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Saving-Enhanced Memory: The Benefits of Saving on the Learning and Remembering of New Information

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Abstract

With the continued integration of technology into people's lives, saving digital information has become an everyday facet of human behavior. In the present research, we examined the consequences of saving certain information on the ability to learn and remember other information. Results from three experiments showed that saving one file before studying a new file significantly improved memory for the contents of the new file. Notably, this effect was not observed when the saving process was deemed unreliable or when the contents of the to-be-saved file were not substantial enough to interfere with memory for the new file. These results suggest that saving provides a means to strategically off-load memory onto the environment in order to reduce the extent to which currently unneeded to-be-remembered information interferes with the learning and remembering of other information.

Keywords

memory, human-computer interaction, cognition(s), forgetting

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Albert Einstein is regarded as one of the foremost thinkers this world has known, yet even his mind had limits. In one famous example, Einstein was asked a question developed by Thomas Edison to screen the knowledge and expertise of potential job candidates. The question should have been easy for a physicist of Einstein's stature and experience to answer—namely, "What is the speed of sound?" After admitting to not knowing the answer, Einstein clarified, "[I do not] carry such information in my mind since it is readily available in books. . . . The value of a college education is not the learning of many facts but the training of the mind to think" (Isaacson, 2007, p. 299). At the core of Einstein's response is the idea that the effectiveness of memory, and its role in cognition, cannot be considered separately from how information can be stored and accessed in the environment.

The fallibilities of organic memory are well established. What can be encoded or retrieved at a given time is severely limited (R. A. Bjork & Bjork, 1992; Schacter, 2001). By taking advantage of the external environment, however, the human mind can radically expand its capabilities. The idea that cognition can be enhanced via off-loading is not new (see, e.g., Clark, 2008; Clark & Chalmers, 1998; Dror & Harnad, 2008; Kirsh & Maglio, 1994; Maeda, 2012; Tversky, 2011; M. Wilson, 2002; R. A. Wilson, 2004). Many tools, including paper and pen, shopping lists, calendars, and computers, have been used extensively to externally record thoughts and memories onto tangible resources. Now, with computers and smart phones connected to the Internet and capable of recording and retrieving functionally infinite quantities of information, off-loading has become even more efficient, a fact that has led to important changes in the way humans think and remember.

In a recent study examining the effects of off-loading memory onto technology, Sparrow, Liu, and Wegner (2011) tested participants' memory for information that was either saved on a computer or erased. Erased information was better remembered than saved information, presumably because participants assumed they would have access to the saved information, which would thus obviate the need

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to fully encode it. Sparrow et al. also found that difficult questions automatically primed participants to think of computers, presumably because that is where the answers to such questions could be obtained. Henkel (2014) extended these findings by leading participants on a guided tour of a museum and asking them to take photographs of some objects and only observe others. Participants recalled less about objects they photographed (and thus saved) than they did about objects they simply observed.

One dynamic that has yet to be investigated, however, is the impact of saving certain information on memory for other information. Research has shown that saving information (whether via camera or computer) can make it more difficult to remember, but what effect does saving have on the ability to encode and remember other information? Presumably, the costs incurred by saving serve an adaptive function—namely, the reallocation of cognitive resources toward other matters. It may be, for example, that by saving some information, people put themselves in a better position to remember other information. This possibility seems particularly likely given work on directed forgetting, which has shown that telling participants that an initial list of items is to be forgotten—and thus unnecessary to remember—can enhance memory for a second list of items (e.g., E. L. Bjork & Bjork, 1996; R. A. Bjork, 1989; Pastötter & Bäuml, 2010; Sahakyan & Kelley, 2002). One explanation of the directed-forgetting effect is that the cue to forget reduces proactive interference, which thus allows new information to be better remembered than it would have been otherwise (for a review of theoretical accounts, see Sahakyan, Delaney, Foster, & Abushanab, 2013). Saving information onto a computer may function similarly. Because one expects saved information to remain available indefinitely, there should be less need to remember that information than if it were not saved, and therefore the extent to which it proactively interferes with the learning of new information should be reduced.

To explore this possibility, we asked participants in the present research to study lists of words contained in PDF files on a flash drive. Participants were instructed to save some files onto the computer's hard drive so they would be available for subsequent restudy. Participants simply closed other files without saving. Critically, after either saving or not saving a given file, participants were given a new file to study and be tested on. We predicted that saving the initial file would reduce proactive interference and thus enhance memory for the new file.

