The Isolation Effect When Offloading Memory

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Abstract

Offloading is a widespread and vital strategy for remembering. Yet, we lack a deep understanding of the mechanisms involved during the offloading of to-be-remembered information. One hypothesis is that offloading information is associated with a reduced engagement of top-down mnemonic strategies. A resulting prediction is that phenomena not solely by-products of such mechanisms should remain during offloading. We tested this prediction using the isolation effect (when recall is better for distinct items relative to nondistinct items). Participants had to remember lists of items (words) and, in most cases, were told that they could rely on an external store. On one trial, this expectation was violated, and participants had to unexpectedly rely on their internal/biological memory. Consistent with the prediction, results demonstrate a robust isolation effect irrespective of whether individuals could offload. The findings suggest that memory for distinct events is less susceptible to the typical cost of offloading to-be-remembered information.

Keywords: *cognitive offloading, isolation effect, distinctiveness*

General Audience Summary

When we use external aids to reduce cognitive demands (e.g., keep a grocery list), we are engaging in cognitive offloading, a widespread and vital memory strategy. Yet, we lack a deep understanding of the mechanisms involved during the use of this strategy. How might the act of cognitive offloading influence the representation of the offloaded information itself? Recent work has demonstrated that when we offload to-be-remembered information, there is an overall cost to memory when it is tested without the aid. It is possible that when individuals offload information, they engage in less top-down mnemonic strategies (e.g., rehearsal, imagery) than when not offloading. This idea suggests that memory phenomena that are not solely reliant on such topdown

mechanisms should still occur when we offload information. In the present investigation, we tested this prediction using the observation that individuals have better memory for distinct events. Participants had to remember lists of words and in most cases, were told that they could rely on an external store. In one trial, however, this expectation was violated and, instead, participants had to rely on their internal/biological memory. Consistent with the earlier prediction, we show that when individuals are able to offload memory demands, they still show enhanced memory for a distinct item (an *isolate*) relative to nondistinct (*control*) items. Thus, although cognitive offloading appears to have a generally negative effect on what is remembered, the ability to recall distinctive information remains, even when offloading is an available strategy. Further insights of this type will help clarify the costs and benefits of cognitive offloading.

The Isolation Effect When Offloading Memory

The use of artifacts to offload cognitive demands has long been an integral part of our dayto-day cognitive experiences (for a review, see Risko & Gilbert, 2016). However, despite gaining attention in recent years (e.g., Cherkaoui & Gilbert, 2017; Dunn & Risko, 2015; Eskritt & Ma,

2014; Gilbert, 2015a, 2015b; Gilbert et al., in press; Kelly & Risko, 2019; Risko & Dunn, 2015; Risko, Kelly, Patel, & Gaspar, 2019; Risko, Medimorec, Chisholm, & Kingstone, 2013; Sparrow, Liu, & Wegner, 2011; Storm & Stone, 2015), the nature of the processes engaged (or not) when we offload remains unclear. One pervasive type of cognitive offloading is when we record information into an external store for future recall (e.g., writing down a grocery list to refer to once at the store; Eskritt & Ma, 2014; Storm & Stone, 2015). A critical question that arises in the context of this type of offloading regards the internal fate of the offloaded information. When we can rely on an external store for information, how is that information stored in our internal/biological memory?

Recent work suggests that there are consequences for memory when individuals offload information. Risko et al. (2019) demonstrated that when offloaded information has been surreptitiously altered within an individual's external store, individuals often accept that altered information as legitimate. Furthermore, memory for offloaded information is poor compared to information stored without the expectation that one can rely on an external store (e.g., Eskritt & Ma, 2014; Kelly & Risko, 2019; Sparrow et al., 2011). Sparrow et al. tested memory for facts that individuals stored in a computer file. Half of their participants were told that their inputted information would be saved, while the rest of the participants were told that their information would be erased. Critically, no participants were given later access to the stored files. Those who thought that the computer had saved their information showed significantly worse memory for the facts than did participants who thought that the computer had erased their information. These findings support the idea that offloading information impairs the internal/biological memory of the information being offloaded. More recent investigations report similar findings (Eskritt & Ma, 2014; Kelly & Risko, 2019).

One idea is that the cost of offloading with respect to memory is related to intentional/directed forgetting (Eskritt & Ma, 2014; Kelly & Risko, 2019; Sparrow et al., 2011). In a typical directed forgetting paradigm (item level), participants are given items that they are to either remember or forget (e.g., Bjork & Woodward, 1973; MacLeod, 1999). Later testing of these items typically reveals that remember-cued items are recalled better than forget-cued items (Bjork & Woodward, 1973; MacLeod, 1999). One explanation of this effect is that participants use rehearsal to aid in recall when items are cued as to-be-remembered, while not trying to rehearse items that are cued as to-be-forgotten (Sheard & MacLeod, 2005).

Support for the notion that offloading may be disengaging top-down encoding strategies, like rehearsal, comes from recent work by Kelly and Risko (2019). They compared the serial position curves of freely recalled word lists between two groups of participants. Half of their participants expected access to an external store (offloading) during recall and the other half of participants did not (no-offloading). Participants who did not expect access to their external store (no-offloading) demonstrated typical primacy effects (Glanzer & Cunitz, 1966). Interestingly, participants expecting access to their external store (offloading) demonstrated no primacy effect, but an intact recency effect. This resembles the memory for to-be-forgotten items in directed forgetting paradigms (Bjork & Woodward, 1973; Lee, 2013) and incidentally learned items (e.g., Marshall & Werder, 1972), because both show a less pronounced primacy effect but a relatively intact recency effect.

