The effect of external store reliance on actual and predicted value-directed remembering

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Abstract

We often rely on external devices to store to-be-remembered information in our everyday lives (e.g., writing grocery lists, setting reminders), yet there is limited research about how certain information (i.e., valuable information) may be differentially encoded when we rely on our internal memory versus an external store. Across three preregistered experiments, we examined the effect of relying on an external store on the recall of high-value and low-value information. In Experiments 1a and 1b, we presented participants with words associated with point values and examined mean recall performance during two critical trials in which the external store was not available: (1) a trial in which participants were told that they *would* have access to an external memory store at test (told-external-store) and (2) a trial in which participants were told that they *would not* have access to their external store at test (told-no-external-store). In Experiment 2, we explored participants' metacognitive predictions of performance on the recall test. Critically, across all of the experiments, we found that the value effect (i.e., better recall for valuable information) was significantly reduced when individuals were told that they could rely on an external store. The same pattern was present in participant's metacognitive judgements. Together, these results suggest that when relying on external stores, individuals forgo (to some extent, at least) selective encoding by value and that individuals might be aware of this change in strategy.

Introduction

Given the limitations of our internal memory (e.g., accuracy and capacity limits), we often choose to store to-be-remembered information externally. The use of an external store (e.g., creating a grocery list) in place of some internal cognitive act (e.g., storing grocery items in internal memory)—*cognitive offloading*—offers many benefits, including potentially greater accuracy and the reduction of cognitive demands (Risko & Gilbert, 2016). However, there are costs associated with relying on an external store. Specifically, researchers have found that when given the ability to rely on an external store (compared to when relying on internal memory alone), memory performance is impaired when the external store becomes unavailable (e.g., Kelly & Risko, 2019a; 2019b; 2021; Lu et al., 2020; 2021; Sparrow et al., 2011; Eskritt & Ma, 2014; Marsh & Rajaram, 2019). In the present investigation, we examine a potential cost by investigating how the ability to rely on an external store influences how we remember information that differs in value.

The cost of relying on external stores

Researchers interested in the consequences of offloading memory demands often compare memory performance between two conditions. In one condition, individuals are provided with an external means of storing information and an instruction that this external store will be available at retrieval. Thus, individuals could ostensibly rely on the external store rather than attempt to store the information internally. This condition (we refer to as *told-external-store* condition) is compared to another condition in which participants engage in the same physical act but are told that they will *not* have access to the external store (*told-no-external-store* condition). Hence, participants in this latter condition ought to store the information internally. Importantly, both conditions are compared on a memory test wherein no participants have access to the external store. Across a number of studies, researchers have found that there is a reliable cost to performance on an unaided memory test when individuals are told their external store will be available relative to when they are warned that their store will not be available (Kelly & Risko, 2019a; 2019b; 2021; Lu et al., 2020; 2021; Marsh & Rajaram, 2019). Kelly and Risko (2019) proposed a study-effort hypothesis wherein the memory performance cost is the result of participants engaging in less top-down, intentional memory strategies (e.g., rehearsal, elaboration) at study when they can supposedly deposit the information into an external store (and subsequently retrieve it; i.e., as is the case for the told-external-store condition). Evidence consistent with this notion includes demonstrations that phenomena putatively independent of such effort (e.g., the isolation effect, extraction of gist-based information) are not significantly influenced by the availability of an external store at encoding (Kelly & Risko, 2019b; 2021; Lu et al., 2020; 2021; Pereira et al., 2021).

