studied after a *not save* cue of a previous list. Reasons for this hypothesis stem from the prediction that subjects who are taught to view saved material as being accessible in the future, will perceive the information as 'offloaded' and therefore divert necessary resources towards remembering new, and important information. The saving process will cause benefits for learning new material because of a decrease in motivation to remember prior information that can be re-learned at a later time.

## Experiment 1

## Methods

### Participants

This sample consisted of twenty male and female undergraduate psychology students from the University of California, Santa Cruz between the ages of eighteen and twenty-four. Ten subjects were randomly assigned to each of the two counterbalancing conditions of the single factor. Subjects were recruited on a volunteer basis from sign-ups through the website: *sona-systems.com*. Subjects were compensated with class credit for their participation.

### Design

This experiment was a 2-group design. The single factor was *Instruction.* This was defined as the action that subjects were directed to take after studying *List A* within each trial. This variable contained two levels: (1) *Save Before* and (2) *No Save Before*. This variable was manipulated within-subjects. Counterbalancing was done across the two levels to control for possible variance in list difficulty. Counterbalancing was done by offsetting the *Save* and *No Save* instructions given after *List A* study within each trial. For example, subjects in the first counterbalancing condition were instructed to *save List A* after study in trials one, four, and six, and instructed to *not save List A* after study in trials two, three, and five (and vice versa for the second counterbalancing condition). The dependent variable in this study was free recall performance of words from *List B* at test. Although *List A* recall was recorded, these results were not included in analysis. Free recall performance was measured by the total number of words correctly recalled from *List B* in each trial. *List A* words recalled at *List B* test were not counted just as *List B* words recalled at *List A* test were not counted. Correct recall included plurality of words.

**Materials**

Materials consisted of twelve PDF files, each containing a separate list of ten commonly used nouns. Each noun was between four and seven letters in length to minimize word ease and difficulty. Two files were studied in each of the six trials. Each file was named with a list number and corresponding letter depending on whether it was the first file to be studied in the trial (A) or the second file to be studied in the trial (B). For example: the files named *List 1-A* and *List 1-B* were studied in the first trial and in the order of *List 1-A* followed by *List 1-B*. This was consistent of all twelve lists in each of the six trials. A flash drive was placed into the computer to show participants where the to-be-saved and not-to-be-saved files were being stored (and also to allow the saving process to feel as real as possible). These files were situated inside of the flash drive shortcut on the desktop of the computer. The study phases took part on a PC computer and participant responses were recorded with pen and paper. A stopwatch was used to keep track of the time allocated for each study and test phase.

**Procedure**

After signing consent, subjects watched as the experimenter created a folder on the main desktop screen of the computer. This folder was named with the relevant date and was explained to the subjects as their personal, designated folder for the day. Subjects were shown the flash drive and where its corresponding shortcut had been created on the desktop. They were directed to open up the shortcut, as well as the instructions sheet within, and to listen to the experimenter read the instructions aloud. Subjects were told that they would be participating in six trials of a study and test phase (with a different *List A* and *List B* per trial) and that each list was to be remembered for a later test. They were told that for each trial, they would be directed to either *save* or *not save List A* after studying it. If they were instructed to *save List A*, they were told that they *would* have access to it later on, which would allow them the ability to re-study *List A* before the final test of *List A*. If they were instructed to *not save List A*, they were told that they *would not* have access to it later on, which would deny them the ability to re-study *List A* before the final test of *List A.* After these instructions, the first trial of the experiment began. Subjects opened and studied *List A* for 20 seconds and were advised to scroll down on the page after study (which hid the list of words and prevented prolonged study). They were instructed to either *save* or *not save* the file into their designated folder (depending on which counterbalancing condition and trial they were in). If instructed to *save*, subjects navigated to FILE ->SAVE A COPY, were presented with a classic save window, found their folder, were advised not to change the name of the file that they were saving, and exited out of the file promptly after saving. If they were instructed to *not save List A*, they were told to merely exit out of the file after study. Subjects then studied *List B* for 20 seconds and exited out of the file. A common backwards counting task used by Brown (1958) and Peterson and Peterson (1959) was then administered. Subjects were verbally presented with a 3-digit number between 200 and 999 and asked to count backwards from that number, by three's, and to say each number aloud for the entire 20 second duration. The test for *List B* was then administered. Subjects were instructed to speak aloud as many of the words as they could remember from *List B*, while the experimenter checked off the words from a printed (and occluded) version of *List B.* After 30 seconds of free recall, subjects were given the opportunity to re-study List A *only if* they had previously saved *List A* within that trial. This consisted of subjects accessing the saved copy of *List A* from their designated folder and re-studying it for 20 seconds. If the subject did not previously save *List A* they were told that they would not be able to re-study *List A* because it had not been saved. Promptly after, subjects were given the test for *List A* in the same fashion as the test for *List B*. This entire session was repeated five times with a 1-minute Tetris game administered between trials to alleviate any proactive interference from previous lists.