Isolation Effects and Offloading Memory

A critical prediction based on the above account is that phenomena putatively not solely dependent on top-down efforts (e.g., rehearsal, imagery), should remain even when we offload information to an external store. One such phenomenon is the isolation effect, which is when the recall of an isolated/distinct item is better compared to nondistinct control items (e.g., Köhler & von Restorff, 1995; von Restorff, 1933). Although distinct items may be rehearsed more than control items (Dunlosky, Hunt, & Clark, 2000; Rundus, 1971), isolation effects are still found in conditions where this is unlikely to occur (Dunlosky, et al. 2000; Fabiani & Donchin, 1995). This supports the notion that the isolation effect is not solely a by-product of engaging in top-down mnemonic strategies and suggests that it should be present even when offloading information. Alternatively, if offloading eliminated the isolation effect, then perhaps a more complete disengagement is responsible, that is, even in the mechanisms that underlie the detection of isolated items and/or store distinct information (e.g., encoding similarities/differences across items; Hunt & Lamb, 2001).

Present Investigation

We examined the isolation effect in a cognitive offloading paradigm across two experiments using a method adapted from Kelly and Risko (2019). Participants were presented with to-be-remembered items (words) and recorded them onto paper (external store). On the first three trials, participants were given their external stores to aid in the recall of the items. This was essential in encouraging participants to develop trust in the external store, similar to when offloading in a nonlaboratory setting. In both experiments, the final two trials were critical trials wherein participants were never provided access to their external store during recall. In one of these critical trials, participants expected to have access to their external store during the recall portion of the experiment (offloading), while in the other trial, they did not (no-offloading). Both experiments used this within-participants design for condition (no-offloading vs. offloading). Kelly and Risko used a between-participants design, thus, the present investigation provides an examination of the extent to which similar patterns can be expected across within-participant and between-participant manipulations of offloading. Experiment 2 was a replication of Experiment 1, except that only half of the participants had isolates in their lists. The critical test in both cases is whether there is an isolation effect in the offloading condition and, if so, its magnitude relative to the isolation effect in the no-offloading condition. A secondary motivation for this study is to attempt to replicate findings that offloading predominantly impacts the initial items in a list (Kelly & Risko, 2019).

Experiment 1

Method

Experiment 1 was preregistered at https://osf.io/dcwmu. We note any analyses that were not preregistered.

Participants. Data from 50 participants were collected based on an a priori power analysis with a desired power of .80 when using an alpha level of .05 (two-tailed) to detect a Cohen's *d* of 0.42 for the interaction between condition and the isolation effect. This was based on using a difference in recall of 20% between isolated items and control items (a modest difference; e.g., Fabiani, Karis, & Donchin, 1990; Hunt & Lamb, 2001; Rabinowitz & Andrews, 1973) and the baseline standard deviation of the no-offloading condition from Kelly and Risko (2019). Participants were undergraduate students in psychology participating for course credit.

Stimuli. We created five 19-item word lists (available at https://osf.io/e5wrh/) using the SenticNet 4-word corpus (Cambria, Poria, Bajpai, & Schuller, 2016). Each list consisted of 19 items that were presented in a randomized fashion, with the 10th item (the *isolate*) as a random item for each list and each participant. Control items were items that were presented in positions 8, 9, 11, and 12 within the lists. Isolates were presented in red and size 28 font, as opposed to controls and other items, which were presented in white and size 18 font, against a black background. Lists were counterbalanced across trial position (i.e., 1 to 5) and an isolate appeared during each trial.

Procedure. Participants sat at individual stations that were occluded from one another. Each station had pens, a computer screen (with a computer), and a blue file folder. Participants sat approximately 50 cm in front of their computer screens and followed instructions that were provided by the computer screen and the researcher for the duration of the experiment. Each of the five trials had three parts: an encoding phase, a 13.5-s period with the external store out of view, and a recall phase. The researcher in the room monitored participants to ensure that instructions were followed and that no participants used the external store on the final two trials.

Encoding phase. At the beginning of each trial, the participant was presented with a visual list of to-be-remembered items on the computer screen. Items were presented one at a time for 3 s and were separated by a 4-s pause. During the encoding phase, participants were instructed to write down each item, as they saw them, onto provided paper. Once all items had been presented, the participants placed their written lists into the file folders at their stations, removing the external store from view. After the encoding phase, 13.5 s were provided to give participants time to enclose their list in their folders and to read and understand the onscreen instructions for the following recall task. This time was required during the critical trials (i.e., Trials 4 and 5) to clarify for participants, via onscreen instructions, that they could not use their list for recall, unlike during the recall of noncritical trials (i.e., Trials 1 to 3). To maintain consistency, the same duration and applicable instructions were given during noncritical trials.

Recall phase. In the recall phase of the first three trials, participants typed the items that they were presented with into a text field on the computer, with the aid of their list. We told participants that there would only be one trial wherein they would not be able to consult their list during recall, but that they would be given notice of this before being presented with the items of that list. In actuality, there were two trials wherein they would not be able to consult their list. Indeed, one of these times they were told ahead of time (no-offloading), while the other time, they were not (offloading) and this was necessary for our within-participants design to be effective. The order in which these two trials occurred were counterbalanced. The recall components of the final two trials were free recall tasks and participants were given 150 s to complete them. After all trials were completed, participants were debriefed and excused.

Results

Data from 15 participants were not analyzed because they participated after the preregistered stopping rule (i.e., 50) had been reached. The data were collected as a result of (1) the grouped nature of participation (though the tasks were performed individually) and (2) a desire to retain equal counterbalancing, by offsetting any data loss, if ever participants needed to be excluded upon viewing responses. Two participants were replaced because they were unable to demonstrate an understanding of the instructions, thus counterbalancing was preserved, as was the preregistered stopping rule. There were 79 instances (across trials) wherein participants falsely recalled an item not on their list. Thirty-three percent of these items were from other lists within the study, while the remaining items were not. All confidence intervals reported (including in figures) are bias-corrected accelerated bootstrap 95% confidence intervals (CIs) using 10,000 replications. Effect sizes are reported in terms of generalized η^2 (*ez* package in *R*; Lawrence, 2016).