The influence of information value on memory

During learning, the information that we seek to remember often varies in importance, thus, there may be a benefit to selectively remembering items based on value. Indeed, when individuals are presented with information associated with point values (i.e., an indicator of importance) that are rewarded for correctly recalling the information, individuals recall more high-value information than low-value information (e.g., Castel et al., 2009; 2011; 2013; Hennessee et al., 2017; 2019; Knowlton & Castel, 2021; Murphy et al., 2021). When presented with more information than they can remember, individuals are able to use value as a guide in what to learn/prioritize (Hargis et al., 2021; Knowlton & Castel, 2021; Murphy et al., 2021). An influential account of this value-directed memory effect takes a similar form to the study-effort hypothesis used to explain the effect of relying on an external store on memory. That is, the value effect is thought to be due to the strategic, intentional encoding of high-value items (and/or a removal of such from low-value items) leading to a difference in memory performance which favors high-value items (Hennessee et al., 2017; 2019; Ariel et al., 2015). For example, Ariel et al. (2015) found that when given an opportunity to study items before a memory test, participants spent more time studying high-value items than low-value items and that high-value items were re-studied more frequently than low-value items. Further evidence seemingly consistent with this strategic view comes from work examining the influence of value on metacognitive judgements. A number of studies have provided evidence consistent with the notion that, when study effort is interpreted to be goal driven, there is a positive relation between metacognitive judgments (e.g., of learning and confidence) and study effort (Koriat et al., 2006; 2014; Koriat & Nussinson, 2009). Thus, if individuals differentially invest effort in accordance with item value, then value effects should be evident in metacognitive judgements, which does appear to be the case (McGillivray & Castel, 2011; Murphy et al., 2021; Murphy et al., in press; Koriat, Ma'ayan & Nussinson, 2006; Soderstrom & McCabe, 2011). That said, it is important to note that a positive relation between item value and metacognitive judgements could also arise from contributions other than the strategic application encoding effort (e.g., Soderstrom & McCabe, 2011).

The ideas that (i) value-directed remembering effects reflect this kind of strategic allocation of encoding effort and that (ii) effort investment can be interpreted within cost/benefit frameworks lead to a seemingly straightforward prediction in the context of having an external memory store available. Specifically, in the Expected Value of Control model (Shenhav, Botvinick & Cohen, 2013; Shenhav et al., 2017; Shenhav, Fahey & Grahek, 2021), investing effort—i.e., the cognitive control resources seemingly required to intentionally use memory strategies (selectively or otherwise)—is inherently costly and committed only to the extent that the expected payoff associated with doing so will exceed the expected cost. If one believes that they can rely on an external memory store, then there would seem to be little expected payoff associated with investing the requisite effort involved in selectively encoding items of higher versus lower value. That is, the need to selectively encode high-value items is predicated on the notion that one cannot remember all of the to-be-remembered information. Critically, when individuals can rely on an external memory store, this capacity limitation is seemingly absent and, with it, any incentive to selectively encode items of higher versus lower value. This should lead to a reduction (or elimination) of the value effect when individuals believe that they can rely on an external store. Furthermore, to the extent that these strategies represent the goal driven application of study effort, we might also expect to observe this pattern in individuals' metacognitive predictions.

While the aforementioned prediction seems intuitive, there is also work that has provided some (albeit, limited) evidence that the kind of value-directed effects discussed earlier may have a more automatic influence (Madan & Spetch, 2012; Mather & Schoeke, 2011; Murayama & Kitagami, 2014; Hennessee et al., 2019). That is, valuable information may be automatically strengthened in our memory rather than requiring a more intentional act on behalf of the individual. Provided the previous parallels drawn between relying on external memory stores and directed forgetting (e.g., Eskritt & Ma, 2014; Kelly & Risko 2019a; Lu et al., 2020), a particularly relevant example of automatic value-directed remembering was reported by Hennessee, Patterson, Castel, and Knowlton (2019) who investigated value-directed remembering within a directed-forgetting paradigm. The authors presented participants with high and low-value words and prompted participants to either "remember" or "forget" the words. In line with previous directed forgetting literature, during a surprise memory test of all the items, there was better overall memory for to-be remembered items than to-be forgotten items (e.g., Lee, 2013, MacLeod, 1989; 1998; Sheard & MacLeod, 2005). Interestingly, when participants were directed to forget the item, they still had better recognition for high-value items than for low-value items. Hennessee et al. (2019) suggested that the observation of a value effect when participants were directed to forget the item reflects a level of automatic enhancement of encoding by value. In the present context, such a view would predict a significant effect of value even when individuals can rely on an external memory store—a strong view would predict an equally robust value effect regardless of whether an individual could rely on an external memory store or not.

Examining the effect of information value in combination with external store reliance provides a unique perspective on this issue as the availability of an external store can be manipulated between lists or between participants (e.g., Kelly & Risko, 2019a; 2021). Thus, we can examine the influence of value in a context in which all items of a set are encountered with or without the expectation that one has access to an external store.

Overview of the current investigation

In the current experiments, participants completed five trials in total. During the encoding phase, participants saw a list of words, half of which were paired with a high-value (12) and the other half with a low-value (3) based on the point values used by Hennessee et al. (2019). Participants typed out each word, one at a time, to create a record of the items presented to them during the study phase. During the recall phase, participants were to recall as many words as they could from the encoding phase. Participants were told that for every word they could correctly recall, they would earn the associated point value presented at encoding and that the goal of the task was to maximize their score (i.e., the summation of the points associated with accurately recalled items).