Experiment 1

Method

Participants. Twenty University of California, Santa Cruz (UCSC) undergraduates participated for credit in a psychology course (mean age = 20.1 years). We stopped running participants when the effect became apparent so we could focus subsequent data-collection efforts on Experiments 2 and 3.[1]

Design. The critical independent variable was whether an initial PDF file was saved or not saved before participants learned and were tested on a second PDF file. This variable was manipulated within subjects such that every participant experienced three save trials and three no-save trials. The dependent variable was the proportion of words correctly recalled from a given file.

Materials. Twelve PDF files were created, each containing a single list of 10 common nouns (four to seven letters long). Two files were randomly selected to be used for each of six trials. One of the files associated with each trial was designated as File A, whereas the other was designated as File B. The files were then named with a trial number and corresponding letter (1A, 1B, 2A, 2B, etc.) and placed on an external flash drive.

Procedure. The experiment began with participants watching the experimenter create a folder on the desktop. The folder was named with the date (e.g., 5-4-2014), and participants were told that they would be able to use the folder during the experiment. Participants were then alerted to the flash drive connected to the computer and instructed to open it to view the files inside. The files were said to exist only on the flash drive, not on the computer.

Participants were told that the experiment would consist of six trials, each involving the study and testing of the contents of two PDFs. For example, on the first trial, participants studied and were tested on the contents of Files 1A and 1B. They were told that they would always study File A first, but that before being tested on it, they would study and be tested on File B. Half of the trials were save trials, and the other half were no-save trials. Counterbalancing ensured that each file served equally often in the save and no-save conditions. On save trials, participants saved File A before studying and being tested on File B. On no-save trials, participants simply exited File A without saving before studying and being tested on File B. Participants were told that saving File A would ensure that they would be able to restudy it prior to test, which they were indeed allowed to do. A schematic of the procedure on a given trial is shown in Figure 1.

On each trial, participants studied File A unaware of whether they would be instructed to save it. After 20 s of study, participants were told to either save or not save the file into the designated folder. If instructed to save the file, participants navigated to the "Save a copy" option on the file menu and then saved the file into their folder. If instructed to not save the file, participants simply exited

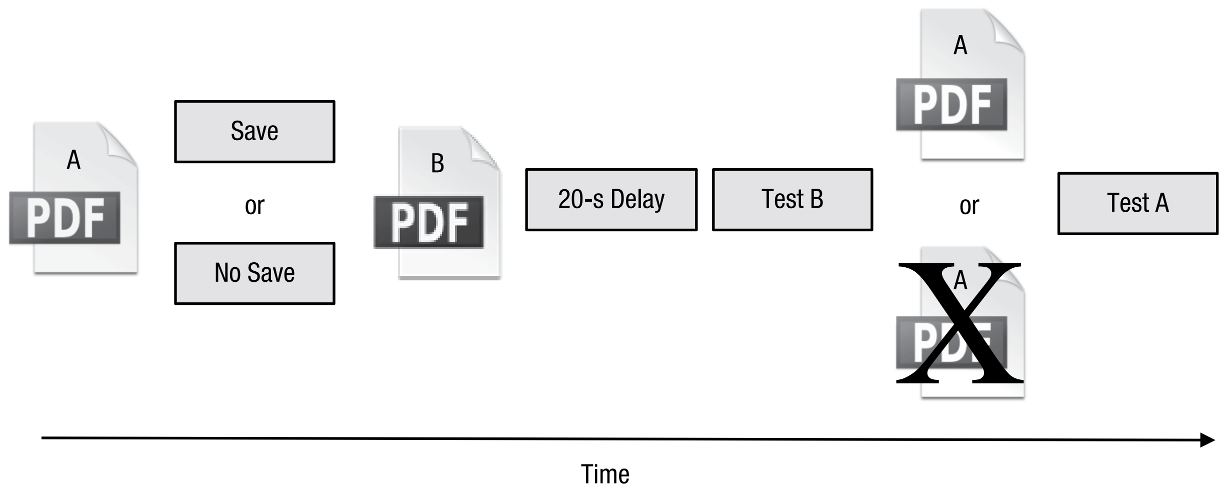

Fig. 1. Sample trial sequence in the current experiments. Participants studied File A, after which they were instructed to save it or close it without saving. They knew that they would be tested on this file but that they would be able to restudy it only if they had saved it. They then studied, and after a short delay were tested on, File B, after which they restudied File A on trials where they had saved it. Finally, they were tested on File A.