Data and analysis code are available at https://osf.io/e5wrh/. The mean proportions of recalled control items (in positions 8, 9, 11, and 12 within lists) and isolates (items from position 10 within lists) during the first three trials, where participants could rely on their external memory store, ranged from .95 to .99 and .98 to 1.00, respectively. When all items were considered, the mean proportions of items recalled during the first three trials ranged from .97 to .99. Because these trials were ones during which participants had access to their externally stored information, performance for these trials was near ceiling, as expected (Kelly & Risko, 2019; Risko & Dunn, 2015; Risko et al., 2019).

We opted to deviate to some extent from the preregistration of this experiment by foregrounding mixed effects regression (*lme4* package in R; Bates, Maechler, Bolker, & Walker, 2015) instead of analysis of variance (ANOVA; both were preregistered). The mixed models (logit link function, binomial distribution) included random intercepts for participant only, due to the limited number of observations per participant (e.g., within each condition, there are four controls and a single isolate, per participant). Moreover, each model initially included the highest-level interaction terms where appropriate. If the highest-level interaction was not statistically significant, then it was removed from the model. This process of elimination ensued (if necessary) until only the estimates for the individual fixed effects remained.

Isolation effects. To investigate the isolation effect, we included condition (no-offloading vs. offloading) and item type (control vs. isolate) as fixed effects on recall performance. Offloading condition and item type did not interact, $b = 0.92$, $SE = 0.55$, $z = 1.69$, $p = .091$, thus, this interaction term was removed from the mixed model. Participants in the no-offloading condition were more likely to recall items than participants in the offloading condition, $b = -0.91$, $SE = 0.20$, $z = -4.60$, $p < .001$, and control items were less likely to be recalled than isolates, $b = 1.53$, $SE = 0.28$, $z = 5.44$, $p < .001$. Critically, isolates were more likely to be recalled than control items within both the no-offloading condition, $b = 1.05$, $SE = 0.40$, $z = 2.63$, $p = .009$, and the offloading condition,

$b = 2.24$, $SE = 0.44$, $z = 5.11$, $p < .001$. Though not preregistered, we also found that there was no significant effect of offloading for isolates, $b = -0.15$, $SE = 0.54$, $z = -0.27$, $p = .787$, but that there was for control items, $b = -1.07$, $SE = 0.22$, $z = -4.88$, $p < .001$. A qualitatively similar pattern was found using a 2 (condition: no-offloading vs. offloading) □ 2 (item type: control vs. isolate) within-participants ANOVA. However, in this latter analysis, there was a significant interaction between condition and item type, $F(1, 49) = 5.56$, $p = .022$, $\eta_G^2 = .02$, such that the isolation effect was larger in the offloading condition than the no-offloading condition. The mean proportions of items recalled as a function of condition (no-offloading vs. offloading) and item type (control vs. isolate) is presented in Figure 1.

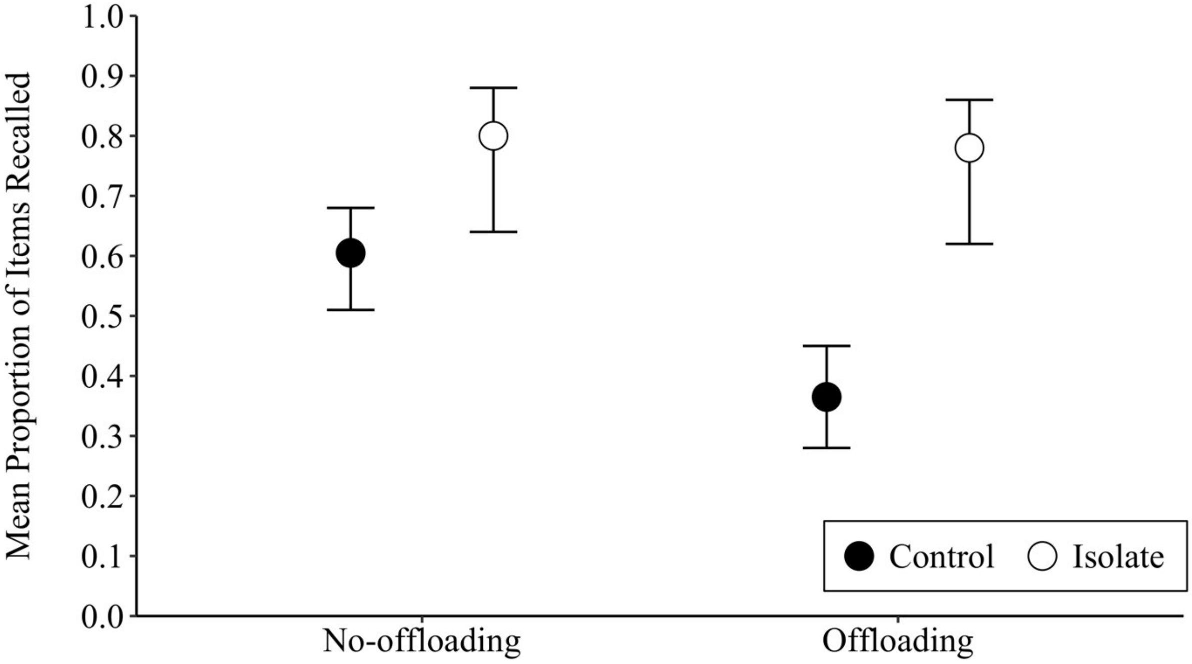

Figure 1. Mean proportions of items recalled in Experiment 1 by condition and item type. Error bars are bias-corrected accelerated bootstrap 95% confidence intervals using 10,000 replications.