## Results and Discussion

We ran analysis on collected data to test our hypothesis of whether word recall is better for lists studied after *saving* than studied after *not saving*. An alpha level of .05 was used to run a paired samples t-test between mean recall of words in *B* lists studied in *Save Before* and *No Save Before* trials. See *Figure 1* for a graph of results. The test concluded that memory for words was negatively affected by *not saving* a list prior to the study of a new list, $t(19)=3.237$, $p=.004$. *Save Before* recall ($M=.43$, $SD=.18$) was significantly better than *No Save Before* recall ($M=.33$, $SD=.14$) and a 95% confidence interval concluded that the mean recall of *List B* words was 3 to 17 percent higher for lists studied after a *save* cue of *List A* than a *not save* cue of *List A*. Memory benefited from saving a prior list before studying a new one, confirming our predicted hypothesis.

These results suggest that saving information allows memory resources to be better allocated towards learning new information, presumably because of the perceived importance of new material in comparison to material that is saved and therefore unimportant to remember. The saving process, which offers the ability to re-learn information, may be acting as an implicit *forget* cue that causes subjects to employ attentional resources towards remembering new information instead of previously offloaded information. This intentional decision to change encoding strategies in preparation for new learning may be due to the unknown accessibility of new information. Because subjects do not know the fate of new material in the same way that they do saved material, they may be inclined to treat new information with importance and focus more intently on remembering it.

To further our understanding of this phenomenon, we ran a follow-up experiment to investigate what would happen if the saving process, which presumably contributed to the observed *List B* benefits, was made unreliable. If the ability to re-study saved material causes subjects to change their encoding strategies for lists studied after saving, then what will happen to *List B* benefits if the re-study phase for *List A* is eliminated? We predict that if the saving process is made fallible (i.e. does not generate a re-study phase), subjects who save a first list prior to the study of a second list will not perceive the first list as offloaded, and therefore, will not have improved memory for the second list in comparison to lists studied after not saving.

## Experiment 2

## Methods

### Participants

This sample consisted of forty-eight male and female undergraduate psychology students from the University of California, Santa Cruz between the ages of eighteen and thirty-four. Each subject was randomly assigned into one of eight counterbalancing conditions in either of the two experimental factors. Subjects were recruited on a volunteer basis from sign-ups through the website: *sona-systems.com*. Subjects were compensated with class credit for their participation.

### Design

This experiment was a 2x2 factorial design. One factor, *Instruction* acted as a replication condition of Experiment 1. This was again defined as the action that subjects were directed to take after studying *List A* within each trial. This variable contained two levels: (1) *Save Before* and (2) *No Save Before*. This variable was manipulated within-subjects and counterbalancing was done just as before to control for list difficulty. To investigate list ordering effects on *List B* recall, we included four counterbalancing conditions within each two *Instruction* counterbalancing conditions so that all pairs of lists (*List A* and *List B*) had equal chances of being in every position within a single session. The second factor was a between-subjects factor termed *Reliability*. This factor was defined as the fallible nature of the designated folder that subjects saved into. This factor contained two levels: (1) *Reliable* and (2) *Unreliable*. The dependent variable in this study was the same as that in Experiment 1: free recall performance of words from *List B* at test.

**Materials**

The materials used in Experiment 2 were slightly modified from those used in Experiment 1. Two more trials of *List A* and *B* study and test were added to the procedure in Experiment 2, making a total of eight trials instead of six in Experiment 1. Consequently, a total of sixteen PDF files were used rather than twelve in order to obtain a greater observation of participant responses averaged over trials. The length of *List A* and *List B* files was shortened from ten words to eight words for all trials so that the duration of Experiment 2 did not increase despite two additional trials. A security lock was put in place on a desktop folder and acted as the between-subjects manipulation for subjects randomly assigned into the *Unreliable* level. This folder was locked by changing the folder's attributes under the folder's settings. This modification disabled any user (who was not authorized by the primary user) from accessing files that had been saved within the folder. An error message was produced whenever a saved PDF file was clicked on within this locked folder.