the file by clicking the "X" on the top-right corner of the PDF. Immediately following, participants were asked to open and study the corresponding File B for 20 s. After File B was closed, there was a short 20-s delay during which participants counted backwards by 3s from a random 3-digit number between 200 and 999. Participants were then given 30 s to recall out loud the words from File B. Finally, participants were given either 30 s to recall the words from File A (no-save trials) or were instructed to open their designated folder and restudy File A for 20 s before being tested on it (save trials). After the conclusion of each trial, participants were given an unrelated distractor task (i.e., the game Tetris for 1 min) before beginning the next trial.

Results

Not surprisingly, participants recalled a significantly greater proportion of words from File A when they saved and restudied it prior to test (M = .75, SE = .03) than when they did not (M = .27, SE = .03), $t(19)$ = 12.01, p < .001, d = 2.69, mean difference = .48 (95% confidence interval, or CI, = [.39, .56]). The predicted saving-enhanced memory effect was observed for File B. Specifically, participants recalled a significantly higher proportion of words from File B when they had saved File A (M = .43, SE = .04) than when they had not saved File A (M = .33, SE = .03), $t(19)$ = 3.23, p = .004, d = 0.72, mean difference = .10 (95% CI = [.04, .17]).

Experiment 2

The second experiment had two goals: to replicate the effect observed in Experiment 1 and to show that the effect depends on the reliability of the saving process. We predicted that saving File A would not enhance memory for File B if participants did not believe that the saving process would actually make the contents of File A available for restudy.

Method

Participants. Forty-eight UCSC undergraduates participated for credit in a psychology course (mean age = 20.2 years). Because of experimenter error (participants were instructed to save the wrong files), data from 2 participants were excluded and replaced. The sample size was determined on the basis of a power analysis of data from Experiment 1. Specifically, assuming the same effect size and variance, the estimated power to observe a significant effect in each condition with 24 participants was 94%.

Materials. The materials in Experiment 2 were the same as in Experiment 1, with the following exceptions. Two additional trials were added, which brought the total number of PDFs to 16. The length of the list in each PDF was also shortened from 10 words to 8 words.

Procedure. The procedure was mostly the same as that of Experiment 1. In keeping with the shortened list lengths, we reduced study and test time to 15 and 20 s, respectively. The more critical change was that participants were randomly assigned to either a reliable- or an unreliable-computer condition. All participants were told that the saving process was potentially fallible and that sometimes they might save a file on the computer only to later find it unavailable for restudy. In actuality, for half of the participants, the saving process was always reliable, whereas it was always unreliable for the other half of the participants. Although participants in the unreliable condition saved File A on half of the trials, when they attempted to open it later for restudy, the computer always produced an error message saying that the file could not be accessed. When this happened, participants were instructed to exit the error message and were then immediately tested on File A. Presumably, participants in the unreliable condition would learn very quickly that they could not trust the saving process, which would thus negate any benefits that saving might have on the encoding and remembering of File B. The main analysis focused on data from Trials 3 through 8. Trials 1 and 2 were included to give participants the experience of both a save trial and a no-save trial, and thus the opportunity to experience either the reliability or unreliability of the saving process.

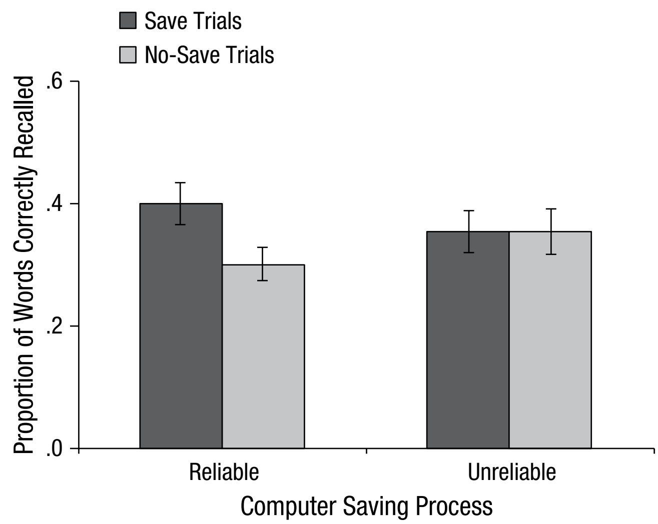

Fig. 2. Results from Experiment 2: mean recall performance for File B as a function of the reliability of the saving process and whether or not participants had previously saved File A. Error bars represent standard errors of the mean.