Our offloading manipulation was implemented using a within-participants design wherein half of the participants had the no-offloading condition first, and the other half had the offloading condition first. We examined the influence of condition order (no-offloading first vs. offloading first) by including if with condition and item type as fixed effects on recall performance (this analysis was not preregistered). Nothing involving condition order (no-offloading first vs. offloading first) was significant (all $|b|\text{s} \leq 1.69$, $p\text{s} \geq .089$). Qualitatively similar results were found when using a 2 (condition: no-offloading vs. offloading) × 2 (item type: control vs. isolate) × 2 (condition order: no-offloading first vs. offloading first) mixed ANOVA with condition order as the between-participants factor. Table S1 of the *Supplementary Materials* presents the mean proportions and CIs of items recalled as a function of condition (no-offloading vs. offloading), item type (control vs. isolate), and condition order (no-offloading first vs. offloading first) for Experiment 1.

Primacy and recency effects. Analyses are focused on the initial two (1 and 2), middle two (9 and 11; nonisolates), and final two (18 and 19) item positions across offloading and nooffloading conditions for only the final two trials (i.e., the critical trials; similar to Kelly & Risko, 2019). To investigate primacy, we included condition (no-offloading vs. offloading) and position (initial vs. middle) as fixed effects on recall performance. Condition and position did not interact, $b = -0.65$, $SE = 0.48$, $z = -1.36$, $p = .174$, thus, this interaction term was removed from the model. Participants in the no-offloading condition were more likely to recall items than those in the offloading condition, $b = -1.42$, $SE = 0.24$, $z = -5.98$, $p < .001$, and items in the initial positions were more likely to be recalled than middle items, $b = 1.20$, $SE = 0.24$, $z = 5.09$, $p < .001$. Qualitatively similar results were found using a 2 (condition: no-offloading vs. offloading) × 2 (position: initial vs. middle) within-participants ANOVA. For recency, condition and position did not interact, $b = 0.43$, $SE = 0.42$, $z = 1.03$, $p = .302$, thus, this interaction term was removed from the model. Participants in the no-offloading condition were more likely to recall items than those in the offloading condition, $b = -0.89$, $SE = 0.21$, $z = -4.22$, $p < .001$, and there was no significant effect of position, $b = -0.09$, $SE = 0.21$, $z = -0.42$, $p = .676$. Qualitatively similar results were found using a 2 (condition: no-offloading vs. offloading) × 2 (position: middle vs. final) withinparticipants ANOVA. The mean proportions of items recalled by condition and position are presented in Table 1.

Table 1.

Mean Proportions of Items Recalled by Position, Primacy, and Recency Effects by Condition and Experiment

	Initial positions	Middle positions	Final positions	Primacy	Recency
Experiment 1					
No-offloading	.87 [.79, .92]	.60 [.48, .69]	.53 [.43, .61]	.27	− .07
Offloading	.55 [.43, .66]	.34 [.24, .44]	.37 [.28, .46]	.21	.03
Experiment 2					
No-offloading	.90 [.75, .95]	.57 [.42, .68]	.47 [.32, .58]	.33	− .10
Offloading	.60 [.42, .73]	.35[.20, .48]	.35 [.22, .48]	.25	0
Trial 4 combined					
No-offloading	.85 [.77, .90]	.54 [.43, .62]	.50 [.40, .59]	.31	− .04
Offloading	.47 [.35, .58]	.33 [.23, .42]	.34 [.25, .43]	.14	.01

Note. Trial 4 combined comprises data across Experiments 1 and 2 for Trial 4 only. For Experiment 1 and Trial 4 combined, middle positions comprise the 9th and 11th items, while for Experiment 2, the middle positions comprise the 10th and 11th items. All confidence intervals are bias-corrected accelerated bootstrap 95% confidence intervals using 10,000 replications.

Exploratory. The following analyses were not preregistered. Although our focus was on the isolation effect as a function of offloading, it was useful to assess the overall effect of offloading across all 19 item positions. This differed from the effect of offloading in the above analyses of the isolation effects, which focused on a subset of items (i.e., items 8 to 12 as controls with item 10 as the isolate) for Trials 4 and 5 (critical trials). To investigate the overall offloading effect, we included condition (no-offloading vs. offloading) as a fixed effect on recall performance across all items from Trials 4 and 5 (including isolates). Participants in the no-offloading condition were more likely to recall items than participants in the offloading condition (no-offloading: .61; offloading: .38), $b = -0.98$, $SE = 0.10$, $z = -10.01$, $p < .001$. Qualitatively similar results were found using an analogous one-way ANOVA. Figure S1 of the *Supplementary Materials* presents the mean proportions of items recalled in Experiment 1 by serial position and offloading condition. In addition to the comparison of primacy and recency effects as a function of condition (reported above), Kelly and Risko (2019) also directly compared the effects of offloading on the initial items and final items and demonstrated that offloading had a larger effect on the former. To investigate this with the current data, we included condition and position as fixed effects on recall performance. Condition and position interacted, $b = 1.12$, $SE = 0.48$, $z = 2.33$, $p = .020$, such that the effect of offloading was larger on the initial list items than the final items and this is consistent with Kelly and Risko. Participants in the no-offloading condition were more likely to recall items than participants in the offloading condition within initial items, $b = -2.05$, $SE = 0.44$, $z = -4.70$, $p < .001$, and final items, $b = -0.66$, $SE = 0.29$, $z = -2.26$, $p = .024$. Qualitatively similar results were found using a 2 (condition: no-offloading vs. offloading) □ 2 (position: initial vs. final) within-participants ANOVA, though the interaction between condition and position was not significant, $F(1, 49) = 2.82$, $p = .099$, $\eta_G^2 = .01$.

Discussion

Participants recalled information more poorly when able to offload the to-be-remembered information (i.e., expecting the aid), than when unable to offload. Critically, we observed robust isolation effects regardless of whether or not participants could offload. These findings are consistent with the prediction that phenomena putatively not dependent on top-down efforts to memorize information would remain when individuals can offload.