During the first three trials, participants had access to their typed list during recall (and were instructed that they would) to encourage developing trust in the external store. During the two final critical trials, we manipulated participants' beliefs regarding their access to their external store at test. On *one* trial, participants were told *prior to* encoding that they would not have access to their typed list at test (told-no-external-store) and on the other trial, participants' typed lists were unexpectedly taken away before the recall phase (told-external-store). The order in which these two final trials occurred was counterbalanced. Experiment 1a (E1a) and Experiment 1b (E1b) were identical in method as E1b was a replication of E1a. In Experiment 2, we asked participants to make predictions about how they would perform on the memory test to investigate whether individuals are aware of the effect of relying on an external store, value, and their interaction. Provided the similarity across studies, we report all three experiments together.

Method

Participants. In Experiments 1a and 1b, undergraduate students ($N = 60$ each) were recruited from the University of Waterloo. For Experiment 2, participants ($N = 90$) were recruited from Prolific (reported sex: 54% female, 2% unreported; mean age: 34.73 years). All participants completed the experiment online with students receiving course credit and Prolific participants receiving GBP £5.63 as remuneration. The sample size in each case was determined by doubling the approximate number of participants required to detect a medium effect size (Cohen's $d = 0.50$) for the difference between high and low-value items (i.e., the value effect) for the told-no-external-store condition with a power of .80 ($\alpha = .05$, two-tailed), resulting in power of .97 ($\alpha = .05$, two-tailed).

Stimuli. Each participant was presented with five lists, with each list containing 24 words with word lengths ranging from four letters to ten letters and frequencies ranging from seven to 82060 using FreqCount (a measure of frequency out of 1 million occurrences) from SUBTLEX-UK which were generated based on subtitles from British television programmes (Van Heuven, Mandera, Keuleers, & Brysbaert, 2014). For each participant, the order in which the five lists was presented was selected randomly from a set of four counterbalanced list orders in Experiment 1a and five counterbalanced list orders in Experiments 1b and 2.[1] The 24 words within each list were presented in a randomized order, differing across participants. For each list, participants saw a word and a value corresponding to the number of points rewarded for remembering that particular item. For example, if participants saw the item "nephew 12" they would be rewarded 12 points for correctly recalling the word "nephew". Half of the words in each list were randomly paired with a high-value (12) and the other half were randomly paired with a low-value (3). All words were presented in Open Sans size 30 font and appeared on the screen for six seconds in Experiments 1a/b and was reduced to four seconds in Experiment 2 to discourage multitasking in the study.

Procedure. Before the experiment began, participants were told that they would always have access to their typed list during recall except for one trial wherein the external store would be inaccessible. However, participants were told that they would be warned of the inaccessibility of their list prior to the encoding portion of the trial. These instructions were implemented to try to prevent participants from anticipating that future tests would be unaided. Critically, for Trials

[1] There were four possible word list orders rather than five possible word list orders in Experiment 1a due to a programming error. (i.e., order 1: [list 1, list 2, list 3, list 4, list 5], order 2: [list 2, list 3, list 4, list 5, list 1], order 3: [list 3, list 4, list 5, list 1, list 2], order 4: [list 4, list 5, list 1, list 2, list 3], order 5: [list 5, list 1, list 2, list 3, list 4]). This error was corrected for Experiment 1b.

4 and 5, the list was never available at test and all participants completed a trial where they were told their list would be inaccessible at test and a trial where they were told their list would be accessible at test.

Encoding. During the encoding phase, word-value pairs appeared one at a time on the screen and participants were instructed to type out each word and not the value. If participants typed out both the word and the value, only the word would show up on their list. Participants were told that each word would be paired with a value indicating the number of points to be awarded for recalling that word. As participants typed out the words, each word was visibly saved on the screen, thus forming an accumulating list of the items presented. The position that the list appeared on the screen (either the left or right side) was randomized between participants but remained consistent during the study for each participant.