**Procedure**

Instructions were modified to include new information about the length and study time duration for each list. A slight change was also made to more precisely explain *Save Before* trials. Subjects heard: "If you are instructed to *save*, you will save the list into your designated folder. Because you are saving this file into your folder, you *may* have access to it later on. This will allow you the ability to re-study *List A* before the final test of *List A*." Another feature was also added: "NOTE: The saving process in the computer does not always work. Sometimes, you will save a file and it will be available for later study. Other times, you will save a file and it will not be available for later study. Just keep that in mind." Instructions were the same for both between-subject levels. Before data collection began, two folders were created and placed on the desktop; one folder had a locked setting and the other did not. Prior to running each subject, experimenters named the folder that was to be used (based on whichever between-subject condition was being run) and renamed the irrelevant folder with an arbitrary name. The irrelevant folder was never brought to the attention of the subject. Besides this, the only difference between the two *Reliability* levels was at *List A* re-study. Subjects who were randomly assigned to the *Reliable* level were able to access and re-study *List A* files from their (normal) designated folders in *Save Before* trials (just as in Experiment 1). Subjects who were randomly assigned to the *Unreliable* level were denied access to *List A* files from their (corrupted) designated folders in *Save Before* trials. When directed to re-study a *List A* file within the *Unreliable* level, subjects clicked open their designated folder and selected the file that they were to re-study. Rather than opening the file of interest, the computer produced an error message in place of *List A*, stating that the subject did not have access to this file. Subjects were told to exit out of the file and were then immediately tested on *List A*. This event occurred every time a subject in this level tried to re-study a file. Because of the change in list length and the presence of two more trials, *List A* and *B* study time (and re-study time of *List A*) was decreased from twenty seconds to fifteen seconds for all lists in each trial. Testing time of *List A* and *B* was also shortened from thirty to twenty seconds in order to replicate the study to test-time ratio of Experiment 1 in Experiment 2.

**Results and Discussion**

We ran analysis on collected data to see whether the benefits of *List B* study would disappear in *Save Before* trials if the saving process did not yield a re-study phase. An alpha level of .05 was used to run a 2x2 mixed analysis of variance (ANOVA) on the effect of *Reliability* (*Reliable*, *Unreliable*) on *List B* recall by *Instruction* (*Save Before/No Save Before*). *List B* recall in trials 1 and 2 were not included in analysis because they were intended as practice trials. *List A* recall was also not included. See *Figure 2* for a graph of results. The test concluded that there was a significant main effect for *Instruction*, F(1,46) = 5.56, p = .02, n^2 = .09, an insignificant main effect for *Reliability*, F(1,46) = .01, p = .92, and a significant interaction, F(1,46) = 5.56, p = .02, n^2 = .09. In a successful replication of Experiment 1, *Instruction* yielded a significant difference (9%) for *List B* recall between *Save Before* (M = .39, SE =.03) and *No Save Before* (M = .30, SE = .03) trials in the *Reliable* level, but no difference (0%) between *Save Before* (M =.35, SE =.03) and *No Save Before* (M = .35, SE = .03) trials in the *Unreliable* level. These results supported our predictions: when re-study was denied, saving *List A* before *List B* study did not procure benefits for *List B* memory. There was no difference in *List B* benefits between *Save Before* and *No Save Before* trials when the re-study phase was denied in *Save Before* trials.

Given the above data, a stronger argument can be made about how subjects are being influenced by the saving process and how saved information is being perceived by those who save it. When subjects were faced with a piece of technology that did not act as it should, subjects were able to adjust their encoding strategies to make up for the computer's fallibility. Those who were able to rely on the saving process benefited from the accessibility of saved information and were better prepared for future learning. However, those who were not able to rely on the saving process were unable to benefit from the accessibility of saved information and were less prepared for future learning. The resources used to encode new information seem to be reliant on two factors: (1) whether old information is offloaded and (2) whether that old information can stand to be forgotten. If a tradeoff exists between forgetting *List A* and remembering *List B*, then *List A must* be available later in order for this strategy to be trusted. If, however, *List A* cannot be forgotten because of a faulty memory source, *List A* is not selected against in memory. As a result, *List B* is encoded more poorly than it would have been if preceded by a reliable saving process.

To investigate other factors that may influence encoding strategies within this context, a third experiment was ran to explore what would happen to *List B* recall if the lengths of first-studied lists were varied. Does the amount of to-be-remembered information influence how well resources are allocated towards encoding new information? If we lighten the memory load so that remembering a list is easy, will the save function fail to support memory for future learning? We predict that because subjects will not feel the need to offload short lists as much as they do long lists, memory for new lists studied after *saving* short lists will not differ in comparison to memory for new lists studied after *not saving* short lists.