The analyses of primacy and recency effects were somewhat inconsistent with the findings of Kelly and Risko (2019). Unlike Experiment 1b (but consistent with Experiment 1a) of Kelly and Risko, we found no significant recency effect overall, across conditions. We did not find an interaction between offloading and the magnitude of the primacy effect, although, consistent with Kelly and Risko, the effect of offloading on the initial items was greater than on the final items. There were a number of differences between the present work and that of Kelly and Risko, namely, the presence of an isolate and the within-participant design, which may help to explain the inconsistencies. We address this matter further in both Experiment 2 and the General Discussion.

Experiment 2

In Experiment 1, control items were located within the same list and, thus, not at an equivalent position to the isolate. A more typical design includes lists that do not have isolates, allowing one to compare isolates versus nonisolates (controls) of the same position within a list (Dunlosky et al., 2000; Kelley & Nairne, 2001). We implement this more typical design in Experiment 2.

Method

Experiment 2 was preregistered at https://osf.io/5r3ap/.

Participants. Data from 60 participants (*n* = 30) were collected based on an a priori power analysis with a desired power of .80, when using an alpha level of .05 (two-tailed), to detect a Cohen's *d* of 0.80 between the recall rate of the isolate and control items for the offloading condition specifically. This was based on our observed effect size for this condition in Experiment 1. Participants were undergraduate students in psychology participating for course credit.

The method for Experiment 2 was identical to the method used in Experiment 1, with the exception that item type (control vs. isolate) was a between-participants factor. For half of the participants, the 10th item of their lists was an isolate while the other half of participants had only control items. We indexed the isolation effect by comparing the 10th position items, which were either isolates or control items.

Results

Data from 26 participants were not analyzed because they participated after the stopping rule (i.e., 60) had been reached due to the grouped nature of participation (though the tasks were performed individually). The data were collected for the same reasons outlined in Experiment 1. Participants were always assigned to the same item type manipulation (control vs. isolate) as others in their participation group. None of the 60 participants required replacing. There were 104 instances (across trials) wherein participants falsely recalled an item not on their list. Thirty-four percent of these items were from other lists within the study, while the remaining items were not.

The reported confidence intervals and effect sizes were calculated in the same manner as in Experiment 1. Data and analysis code are available at https://osf.io/e5wrh/. The mean proportions of items recalled for controls and isolates (both in the 10th position) during the first three trials, wherein participants could rely on external memory stores, ranged from .97 to 1.00 and .93 to 1.00

respectively. When all items were considered, the mean proportions of items recalled during these trials ranged from .95 to .98 for participants in the control condition and .95 to .99 for those in the isolate condition. As in Experiment 1, performance for these trials was near ceiling, as expected (Kelly & Risko, 2019; Risko & Dunn, 2015; Risko et al., 2019). As in Experiment 1, we deviate from the preregistration by foregrounding mixed effects regression rather than ANOVAs (both were preregistered). All model specifications are the same as those described in Experiment 1.

Isolation effects. To investigate the isolation effect, we included condition (no-offloading vs. offloading) and item type (control vs. isolate) as fixed effects on recall performance. Condition and item type did not interact, *b* = 0.58, *SE* = 0.96, *z* = 0.60, *p* = .546, thus, this interaction term was removed from the model. Unlike in Experiment 1, participants in the no-offloading condition were not more likely to recall items than participants in the offloading condition, *b* = −0.33, *SE* = 0.48, *z* = −0.70, *p* = .485. Similar to Experiment 1, isolates were more likely to be recalled than control items, *b* = 2.00, *SE* = 0.72, *z* = 2.77, *p* = .006. Qualitatively similar findings were found when using a 2 (condition: no-offloading vs. offloading) □ 2 (item type: control vs. isolate) mixed ANOVA with item type as the between-participants factor. The mean proportions of items recalled as a function of item type (control vs. isolate) and condition (no-offloading vs. offloading) is presented in Figure 2.

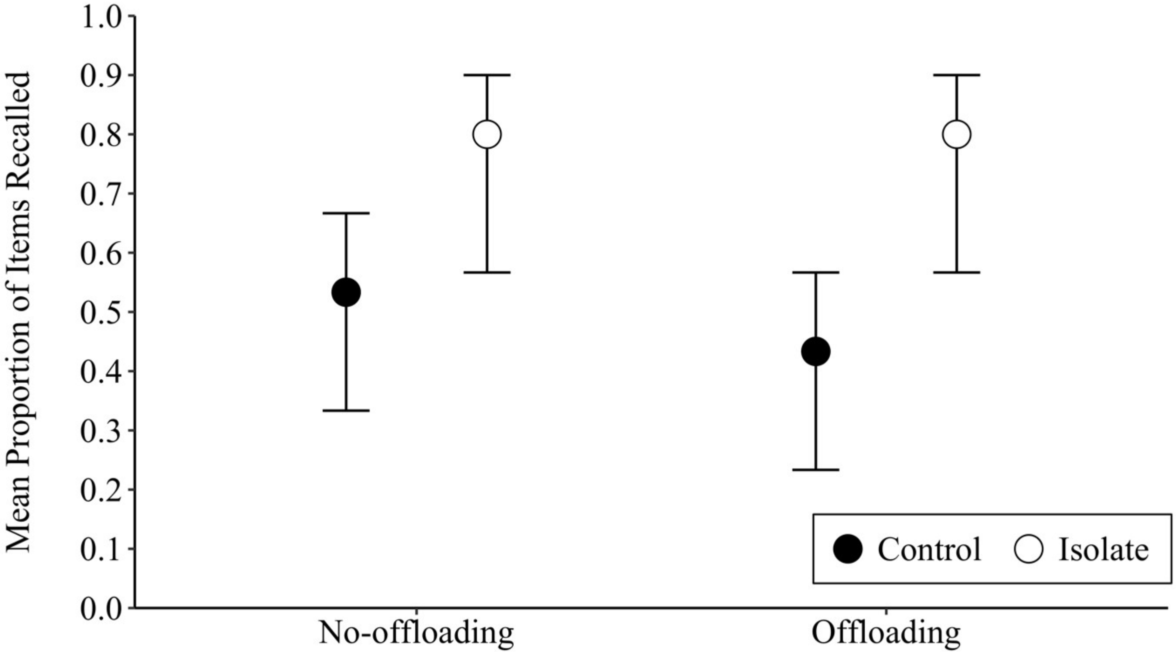

Figure 2. Mean proportions of items recalled in Experiment 2 by condition and item type. Error bars are bias-corrected accelerated bootstrap 95% confidence intervals using 10,000 replications.