Recall. During the recall phase, participants were instructed to recall as many words as they could remember from the encoding phase; recall was produced by typing words into a text box and was self-paced. After the recall test, participants were shown how many points they earned that trial. The score was calculated by totalling the associated point values of correctly recalled words. For the first three trials, participants' typed lists were on-screen during all recall tests. During the final two trials, participants' typed lists were not on-screen during recall. However, on the told-no-external-store trial, participants were warned prior to encoding that they would not have access to their typed list during recall whereas, on the told-external-store trial, participants were not given such notice. As indicated earlier, the order of the two critical trials was randomized so that each participant had a 50% chance of being assigned to the told-no-external-store condition first (Experiment 1a: 33/60 participants, Experiment 1b: 20/60 participants, Experiment 2: 37/90 participants), and a 50% chance of being assigned to the told-external-store condition first (Experiment 1a: 27 participants, Experiment 1b: 40 participants, Experiment 2: 53 participants). Due to the random assignment of order, the number of participants who experienced the told-no-external-store condition first was not equal to the number of participants who experienced the told-external-store condition first.

Metacognitive prompt. In Experiment 2, during the critical trials, after the encoding phase, participants were told that, of the list of presented words, 12 words were worth 12 points (high value) and 12 words were worth three points (low value), and were asked to predict how many high-value and low-value words that they would correctly remember during the recall phase. In the told-no-external-store condition, participants were told *prior to* encoding that they would not receive their external store. In the told-external-store condition, participants were told they would not receive their list *after* encoding. Metacognitive prompts were gathered after they were given notice about the inaccessibility of their external stores.

Post-study questionnaire. After completion of the study, participants were asked to report what their expected strategy for the memory test was before the two critical recall trials. Participants rated their expected strategy for the two final critical trials using the following scale: *1 (rely only on saved list), 2 = rely mostly on saved list, 3 = rely equally on saved list and own memory, 4 = rely mostly on own memory, 5 (rely only on own memory).*

Results

All three experiments were pre-registered at *E1a:* osf.io/92a4s, *E1b:* osf.io/vcwu6 and *E2:* osf.io/3aemx. Data and analysis code are available at osf.io/2wke5/. All analyses were conducted using RStudio. In Experiments 1a, 1b and 2 a total of 35, 24 and 28 participants were excluded, respectively. Exclusion information is presented in Table 1. Participants who did not complete the strategy ratings were removed from the strategy rating analyses *(E1a:* 4

participants, *E1b:* 1 participant, *E2:* 1 participant). All exclusion criteria were preregistered. Excluded participants were replaced, thus target sample size was retained.

Table 1

Percentage of participants removed based on pre-registered exclusion criteria in Experiments 1a, 1b, and 2

	E1a	E1b	E2
(1) did not complete the experiment	23%	13%	14%
(2) indicated that they would not like their data to be used	6%	17%	4%
(3) indicated that they were doing something else while completing the experiment	51%	50%	0%
(4) answered *yes* to taking notes or screen captures to aid memory outside of the means offered within the experiment	0%	8%	4%
(5) did not type at least 85% (E1a/b) or 80% (E2) of words for Trials 2 to 5 during encoding	14%	8%	41%
(6) did not reach at least 85% (E1a/b) or 80% (E2) recall rate for the words in the told-external-store condition during the first three trials when they had access to their typed lists at test	6%	4%	37%

Note. Exclusions were done in a stepwise fashion (e.g., participants who were removed due to Exclusion Criterion #1 were not assessed on the criteria to follow). Differences in the proportions of exclusions across experiments should be interpreted while considering that (i) the presentation rate during encoding was six seconds in Experiments 1a/b and reduced to four seconds in Experiment 2 and that (ii) participants in Experiments 1a/b were recruited from a different participant pool than in Experiment 2.

Analyses are focused on the two critical trials in which participants experienced the list conditions and value conditions. Across all experiments, the mean proportions of recall for Trials 1 to 3 were near ceiling, as to be expected (Table 2). As preregistered, we report both ANOVA/t-tests using participant means and mixed effects models (wherein continuous variables are standardized) to provide an assessment of the statistical claims across different statistical approaches (see Steegen et al., 2016). Note that both types of analyses often yield the same statistical conclusions, and that, more importantly, the same qualitative conclusions can be drawn.

Table 2

Mean proportion of recall in Experiments 1a/b and 2 for Trials 1-3 wherein participants had access to their external memory store.