## Experiment 3

## Methods

### Participants

This sample consisted of forty male and female undergraduate psychology students from the University of California, Santa Cruz between the ages of eighteen and twenty-seven. Ten subjects were randomly assigned to one of the two counterbalancing conditions in either of the two experimental factors. Subjects were recruited on a volunteer basis from sign-ups through the website: *sona-systems.com*. Subjects were compensated with class credit for their participation.

**Design**

This experiment was a 2x2 factorial design. One factor, *Instruction*, acted as another replication condition of Experiment 1 with the same operational definition and levels as in Experiments 1 and 2. This variable was again manipulated within-subjects and counterbalancing was done just as before to control for list difficulty. The second factor was a between-subjects factor called *List Length*. This factor was defined as the number of words in all *List A* files within each trial. This factor contained two levels: (1) *Eight-word List* and (2) *Two-word List*. The dependent variable in this study was the same as that in Experiment 1 and 2: free recall performance of words from *List B* at test.

**Materials**

The materials used in Experiment 3 were slightly modified from those used in Experiment 2. The number of words within each *List A* file varied depending on the between-subjects condition (*List Length*) that the file was to be presented in. If presented in the *Eight-word List* level, all *List A* files were eight words long across all eight trials. If presented in the *Two-word List level*, all *List A* files were two words long across all eight trials. Two-word *List A* files (found in the *Two-word List* level) were constructed from randomly selecting two words from the eight-word *List A* files (found in the *Eight-word List* level) in each respective trial. *List*

*B* files were consistently eight words long throughout all levels so that *List B* benefits could be compared across all variations of *List A* (*Save*/*No Save* and *Eight-word List*/*Two-word List*).

**Procedure**

The procedure was very much the same as Experiment 1. *List A* and *List B* were studied for fifteen seconds regardless of which *List Length* condition participants were in (whether studying eight-word lists or two-word lists). The only difference in the between-subjects levels was the varying length of *List A*. A full fifteen second re-study was mandatory for all *List A* files that were saved no matter the length of *List A*.

## Results and Discussion

We ran analysis on collected data to test our hypothesis of whether the shortening of *List A* would produce a zero difference in *List B* recall between *Save Before* and *No Save Before* trials. Trials one and two (and *List A* recall) were not included in analysis, for reasons stated above. An alpha level of .05 was used to run a 2x2 mixed analysis of variance (ANOVA) to examine the influence of *List Length* (*Eight-word List, Two-word List*) on *List B* recall by *Instruction* (*Save Before, No Save Before*). See *Figure 3* for a graph of results. The test concluded that there was a significant main effect for *Instruction*, $F(1,38) = 11.06$, $p = .002$, n^2 = .17, a significant main effect for *List Length*, $F(1,38) = 8.05$, $p = .007$, n^2 = .17, and a significant interaction, $F(1,38) = 13.13$, $p = .001$, n^2 = .21. *List B* recall in the *Eight-word List* level yielded a significant difference (14%) in *Save Before* (M =.44, SE = .03) and *No Save Before* (M = .30, SE = .03) trials, but did not yield a significant difference (1%) in the *Two-word List* level for *Save Before* (M = .48 , SE = .03) and *No Save Before* (M = .49 , SE =.03) trials. These results supported our hypothesis that *List B* recall did not benefit from saving prior *short* lists, but did benefit from saving prior *long* lists.

An explanation of these results may help us better understand *why* humans are using computers to offload information and *when* they are strategically deciding to do so. The above results suggest that the decision to allow memory resources to be used for new encoding specifically depends on *how much* information needs to be remembered. If a list is short then it is not a burden to personally remember and, thus, does not need to be offloaded. Because the effort required to remember a short list is small, the resources used to remember old information can also be used to encode new information. For this reason, saving does not alleviate the pressure for remembering a two-word list in the same way that it does for remembering an eight-word list. It is only when there is pressure to remember a large list that the benefits of saving old information are observed and recall for later learned material is improved.