The lack of a main effect of condition on the control and isolate items raises the possibility that the offloading manipulation was ineffective. This does not appear to be the case (see exploratory analyses below). Nonetheless, we conducted an analysis similar to the mixed effects analysis above where we included the same fixed effects of condition and item type; however, we treated items in positions 8, 9, 11, and 12 as control items (as in Experiment 1), rather than just the item in position 10. The offloading manipulation remained as a within-participants factor and item type remained as a between-participants factor (the following analyses were not preregistered). When using these control items, condition and item type interacted, $b = -1.58$, $SE = 0.75$, $z = 2.10$, $p = .035$, such that the isolation effect was larger in the offloading condition (control .28; isolate: .80) than in the no-offloading condition (control: .59; isolate: .80). Isolates were more likely to be recalled than control items for both the no-offloading condition, $b = 1.03$, $SE = 0.51$, $z = 2.04$, $p = .041$, and the offloading condition, $b = 3.46$, $SE = 0.91$, $z = 3.80$, $p < .001$. Identical to Experiment 1, there was no significant effect of offloading for isolates, $b < .001$, $SE = 0.69$, $z = 0$, $p = 1.00$, (this effect of offloading on isolates is the same as what would be found in the original analyses above because isolates were the same items in both sets of analyses). Contrary to the original set of analyses, there was a significant effect of offloading for control items, $b = -1.58$, $SE = 0.31$, $z = -5.03$, $p < .001$. Qualitatively similar results were found when using a 2 (condition: no-offloading vs. offloading) □ 2 (item type: control vs. isolate) mixed ANOVA.

As in Experiment 1, we examined the influence of condition order by including condition order (no-offloading first vs. offloading first) as a second between-participants factor (this analysis was not preregistered). We included condition, item type, and condition order as fixed effects on recall performance, and found that nothing involving condition order (no-offloading first vs. offloading first) was significant (all $|b|$s ≤ 1.59, ps $\geq .054$). Qualitatively similar results were found when using a 2 (condition: no-offloading vs. offloading) □ 2 (item type: control vs. isolate) □ 2 (condition order: no-offloading first vs. offloading first) mixed ANOVA. Table S1 of the *Supplementary Materials* presents the cell means and CIs for mean proportions of items recalled as a function of offloading condition (no-offloading vs. offloading), item type (control vs. isolate), and condition order (no-offloading first vs. offloading first) for Experiment 2.

Primacy and recency effects. Analyses are focused on the data from the final two trials for the participants in the control condition only (i.e., participants without isolates in their lists). We focus on the initial two (1 and 2), middle two (10 and 11), and final two (18 and 19) item positions across the offloading and no-offloading conditions. The mean proportions of items recalled by position and condition are presented in Table 1. To investigate primacy, we included condition (no-offloading vs. offloading) and position (initial vs. final) as fixed effects on recall performance. Condition and position did not interact, $b = -1.00$, $SE = 0.68$, $z = -1.47$, $p = .142$, thus, this interaction term was removed from the model. Participants in the no-offloading condition were more likely to recall items than participants in the offloading condition, $b = -1.47$, $SE = 0.33$, $z = -4.41$, $p < .001$, and initial items were more likely to be recalled than middle items, $b = 1.64$, $SE = 0.34$, $z = 4.86$, $p < .001$. Qualitatively similar results were found when using a 2 (condition: no-offloading vs. offloading) □ 2 (position: initial vs. middle) within-participants ANOVA. For recency, condition and position did not interact, $b = 0.48$, $SE = 0.58$, $z = 0.83$, $p = .406$, thus, this interaction term was removed from the model. Participants in the no-offloading condition were more likely to recall items than participants in the offloading condition, $b = -0.82$, $SE = 0.29$, $z = -2.81$, $p = .005$. The effect of position was not significant, $b = -0.25$, $SE = 0.29$, $z = -0.87$, $p = .386$. Qualitatively similar results were found when using a 2 (condition: no-offloading vs. offloading) □ 2 (position: middle vs. final) within-participants ANOVA. The mean proportions of items recalled by position, offloading condition, and experiment are presented in Table 1.

Exploratory. The analyses of this section were not preregistered. As in Experiment 1, we investigated the overall effect of condition on recall performance. This differed from the effect of offloading in the above analyses of the isolation effects, which focused on the 10th items of lists from Trials 4 and 5 (critical trials). With condition (no-offloading vs. offloading) as a fixed effect on recall performance across all items from Trials 4 and 5 (including isolates), we found participants in the no-offloading condition were more likely to recall items than participants in the offloading condition, $b = -1.00$, $SE = 0.09$, $z = -10.93$, $p < .001$. Qualitatively similar results were found using an analogous one-way within-participants ANOVA. Figure S2 of the *Supplementary*

Materials presents the mean proportions of items recalled in Experiment 2 by serial position and condition.

We also examined the effect of offloading on initial items compared to final items by including condition and position as fixed effects on recall performance. Consistent with Experiment 1 and Kelly and Risko (2019), condition and position interacted, $b = -1.29$, $SE = 0.44$, $z = -2.92$, $p = .004$, such that the offloading effect was larger for initial items than for final items. Participants in the no-offloading condition were more likely to recall items than participants in the offloading condition for initial items, $b = -2.08$, $SE = 0.39$, $z = -5.27$, $p < .001$, and for final items, $b = -0.58$, $SE = 0.28$, $z = -2.05$, $p = .040$. Qualitatively similar results were found when using a 2 (condition: no-offloading vs. offloading) □ 2 (position: initial vs. final) within-participants ANOVA (see Table 1).