Results

Recall performance for File A. When the saving process was reliable, the proportion of words recalled from File A was significantly higher on save trials (M = .79, SE = .03) than on no-save trials (M = .33, SE = .04), $t(23)$ = 13.71, p < .001, d = 2.78, mean difference = .46 (95% CI = [.38, .52]). When the saving process was unreliable, however, the proportion of recalled words from File A was not significantly different on save trials (M = .33, SE = .04) and no-save trials (M = .35, SE = .05), $t(23)$ = 0.55, p = .59, d = 0.12, mean difference = –.02 (95% CI = [–.11, .06]), which makes sense given that participants never had the opportunity to restudy the contents of File A.

Recall performance for File B. A 2 (trial type: save vs. no save) × 2 (condition: reliable vs. unreliable) mixed-design analysis of variance (ANOVA) was conducted on the proportion of words recalled from File B. As can be seen in Figure 2, a significant interaction was observed, $F(1, 46)$ = 5.71, MSE = 0.02, p = .02, η^2 = .11. When the saving process was reliable, participants recalled significantly more words from File B when they had saved File A than when they had not saved File A, $t(23)$ = 3.68, p = .001, d = 0.75, mean difference = .10 (95% CI = [.04, .16]). This result provides a nearly perfect replication of the effect observed in Experiment 1. A very different result was observed when the saving process was unreliable. Specifically, participants in the unreliable condition did not recall more words from File B when they had saved File A than when they had not saved File A, $t(23)$ = 0.00, p = 1.00, d = 0.00, mean difference = .00, 95% CI = [–.07, .07]. In fact, recall performance for the two trial types was identical. Thus, when participants viewed the saving process as one that could not be trusted, saving initially studied information failed to enhance memory for new, subsequently studied information.[2]

Performance across trials in the reliable condition. The particular files associated with the different trial positions were counterbalanced across participants, which allowed us to assess whether performance changed across trials (note that such counterbalancing was not employed in the other experiments). Notably, the saving-enhanced memory effect was stronger on the second half than on the first half of trials, $F(1, 23)$ = 4.22, MSE = 0.02, p = .05. Although a significant effect was not observed on the first half of trials (save: M = .36, SE = .03; no save: M = .34, SE = .04), $t(23)$ = 0.56, p = .58, d = 0.11, one was observed on the second half of trials (save: M = .42, SE = .04; no save: M = .28, SE = .03), $t(23)$ = 3.87, p = .001, d = 0.79. This finding is consistent with the idea that participants need to believe that saving is reliable to benefit from it. In this case, the experience of saving and having the chance to restudy saved information on one trial in the initial set may have made participants more likely to believe the saving manipulation on subsequent trials, which thus increased the magnitude of the saving-enhanced memory effect.

Experiment 3

One interpretation of the benefits of saving observed in Experiments 1 and 2 is that saving File A reduced the extent to which words from that file proactively interfered with the encoding and remembering of words from File B. If this were the case, then the extent to which saving File A enhanced memory for File B should have depended on the extent to which File A had the potential to interfere with File B. We tested this hypothesis by manipulating the number of items studied in File A. Specifically, for half of the participants, File A contained eight words; for the other half, File A contained only two words. File B always contained eight words. We reasoned that maintaining two words in memory should not overwhelmingly challenge participants and should thus negate the potential benefits of saving the file containing them. If this were the case, we predicted that the saving-enhanced memory effect would be observed in the eight-word condition but not in the two-word condition.

Method

Participants. Forty-eight UCSC undergraduates participated for credit in a psychology course (mean age = 20.2 years). The sample size was determined by a power analysis on the basis of data from the reliable condition of Experiment 2. Assuming the same effect size and variance, the estimated power to observe a significant effect in each condition with 24 participants was 95%.