## General Discussion

In the context of this study, we argue that the influence of technology on cognition is supporting memory processes rather than hurting them. Prior directed forgetting research has alluded to the idea that the costs and benefits of forgetting act in unison to improve the efficiency of the memory system (Sahakyan & Delaney, 2003). It should be noted however, that the costs of directed forgetting do not always foster benefits (Sahakyan, Delaney, Foster & Abushanab, 2014). Regardless, this adaptive process may be interacting with technology in ways to both maximize the benefits and minimize the costs of forgetting. For example, Experiment 1 shows us that when we save our digital information, we are rewarded with improved resources for new encoding. Presumably, these benefits exist because we feel that we can forget saved information while focusing our attention on information that is more important. Because humans understand that saved information can be accessed later, this information may not be perceived as lost even though it is forgotten. If humans are treating computers as extensions of their organic memories, then humans may be using the saving process to both protect themselves from the costs of forgetting and reward themselves with the benefits of forgetting. Similarly, Experiment 2 showed us that when saving does not elicit a re-study phase, the benefits of forgetting disappear. It's almost as if the resources that would have otherwise been free to encode new information suffer from the computer's fallibility. Humans are unable to reap the benefits of forgetting when saving into a faulty source because (1) offloading cannot be trusted and (2) resources cannot be opened up for new learning. Lastly, Experiment 3 showed us that humans only rely on offloading when the amount of information to-be-remembered exceeds memory capacity. The benefits of forgetting are only observed for lists that place a demand on memory, illustrating that we only offload information when we feel the need to. These decisions allow us to judge the constraints of our organic memories in relation to the utility of the prosthetic memory device at hand. If the memory demand exceeds our ability to supply, then we feel more willing to use the computer to offload that memory. Ultimately, this reliance on computers elicits benefits for new learning and allows us to maximize our use of technology.

This study is most specifically limited in its implication that *List A* words are more forgotten to provide necessary resources for *List B* learning. The above evidence does not contribute to the discussion of directed forgetting *costs* within this context, nor does it try to support the idea that forgetting *must* occur in order for improved learning to take place. Although a direct relationship between forgetting *List A* and remembering *List B* may be involved, the question of how these features interact more closely depends on the mechanism responsible for DF; whether it be context-shift (Sahakyan & Kelley, 2002), inhibition (Bjork & Bjork, 1996) or a combination of the two (Anderson, 2005). The novelty of this paradigm also gives reason as to why these questions have not yet been addressed within the scientific literature. In order to gain a better understanding of how forgetting is being influenced by technology, research within this field must continue. If this research is fruitful, then it may provide evidence to suggest that external memory sources are becoming a cohesive part of the memory system; not separated by a gap in the mental and virtual world, but connected in a single, unified cognitive environment. By distributing our memory amongst the things that we own and the technology that we use, human cognition may indeed be changing for the better.

*Acknowledgements*: Special thanks to Steve Whittaker for his support and advice on this project. Another thanks to Payton Small, Peri Gunalp, and Steven Katawetheesakun for their help with data collection.

## References

Anderson, M. C. (2005). The role of inhibitory control in forgetting unwanted memories: a consideration of three methods. In C. MacLeod & B. Uttl (Eds.), Dynamic cognitive processes (pp. 159–190). Tokyo: Springer-Verlag.

Bäuml, K. H. (2008). Inhibitory processes. In H. L. Roediger III (Ed.), Cognitive psychology of memory (pp. 195–220). Oxford: Elsevier.

Bjork, E. L., & Bjork, R. A. (1996). Continuing influences of to-be-forgotten information. Consciousness and Cognition, 5, 176–196.

Bjork, E., Bjork, R. A., & Anderson, M. C. (1998). Varieties of goal-directed forgetting. In J. M. Golding & C. M. MacLeod (Eds.), Intentional forgetting: Interdisciplinary approaches (pp. 103 137). Mahwah, NJ US: Lawrence Erlbaum Associates Publishers.

Bjork, R. A. (1970). Positive forgetting: the noninterference of items intentionally forgotten. Journal of Verbal Learning and Verbal Behavior, 9, 255–268.

Bjork, R. A. (1972). Theoretical implications of directed forgetting. In A. W. Melton & E. Martin (Eds.), *Coding processes in human memory* (pp. 217-235). Washington, D.C.: Winston.

Bjork, R. A. (1989). Retrieval inhibition as an adaptive mechanism in human memory. In H. Roediger & F. M. Craik (Eds.), Varieties of memory and consciousness: Essays in honour of Endel Tulving (pp. 309–330). Hillsdale, NJ England: Lawrence Erlbaum Associates, Inc.

Brown, J. (1958). Some tests of the decay theory of immediate memory. *Quarterly Journal of Experimental Psychology*, *10*(1), 12-21.

Bruce, H. (2005). Personal, anticipated information need. Information research, 10(3), 10-3.