	Point Value	Trial 1	Trial 2	Trial 3
Experiment 1a	Low (3)	.90 [.84, .94]	.95 [.92, .97]	.96 [.92, .98]
	High (12)	.93 [.88, .96]	.97 [.95, .98]	.96 [.92, .98]
Experiment 1b	Low (3)	.92 [.84, .95]	.92 [.86, .95]	.96 [.90, .98]
	High (12)	.93 [.88, .96]	.94 [.90, .96]	.97 [.95, .98]
Experiment 2	Low (3)	.88 [.85, .91]	.92 [.89, .94]	.95 [.92, .96]
	High (12)	.90 [.86, .92]	.93 [.90, .95]	.95 [.92, .97]

Note. All confidence intervals are bias-corrected accelerated bootstrap 95% confidence intervals using 10,000 replications.

Experiment 1a and 1b

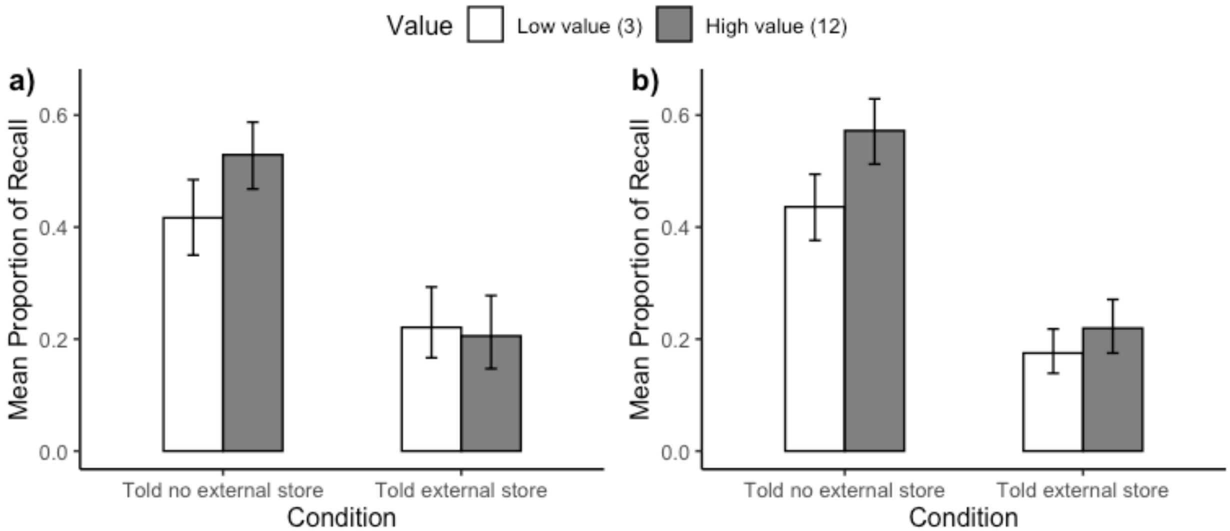
Actual Recall

A 2 (*condition*: told-no-external-store vs. told-external-store) x 2 (*value*: high-value vs. low-value) within-subjects ANOVA revealed that the mean proportion of recall was significantly higher in the told-no-external-store condition than in the told-external-store condition in both E1a, $F(1, 59) = 68.68$, $p < .001$, $\eta_G^2 = .21$, and E1b, $F(1, 59) = 105.79$, $p < .001$, $\eta_G^2 = .36$. Recall was also significantly higher for high-value items than for low-value items in both E1a, $F(1, 59) = 4.72$, $p = .034$, $\eta_G^2 = .01$, and E1b, $F(1, 59) = 16.32$, $p < .001$, $\eta_G^2 = .05$). These main effects were qualified by a significant interaction between condition and value, *E1a:* $F(1, 59) = 8.92$, $p = .004$, $\eta_G^2 = .02$; *E1b*: $F(1, 59) = 6.66$, $p = .012$, $\eta_G^2 = .01$, such that the value effect was significantly larger in the told-no-external-store condition, than in the told-external-store condition in both E1a (*told-no-external-store:* $M_{Diff} = .11$; *told-external-store:* $M_{Diff} = -.02$), and E1b (*told-no-external-store:* $M_{Diff} = .14$; *told-external-store:* $M_{Diff} = .04$).