Similar to Experiment 1, the analyses of primacy and recency effects were somewhat at odds with the findings of Kelly and Risko (2019). There was no recency effect in either condition, nor was there a significant interaction between condition and the primacy effect (though the pattern was similar, i.e., the primacy effect was smaller in the offloading condition). While in Experiment 1, this might have reflected the presence of an isolate, this was not the case in Experiment 2, because we only analyzed the data of participants without isolates in their lists, which was possible due to the between-participants manipulation of isolate versus control in Experiment 2. These discrepancies, instead, might have been caused by our use of a within-participant manipulation of offloading. Kelly and Risko used a between-participant manipulation of offloading.

To examine this possibility further, we collapsed across both experiments and analyzed performance for only the fourth trial, so as not to include any Trial 5 data which might have been affected by potential carryover effects. Similar to earlier serial position analyses, we focus on the initial two (1 and 2), middle two (9 and 11), and final two (18 and 19) item positions for $N = 110$ participants (Experiment 1: $N = 50$; Experiment 2: $N = 60$). For primacy, we included condition and position as fixed effects on recall performance. Unlike earlier analyses, condition and position interacted, $b = 1.12$, $SE = 0.47$, $z = 2.41$, $p = .016$, in a manner consistent with Kelly and Risko (2019), such that participants in the no-offloading condition had a larger primacy effect than participants in the offloading condition. Participants were more likely to recall initial items over middle items for both no-offloading, $b = -1.71$, $SE = 0.36$, $z = -4.80$, $p < .001$, and offloading conditions, $b = -0.77$, $SE = 0.32$, $z = -2.44$, $p = .015$. Qualitatively similar results were found using a 2 (no-offloading vs. offloading) □ 2 (initial vs. middle) mixed ANOVA with offloading as the between-participants factor. For recency, condition and position did not interact, $b = -0.19$, $SE = 0.40$, $z = -0.48$, $p = .629$, thus, this interaction term was removed from the model. Participants in the no-offloading condition were more likely to recall items than participants in the offloading condition, $b = -0.80$, $SE = 0.22$, $z = -3.72$, $p < .001$. The effect of position was not significant, $b = 0.06$, $SE = 0.20$, $z = 0.30$, $p = .765$. Qualitatively similar results were found using a 2 (nooffloading vs. offloading) □ 2 (middle vs. final) mixed ANOVA with offloading as the betweenparticipants factor (see Table 1).

Last, we compared the effect of offloading on the initial and final items using this combined dataset. Condition and position interacted, $b = -1.32$, $SE = 0.46$, $z = -2.87$, $p = .004$, such that the effect of offloading was larger for initial items than for final items. Consistent with earlier analyses, participants in the no-offloading condition were more likely to recall items than participants in the offloading condition for initial items, $b = -2.41$, $SE = 0.55$, $z = -4.37$, $p < .001$, and final items, $b = -0.71$, $SE = 0.30$, $z = -2.35$, $p = .019$. Qualitatively similar results were found using a 2 (condition: no-offloading vs. offloading) □ 2 (position: initial vs. final) within-participants ANOVA. These analyses (which collapsed across Experiments 1 and 2 and only included Trial 4 data) provide some modest support for the idea that the within-participants design did contribute, somewhat, to the lack of an interaction between primacy and offloading, but it seems clear that this is not the whole story. We discuss this further in the General Discussion section.

Discussion

Experiment 2 replicated the critical findings of Experiment 1. We found greater recall for isolates than controls, whether individuals offloaded or not. These findings support the prediction that phenomena putatively not dependent on top-down efforts at memorizing would remain even when individuals can offload. As in Experiment 1, the serial position effects across the two conditions were somewhat inconsistent with Kelly and Risko (2019). The effect of offloading on initial items was, again, larger than it was on final items, which is consistent with Experiment 1 and with findings reported by Kelly and Risko. The exploratory analyses using only Trial 4 data provide some support to the notion that this inconsistency might be a product of the use of a withinparticipants manipulation of offloading.

General Discussion

The use of external aids to offload cognitive demands has long been a widespread and vital memorial strategy. Overall, our findings are consistent with previous work demonstrating poorer memory for offloaded information when without the external aid, compared with when offloading is not an available strategy (e.g., Eskritt & Ma, 2014; Kelly & Risko, 2019; Sparrow et al., 2011). In the present investigation, we aimed to better understand the nature of this deficit. We investigated the isolation effect for both individuals expecting to use a memory aid (offloading) and individuals who were not (no-offloading). Our results demonstrated that when we offload information and subsequently recall it without the aid, isolation effects are clear and robust. As depicted in Figures 1 and 2, offloading appeared to have no appreciable effect on the memory of the isolate. While offloading impairs memory, there exist exceptions to this effect. Events that "stand out" might be relatively immune to the memorial costs associated with expecting to be able to rely on an external store.

Our results shed some light on the nature of the processes that (can) occur when offloading information (i.e., minimally, those that produce the isolation effect). There are various explanations of the isolation effect. One type of explanation focuses on the notion that distinct items prompt additional attention during processing (e.g., Green, 1956; Rundus, 1971; Schmidt, 1991). On this type of account, the present results would suggest that the increased attention to the distinct item would occur whether or not an individual could rely on an external store (i.e., offloading).