Clark, A., & Chalmers, D. (1998). The extended mind. *analysis*, 7-19.

Dror, I. E., & Harnad, S. (2008). Offloading cognition onto cognitive technology. *Cognition Distributed: How cognitive technology extends our minds*, *16*, 1.

Geiselman, R. E., Bjork, R. A., & Fishman, D. (1983). Disrupted retrieval in directed forgetting: a link with posthypnotic amnesia. Journal of Experimental Psychology: General, 112, 58–72.

Golding, J. M., & MacLeod, C. M. (1998). Intentional forgetting: Interdisciplinary approaches. Mahwah, NJ: Erlbaum.

Henkel, L. A. (2013). Point-and-Shoot Memories The Influence of Taking Photos on Memory for a Museum Tour. *Psychological science*, 0956797613504438.

Hutchins, E. (1995). *Cognition in the Wild* (Vol. 262082314). Cambridge, MA: MIT press.

Kahneman, D., & Tversky, A. (1979). Prospect theory: An analysis of decision under risk. *Econometrica: Journal of the Econometric Society*, 263-291.

Liu, X., Bjork, R. A., & Wickens, T. D. (1999, November). *List method directed forgetting: Costs and benefits analyses.* Poster session presented at the 40th Annual Meeting of the Psychonomic Society, Los Angeles.

MacLeod, C. M. (1998). Directed forgetting. In J. M. Golding & C. M. MacLeod (Eds.), Intentional forgetting: Interdisciplinary approaches (pp. 1–57). Mahwah, NJ: Erlbaum.

Maeda, N. (2013). *External working memory: Offloading cognition onto the world.* (Order No. AAI3545643, *Dissertation Abstracts International: Section B: The Sciences and Engineering*, Retrieved from http://search.proquest.com/docview/1449320372?accountid=14523. (1449320372; 2013-99200-127).

McClelland, J. L., Rumelhart, D. E., & PDP Research Group. (1986). Parallel distributed processing. *Explorations in the microstructure of cognition, 2*.

Michaelian, K., & Sutton, J. (2013). Distributed cognition and memory research: History and current directions. *Review of Philosophy and Psychology, 4*(1), 1-24. doi:http://dx.doi.org/10.1007/s13164-013-0131-x

Newell, A., & Simon, H. A. (1972). *Human problem solving* (Vol. 104, No. 9). Englewood Cliffs, NJ: Prentice-Hall.

Peterson, L., & Peterson, M. J. (1959). Short-term retention of individual verbal items. *Journal of experimental psychology, 58*(3), 193.

Reitman, W., Malin, J. T., Bjork, R. A., & Higman, B. (1973). Strategy control and directed forgetting. *Journal of Verbal Learning and Verbal Behavior, 12*, 140–149.

Rochberg-Halton, E. (1984). Object relations, role models, and cultivation of the self. *Environment and Behavior*, *16*(3), 335-368.

Rodden, K., & Wood, K. R. (2003, April). How do people manage their digital photographs?. In *Proceedings of the SIGCHI conference on Human factors in computing systems* (pp. 409-416). ACM.

Sahakyan, L., & Delaney, P. F. (2003). Can encoding differences explain the benefits of directed forgetting in the list method paradigm?. *Journal of Memory and Language*, *48*(1), 195-206.

Sahakyan, L., & Kelley, C. M. (2002). A contextual change account of the directed forgetting effect. Journal of Experimental Psychology: Learning, Memory, and Cognition, 28, 1064–1072.

Sahakyan, L., Delaney, P. F., Foster, N. L., & Abushanab, B. (2014). List-Method Directed Forgetting in Cognitive and Clinical Research: A Theoretical and Methodological Review. In B. H. Ross (Ed.), The Psychology of Learning and Motivation. Elsevier Inc.: Academic Press, 131-190.

Sparrow, B., Liu, J., & Wegner, D. M. (2011). Google effects on memory: Cognitive consequences of having information at our fingertips. *science*, *333*(6043), 776-778.

Tversky, B. (2011). Visualizing thought. *Topics in Cognitive Science*, *3*(3), 499-535.

Whittaker, S., Bergman, O., & Clough, P. (2010). Easy on that trigger dad: a study of long term family photo retrieval. *Personal and Ubiquitous Computing*, *14*(1), 31-43.