Materials and procedure. The methodology was nearly identical to that of the reliable condition of Experiment 2. At the outset of the experiment, participants were given both a save trial and a no-save trial so they could experience the reliability of the saving process, then six experimental trials consisting of three save trials and three no-save trials, presented in a semirandom interleaved order. Participants were randomly assigned to either the eight-word condition, in which File A consisted of eight words, or the two-word condition, in which File A consisted of only two words. The two-word lists were created by randomly selecting two of the words from the corresponding eight-word lists. The two conditions were otherwise identical.

Results

Recall performance for File A. In the eight-word condition, the proportion of words recalled was significantly greater on save trials (M = .80, SE = .03) than on no-save trials (M = .29, SE = .03), $t(23) = 14.24$, $p < .001$, $d = 2.91$, mean difference = .51 (95% CI = [.43, .58]). A similar difference was observed in the two-word condition, with performance being perfect on save trials (M = 1.00, SE = .00) and significantly worse than perfect on no-save trials (M = .79, SE = .05), $t(23) = 3.98$, $p = .001$, $d = 0.81$, mean difference = .21 (95% CI = [.10, .32]).

Recall performance for File B. A 2 (trial type: save vs. no save) × 2 (condition: eight word vs. two word) mixed-design ANOVA revealed a significant interaction, $F(1, 46) = 7.89$, $MSE = 0.01$, $p = .007$, $\eta^2 = .15$. As shown in Figure 3, participants in the eight-word condition recalled significantly more words from File B when they had saved File A than when they had not saved File A, $t(23) = 4.56$, $p < .001$, $d = 0.93$, mean difference = .13 (95% CI = [.07, .18]). However, Figure 3 also shows that saving did not enhance memory in the two-word condition. When File A consisted of only two words, participants did not recall significantly more words from File B after they had saved File A than after they had not saved File A, $t(23) = 0.40$, $p = .69$, $d = 0.08$, mean difference = .01 (95% CI = [−.05, .07]).

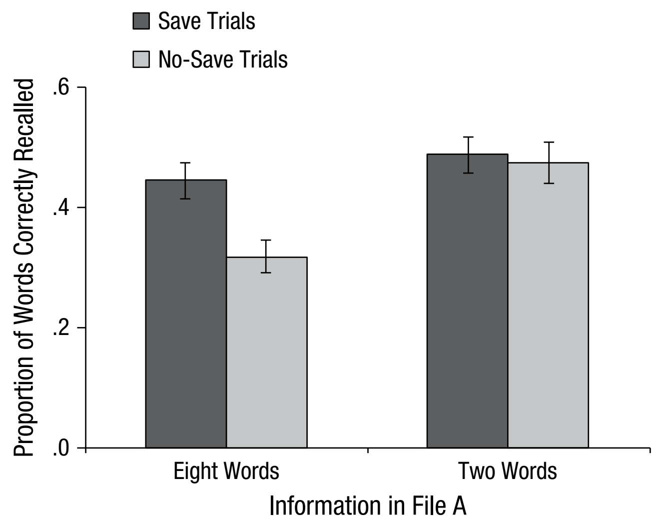

Fig. 3. Results from Experiment 3: mean recall performance for File B as a function of the amount of information contained in File A and whether or not participants had previously saved File A. Error bars represent standard errors of the mean.

General Discussion

As computers and other digital devices become deeply and increasingly ingrained in everyday life, understanding the ways in which people's interactions with such devices affect the functioning of memory will become increasingly important. In the present research, we examined the consequences of saving one computer file on memory for the contents of another computer file. In three experiments, we found that participants recalled significantly more information from a file if they had saved a previous file than if they had not saved that previous file. This saving-enhanced memory effect suggests that saving has the potential to significantly influence how people learn and remember. Specifically, by ensuring that certain to-be-remembered information will be digitally accessible, saving can facilitate the encoding and remembering of new information.

As demonstrated in Experiments 2 and 3, however, the mere act of saving is not sufficient to bestow such benefits. First, when participants viewed the saving process as unreliable, the effect was not observed. For saving to prompt someone to set aside initial information, and thus facilitate the learning of new information, the person doing the saving must genuinely believe that the saving process will work and that the initially studied information will remain available. If the saving process is deemed unreliable, then saving does nothing. Second, for the effect to be observed, the to-be-saved information must actually have the potential to impede memory performance for other information. When the to-be-saved information was relatively inconsequential (i.e., a list of two words), participants were able to maintain access to such information without incurring significant proactive interference, which thus reduced the extent to which saving had the potential to enhance memory for the contents of the new file.