Hunt and Lamb (2001; see also von Restorff, 1933; Köhler & von Restorff, 1995) attribute the isolation effect to poor memory for the nondistinct items (rather than "special" processing of the isolate). They distinguish organizational processing (e.g., emphasizing similarities amongst items) from distinctive processing (e.g., emphasizing differences or item-specific information). From this perspective, the nondistinct items are disadvantaged, relative to the isolate, from a lack of distinctive processing (here, they would all be perceptually similar vs. the single, large, red isolate). Hunt and Lamb compared the isolation effect using categorically homogeneous lists under intentional memory instructions and instructions specifically aimed at encouraging distinctive/item-level processing (encoding differences among items using difference judgments) which eliminated the isolation effect. Moreover, this manipulation influenced recall of control items rather than recall of the isolate. Under this type of framework, the present results suggest that when individuals can rely on an external memory store, these organizational and differentiation/item-specific processes remain operative. Furthermore, those (possibly more intentional) processes, which might support the type of item-level memory required for more successful recall of control items, might not be engaged in (or at least not as much as when individuals cannot offload). Such a view seems particularly consistent with the results of Experiment 1, wherein offloading had no effect on memory for the isolate, but impaired memory for the control items. An interesting prediction from this perspective is that instructions encouraging distinctive/item-level processing should reduce the effect of offloading on memory.

Nairne (2006; see also Chee & Goh, 2018) suggests that increased retrieval for distinctive items occurs because retrieval cues of distinct/isolated instances do not, by definition, match the other nondistinct instances that occur with the isolate. From this perspective, retrieval processes can, at least partially, account for isolation effects. Recall of isolates is enhanced because the retrieval cues for isolates efficiently and selectively specify the isolates and not other items (Chee & Goh, 2018). In the context of the present results, this would suggest that even when we can rely on an external store to offload memory, sufficient information is encoded to enable the greater recall of isolates to arise at retrieval. It is interesting to consider whether this is always the case. The type of isolation used in the current investigation was perceptual salience and, as such, it is possible that other types of isolation could produce different results. For example, isolation effects are also consistently observed with categorical isolates (e.g., Geraci, McDaniel, Manzano, & Roediger, 2009; Hunt & Mitchell, 1982; Schmidt, 1991). It would be valuable to examine whether the effect of offloading might vary with the type of "distinctiveness" employed.

We have emphasized that offloading might reflect a disengagement of effortful attempts at memorizing. While we often point to rehearsal as an instance of this kind of strategy, the disengagement of other top-down mechanisms, or combinations thereof (e.g., deeper levels of processing, imagery, encoding similarities/differences), could additionally/instead be underpinning the effect of offloading. We did not provide any recommendations to participants on strategically encoding the to-be-remembered information, nor did we index whether participants were using any strategy in particular. This would be another interesting direction for future research.

Serial Position Effects

A secondary motivation of the present investigation was to attempt to replicate earlier findings that offloading had a more pronounced effect on the primacy portion of the serial position curve than the recency portion (Kelly & Risko, 2019). As noted above, these results were mixed. First, we did not find a recency effect in either of the reported experiments and, in the no-offloading condition, recall performance appeared to decrease in the later positions (see Table 1). Interestingly, this was not the case in the offloading condition, which is consistent with exploratory analyses reported by Kelly and Risko (i.e., offloading provided a small enhancement to final list items). More problematic was the lack of an interaction between condition and primacy. The within-participants design used here seems to have contributed to this discrepancy, to some extent. It seems clear that aspects of the pattern found by Kelly and Risko are apparent. When we analyzed only Trial 4 (where there is no carryover from a critical trial), there was an interaction that followed the findings of Kelly and Risko such that primacy effect was larger in the no-offloading condition than the offloading condition (though not significant in separate experiments). Throughout analyses comparing initial items to final items, offloading affected initial items significantly more than final items, which is also consistent with Kelly and Risko. While the general patterns might be consistent across studies, it was less robust here and it is informative to consider why this was the case.

The current lack of a robust recency effect may be a product of our paradigm, wherein recall is not immediate (i.e., after encoding, participants must place their written list in a folder, out of view, then read and understand onscreen instructions before recalling the items). This amount of time (~13.5 s) is considered to be delayed recall in some paradigms (e.g., Howard & Kahana, 1999). That said, the task was similar to that of Kelly and Risko (2019) who did find recency effects in the majority of conditions. There might be more general differences in the memorial strategies employed across the samples. Specifically, at the beginning of the experiment, we instructed participants that on one particular trial, they would not be able to use their list and that they would be given notice upon this particular trial (this differed from Kelly & Risko, 2019). This initial instruction might have encouraged some participants to adopt a rehearsal strategy that particularly benefited earlier items relative to later items. This might also explain the lack of recency effects. Indirect support for this idea is apparent when comparing the no-offloading conditions (i.e., baseline for the offloading manipulation) between the current work and the investigation by Kelly and Risko. They report a recency effect for no-offloading in Experiment 1b, whereas the current work did not find a recency effect for no-offloading and the current participants appear to have performed better on the initial and intermediate items. The participants in the current work might have employed a different general encoding or retrieval strategy, such that the addition of the opportunity to offload had more consistent effects across conditions. While speculative, recent work has demonstrated that in memory tasks similar to that employed here, strategies can vary between individuals and within individuals, impacting the form of the serial position curve (Unsworth, Brewer, & Spillers, 2011). Future work could further investigate these differing strategies in the context of offloading. Practically, this may also suggest that betweenparticipants designs for investigating offloading are ideal.

Finally, we must address that in day-to-day life, offloading behavior is likely guided by judgments and situational factors (e.g., Gilbert, 2015a, 2015b; Risko & Dunn, 2015; Risko & Gilbert, 2016). Within the current paradigm, we did not provide participants with free choice regarding what or how they offloaded to their external store. Future research could further address how choosing to offload is affected by various goals in remembering. How might contextual cues (e.g., an individual's perceived difficulty of content) influence these decisions? Indeed, there remains an extensive list of unanswered questions regarding this important and prevalent approach to remembering.

Conclusion

The present research is consistent with the idea that there exist circumstances in which we offload and yet can still recall information without the aid as well as when we could not rely on an external memory store. Further investigation of conditions affecting what we are capable of remembering later (after offloading, but without the aid) will contribute to our understanding of the mechanisms involved (or not) during cognitive offloading and clarify the memorial benefits and costs of this common strategy.

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