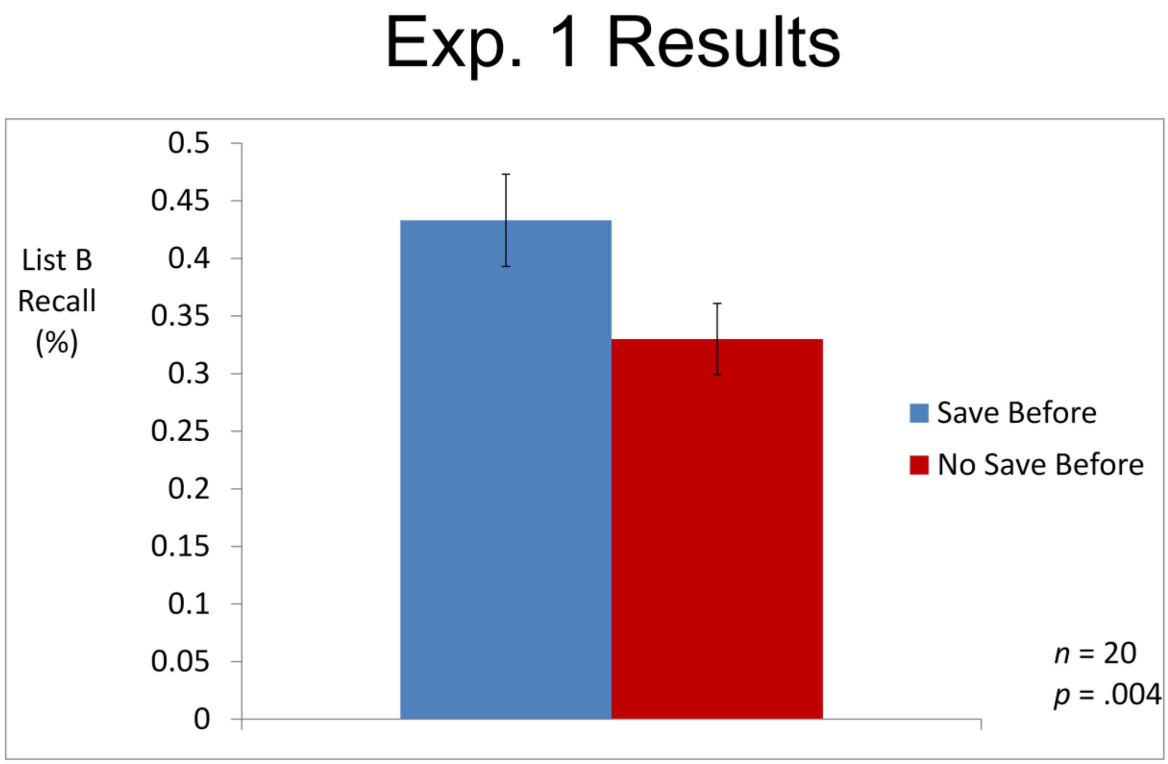


*Figure 1: List B* recall in *Save Before* and *No Save Before* trials

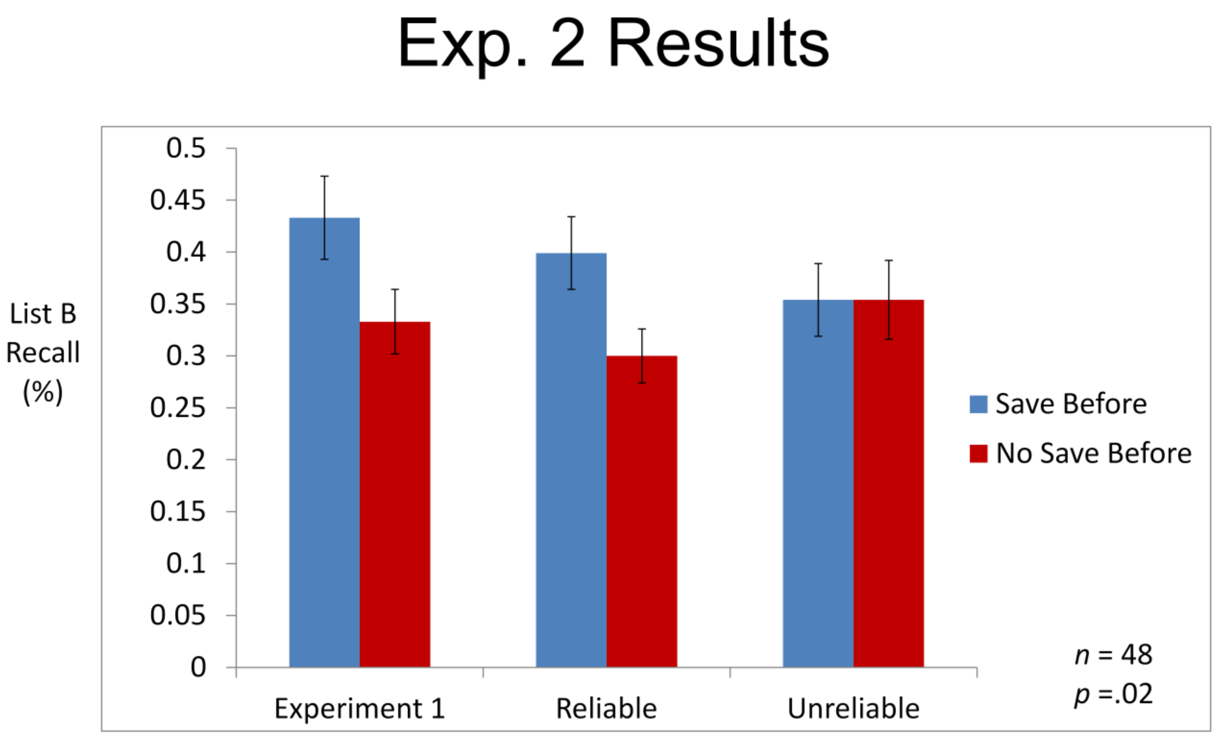


*Figure 2:* The influence of *Reliable* and *Unreliable* conditions on *List