Although the current research explored a specific instantiation of the benefits of saving on new learning (i.e., saving files on a computer), the phenomenon seems likely to generalize to other contexts as well. Indeed, saving may have the potential to enhance memory in any context in which some to-be-remembered information has the potential to interfere with the learning of other information, whether that context is remembering names, grocery items, educational facts, or even one's own ideas. In Henkel's (2014) work, for example, it may have been by taking photographs of some objects that participants were better able to focus attention on (and thus remember) other objects.

The precise mechanisms underlying the saving-enhanced memory effect still need to be more fully explored. One possibility, however, relates to the reduction in proactive interference observed in studies of list-method directed forgetting. Research on directed forgetting has shown that making certain information forgettable—such as by telling participants that they do not have to remember it because they will not be tested on it—not only makes that information less accessible, but it also improves memory for other information (e.g., E. L. Bjork & Bjork, 1996; R. A. Bjork, 1989; Sahakyan et al., 2013). Saving may function like a cue to forget, rendering saved information less likely to cause proactive interference. What makes the current phenomenon different from directed forgetting is that the saved files remain to-be-remembered. Participants were not told to forget the contents of the saved files, and they knew that they would eventually be tested on them, which suggests that explicit instructions or expectations to forget are unnecessary for benefits such as those of directed forgetting to be observed (Foster & Sahakyan, 2011). Other mechanisms also may have played a role in producing the saving-enhanced memory effect. For example, saving may have improved performance because it allowed participants to start fresh when learning the second file (Pastötter & Bäuml, 2010), it may have provided a change in context that allowed participants to more easily target the appropriate file at test (Sahakyan & Kelley, 2002), or it may have augmented the event boundary separating the learning of the two files (Radvansky, 2012). Future work should explore each of these possibilities more closely.

By treating computers as extensions of memory, people may be protecting themselves from the costs of forgetting while taking advantage of the benefits. Even if saved information does become less accessible as a result of the saving process—as has been observed in work by Sparrow et al. (2011) and Henkel (2014)—such an effect would be mostly innocuous because digital access to that information would be maintained. Thus, as long as the saving process is reliable, the benefits of saving can be incurred with minimal to no costs. Indeed, research has shown that losing access to information prior to relearning can actually enhance the effectiveness of relearning (R. A. Bjork, 1994; Storm, Bjork, & Bjork, 2008), which suggests that saving may enhance memory for saved information in the long run even if memory is impaired for such information in the short run.

Finally, it is worth noting that people's ability to offload memory via saving may not only affect their capacity to learn and remember, but it also may affect other cognitive processes, such as the capacity to think, solve problems, and generate new and creative ideas. Cognition is frequently and substantially constrained by the accessibility of irrelevant and extraneous information (e.g., Smith, 2003; Smith & Ward, 2012; Storm & Patel, 2014). When used effectively, saving may help people to overcome such constraints by clearing their heads of information that would otherwise constrain thinking while simultaneously keeping such information available—if only digitally—should that information become relevant or important in the future. This recalls a comment made by Sherlock Holmes in Sir Arthur Conan Doyle's (1892) story, "The Five Orange Pips." In response to Watson's description of Sherlock's penchants and limitations, particularly with regard to his various domains of knowledge, Sherlock retorts "that a man should keep his little brain-attic stocked with all the furniture that he is likely to use, and the rest he can put away in the lumber-room of his library, where he can get it if he wants it" (p. 488).

Author Contributions

Data were collected primarily by S. M. Stone. B. C. Storm and S. M. Stone conceived and designed the study, and both analyzed and interpreted the data. The manuscript was drafted by B. C. Storm with the help of S. M. Stone. Both authors approved the final version of the manuscript for submission.

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Declaration of Conflicting Interests

The authors declared that they had no conflicts of interest with respect to their authorship or the publication of this article.

Notes

1. Using an optional stopping rule (e.g., stopping data collection on the basis of the results observed) greatly inflates the risk of observing a Type 1 error. To compensate for this risk, we endeavored to replicate the effect observed in Experiment 1 in both Experiments 2 and 3 after employing power analyses to determine appropriate sample sizes.
2. Although numerical trends were observed, performance did not differ significantly as a function of the reliability of the saving process on save trials, $t(46) = 0.92$, $p = .36$, or on no-save trials, $t(46) = 1.17$, $p = .25$.

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