Paired-samples t-tests showed a significant value effect in the told-no-external-store condition, *E1a:* $t(59) = 2.82$, $p = .006$, $d = 0.36$; *E1b:* $t(59) = 4.17$, $p < .001$, $d = 0.54$, but not in the told-external-store condition, *E1a:* $t(59) = 0.84$, $p = .402$, $d = 0.11$; *E1b:* $t(59) = 1.87$, $p = .067$, $d = 0.24$, though the effect was marginal in the latter experiment. An analogous mixed effects logistic regression (with by-participant and by-item intercepts) revealed findings qualitatively consistent with those of the ANOVA and paired samples t-tests with the exception of a marginal interaction detected between value and condition in E1b ($b = -0.03$, $SE = 0.02$, $z = -1.76$, $p = .078$). The mean proportions of recall by condition and value are presented in Figure 1.

Figure 1

Mean proportions of recall by condition and value in (a) Experiment 1a and (b) Experiment 1b



Note. Experiment 1a is presented on the left and Experiment 1b is presented on the right. Error bars are bias-corrected accelerated bootstrap 95% confidence intervals using 10,000 replications.

Experiment 2

Actual Recall

A 2 (*condition*: told-no-external-store vs. told-external-store) x 2 (*value*: high-value vs. low-value) within-subjects ANOVA revealed a significant main effect of condition, $F(1, 89) = 214.22$, $p <.001$, $\eta_G^2 = .40$, and value $F(1, 89) = 21.02$, $p <.001$, $\eta_G^2 = .04$, qualified by a significant interaction between condition and value, $F(1, 89) = 13.16$, $p <.001$, $\eta_G^2 = .02$. Two paired-samples t-tests showed a significant value effect (better recall for high value items than low value items) in the told-no-external-store condition, $t(89) = 4.80$, $p < .001$, $d = 0.51$, and a marginally significant value effect in the told-external-store condition, $t(89) = 1.81$, $p = .074$, $d = 0.19$. An analogous mixed effects logistic regression (with by-participant and by-item intercepts) revealed qualitatively similar results with the exception of a marginal interaction ($b = 0.03$, $SE =$

0.02, $z = 1.73$, $p = .084$) detected between value and condition. The mean proportions of actual recall are presented in Figure 2a.

Predicted Recall

A 2 by 2 within-subjects ANOVA revealed a significant main effect of condition, $F(1, 89) = 15.98$, $p < .001$, $\eta_G^2 = .03$, and a significant main effect of value, $F(1, 89) = 5.53$, $p = .021$, $\eta_G^2 = .01$, qualified by a significant interaction between the two, $F(1, 89) = 5.68$, $p = .019$, $\eta_G^2 = .003$. Two paired-samples t-tests revealed a significant value effect in the told-no-external-store condition, $t(89) = 3.25$, $p = .002$, $d = 0.34$, and no significant value effect in the told-external-store condition, $t(89) = 0.57$, $p = .573$, $d = 0.06$. An analogous mixed effects linear regression (with by-participant intercepts) revealed a significant effect of condition ($b = 0.06$, $SE = 0.02$, $t = 2.65$, $p = .008$) but not a significant effect of value ($b = 0.01$, $SE = 0.02$, $t = 0.44$, $p = .659$) or interaction between condition and value ($b = 0.05$, $SE = 0.03$, $t = 1.53$, $p = .127$). Figure 2b depicts the mean proportions of predicted recall.