B* recall in *Save Before* and *No Save Before* trials

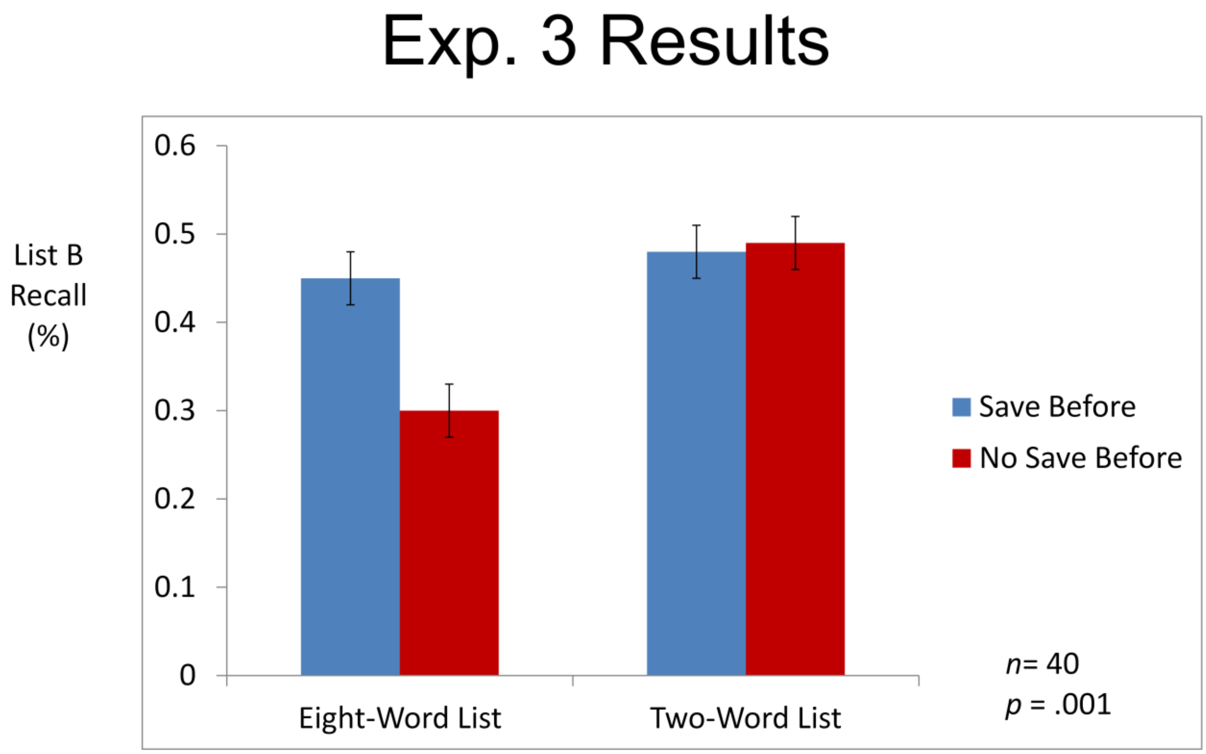


*Figure 3:* The influence of *Eight-Word List* and *Two-Word List* conditions on *List B* recall in *Save Before* and *No Save Before* trials