Exploratory

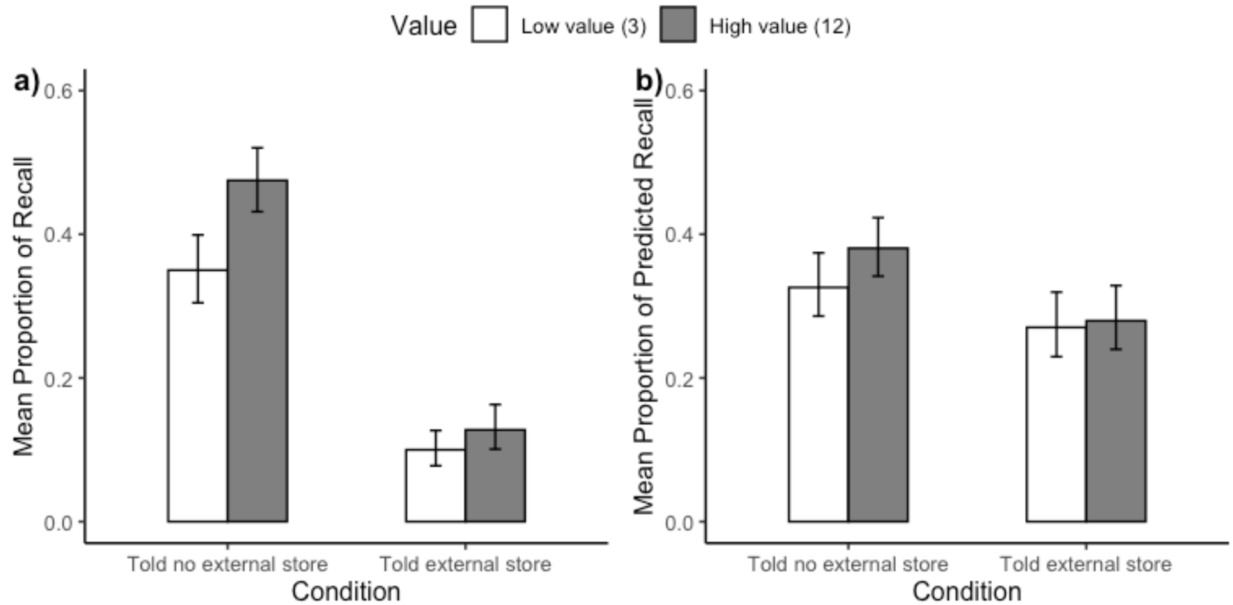
We computed the correlation between predicted and actual recall for both external store conditions. In the told-no-external-store condition, $r(88) = .51$, $p < .001$, the correlation was higher than in the told-external-store condition, $r(88) = .21$, $p = .044$. This difference was significant, $r_{diff}(88) = .30$, $z = 2.50$, $p = .012$.

In order to assess condition and value's influence on bias, a 2 (*condition*: told-no-external-store vs. told-external-store) x 2 (*value*: high-value vs. low-value) within-subjects ANOVA, with the difference score (predicted - actual recall) as the dependent variable, was conducted. This analysis revealed significant main effects of condition, $F(1, 89) = 87.23$, $p < .001$, $\eta_G^2 = .20$ and value, $F(1, 89) = 10.22$, $p = .002$, $\eta_G^2 = .01$, such that individuals were more overconfident in the told-external-store condition (M_{diff} = .16) compared to the told-no-external-store condition (M_{diff} = -.05) and more overconfident for low-value items (M_{diff} = .07) than for high-value items (M_{diff} = .03). No significant interaction was found. We also compared the bias score (the difference score between predicted and actual recall) to 0 (i.e., when predicted recall = actual recall) in each condition. We found that in the told-external-store condition, bias in the high-value condition (M_{diff} = .15), $t(89) = 6.18$, $p < .001$, $d = 0.65$ and low-value condition (M_{diff} = .17), $t(89) = 7.52$, $p < .001$, $d = 0.79$), were significantly higher than 0, indicating higher predicted recall scores than actual recall scores. In the told-no-external-store condition, bias in the high-value condition (M_{diff} = -.09) was significantly lower than 0, indicating lower predicted recall scores than actual recall scores, $t(89) = 4.05$, $p < .001$, $d = 0.43$, and bias in the low-value condition (M_{diff} = -.02) did not differ significantly from 0, indicating no significant bias, $t(89) = 1.11$, $p = .267$, $d = 0.12$.

In two additional experiments reported in the supplementary materials, the effect of value on predicted recall when individuals did not expect access to an external store was significant in one experiment (replicating the result here) but not the other. In the latter experiment, the interaction was also not significant (i.e., there was no effect of value in either condition). The interaction could not be assessed in the former experiment due to a programming error in the told-external-store condition that was fixed for the subsequent experiments. Hence, in 2/3 experiments (E2 + E1/E2 supplementary experiments) where value was manipulated, and individuals did *not* expect access to their external store, participants predicted an effect of value on their recall. In 2/2 cases where value was manipulated and individuals expected access to their external store, they predicted no effect of value on their recall.

Figure 2

Mean proportions of (a) actual and (b) predicted recall by condition and value in Experiment 2



Note. Error bars are bias-corrected accelerated bootstrap 95% confidence intervals using 10, 000 replications.

General Discussion

Consistent with prior literature, across all three experiments we found an overall cost of the availability of an external store on memory, such that participants who were told that they would have access to their external store at test had impaired memory performance in the absence of the external store compared to participants who were warned of the inaccessibility of the external store in advance (e.g., Sparrow et al., 2011; Eskritt & Ma, 2014; Kelly & Risko, 2019a; 2019b; 2021; Lu et al., 2020; 2021). In addition, there was an overall effect of value in all experiments where high-value information was better recalled than low-value information. Critically, the value effect was significantly reduced when individuals expected to have access to an external memory store. In Experiment 2, we found an effect of external store condition and value on predicted recall qualified by their interaction such that participants predicted remembering high-value items better than low-value items when they were warned in advance that their external store would not be available. Participants appear, for the most part, able to accurately predict the influences of external store availability, information value, and their interaction on their memory.

Overall, the results were consistent with the study-effort hypothesis outlined above. When individuals believe that they will have access to an external memory store, they forgo intentional efforts devoted to remembering internally. As a result, the effect of value, arguably a product of the differential application of such efforts, is reduced/eliminated (Knowlton & Castel, 2021; Murphy et al., 2021; in press). This finding is consistent with the notion that selective encoding based on value (i) requires an intention to remember and (ii) is under the control of the participant. The metacognitive results are also seemingly consistent with this view. That is, if the mechanisms responsible for both the influence of an external memory store and the influence of value reflect strategic, intentional control, then we would expect predictions to map positively onto putative differences in study effort (i.e., predictions to be higher where study effort is higher; Koriat et al., 2006; 2014; Koriat & Nussinson, 2009).

The study-effort hypothesis also has implications for how we understand the combined effects of using an external memory store and value on our day-to-day remembering. Namely, the focus on control implies that this relation is mutable. From the Expected Value of Control perspective (Shenhav, Botvinick & Cohen, 2013; Shenhav et al., 2017; Shenhav, Fahey & Grahek, 2021), the pattern observed can be interpreted as reflecting the limited return one may anticipate from investing effort differentially as a function of value when one can rely on an external memory store (for both high- and low-value information) relative to when one cannot. Importantly, there are likely to be situations we encounter in our day-to-day lives under which the expected value of such effort would be higher. For example, when “high value” information is exceptionally high value (e.g., a wedding anniversary) or the external store is of questionable reliability (Pereira et al., 2021), one might expect to observe value-directed effects even when individuals expect to have access to an external memory store. In this case, the situational demands might lead individuals to use the external store in a more duplicative fashion wherein they attempt to store the to-be-remembered information both externally and internally (this would, of course, reduce any effort savings associated with using the external store). The latter would then be expected to be value sensitive (as we observed here and has been observed numerous times previously; Castel et al., 2009; 2011; 2013; Hennessee et al., 2017; 2019; Knowlton & Castel, 2021; Murphy et al., 2021). Future work examining factors that modulate the relation between external memory store use and information value would provide additional insight into individuals’ control of their memory. This work will become particularly important as technological memory supports become increasingly widespread (e.g., as healthcare workers rely on electronic alerts for potential medication errors or adverse drug events, Ammenwerth et al., 2008).

External store availability and directed forgetting

Given the parallels between reliance on an external store and directed forgetting, the lack of correspondence between the results from Hennessee et al. (2019), described in the introduction, and the current experiments is worth exploring. Hennessee et al. (2019) found a value effect for to-be-*forgotten* items, however, we did not find a value effect in the arguably analogous told-external-store condition. The designs employed, however, were quite different. For example, Hennessee et al. (2019) manipulated remember, forget, high-value and low-value items in a mixed-list design in a recognition task, whereas, here, high- and low-value items occurred intermixed but within a list that was completely studied under either an expectation that the external store would be available or not (i.e., blocked-list design) followed by a recall task. The former seemingly presents a scenario much more demanding of working memory, which could be responsible for the difference between the current results and those found by Hennessee and colleagues (2019). Regardless of the reasons for the divergent results, it should be noted that in two of the three current experiments, the value effect in the told-external-store-available condition was in the expected direction of a value driven memory effect. Whether this effect reflects an "automatic" influence of value or a small number of participants enacting a selective encoding strategy even with an external store available would be an interesting issue to examine in the future.

Conclusion

The results of the present experiments demonstrate that relying on an external store significantly reduced the difference in recall typically observed between valuable versus less valuable information. In addition, this pattern was reflected in individuals' metacognitive judgements. The results are consistent with the notion that the influences of relying on an external store and information value on memory reflect the strategic application of study effort wherein the opportunity to rely on an external store supersedes differences in assigned value.

Open Practices Statement

The data and materials for all experiments are available at osf.io/2wke5/ and all experiments were pre-registered (*E1a:* osf.io/92a4s, *E1b:* osf.io/vcwu6*E2:* osf.io/3aemx).

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