On the effects of offloading memory on memory performance

by

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Author’s declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

Abstract

The use of external aids to reduce cognitive demands is known as *cognitive offloading*. I present five preregistered experiments aimed at better understanding the effects of cognitive offloading on memory performance. The first two experiments (Chapter 1) tested the extent to which offloading resembles intentional/directed forgetting by examining the serial position effect for offloaded information. Both experiments demonstrated a reduced primacy effect under offloading conditions, thereby supporting the idea that similar processes might be engaged during offloading and intentional/directed forgetting. That is, both may be associated with a reduced engagement in intentional mnemonic strategies (e.g., rehearsal). In the next two experiments (Chapter 2), I tested a resulting prediction that memory phenomena that are not solely by-products of such mechanisms should remain even when we offload. These two experiments used the isolation effect (better recall of a salient item than of surrounding items) and, consistent with this prediction, revealed robust isolation effects in both offloading and no-offloading conditions. These two experiments also re-examined the serial position effect as a function of offloading with a within-participants design and found mixed support for the results of the first two experiments (Chapter 1). A fifth and final experiment (Chapter 3) replicated and extended the experiments in both prior chapters with respect to whether offloading influences isolation and serial position effects. This final investigation concluded that findings were generally consistent across all experiments, however, the effect of offloading on the primacy effect may be smaller than found initially. Taken together, these investigations provide deeper insight into the nature of the underlying mechanisms when offloading memory and, as a result, enhance our understanding of the associated costs and benefits.

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Chapter 1

The following work has been published in *Psychonomic Bulletin & Review* (Kelly & Risko, 2019a). Note that wording in the main text, in addition to the numbering and referencing of experiments, figures, and tables have been adjusted from the published version of record to accommodate the structure of and technical feedback given regarding this thesis.

The limited capacity of our cognitive systems has long led us to offload cognitive demands by integrating our bodies and artifacts in our physical environment into our cognitive acts (e.g., Cherkaoui & Gilbert, 2017; Dunn & Risko, 2015; Eskritt & Ma, 2014; Gilbert, 2015; Gilbert et al., 2018; Risko & Dunn, 2015; Risko, Medimorec, Chisholm, & Kingstone, 2013; Sparrow, Liu, & Wegner, 2011; Storm & Stone, 2015). One pervasive form of offloading demand is storing to-be-remembered information externally (e.g., storing important commitments in an agenda; Risko & Gilbert, 2016). An interesting question that emerges when considering offloading as a memory strategy regards the internal fate of the externally stored information. Recent work demonstrates that offloading to-be-remembered information impairs the ability to remember that information in the absence of the external store (e.g., Eskritt & Ma, 2014; Sparrow et al., 2011). In two experiments, we further examine the fate of offloaded information by investigating the influence of serial position in the unaided remembering of an offloaded list of words.

Offloading influences memory

The idea that offloaded information is more readily "forgotten" draws support from recent work by Sparrow et al. (2011) and Eskritt and Ma (2014). Sparrow et al. (2011) tested memory for facts that participants typed into a computer file. Half of the participants were told that the computer would save what they typed (i.e., it would act as an external store) whereas the other half were told that their information would be erased. Critically, no participant actually had access to their files at test. Individuals who thought that their typed information was erased had significantly better recall than did participants who thought it was saved. Eskritt and Ma (2014) reported similar results. Sparrow et al. (2011) and Eskritt and Ma (2014) likened their findings to forms of intentional/directed forgetting (see MacLeod, 1998, for a review). In intentional/directed forgetting experiments, individuals are presented with items and are told to remember some and to forget others. When individuals are later tested on all items (including "forget" items), they are less likely to recall forget items than remember items. Multiple explanations for this differential recall have been proposed (e.g., inhibition, Yang, Lei, & Anderson, 2016; context change, Sahakyan & Kelley, 2002). An account that is particularly relevant to the current work is selective rehearsal (Bjork, 1972; Sheard & MacLeod, 2005). According to this account, items cued as to be remembered are rehearsed more than items cued as to be forgotten. Here, we provide a test of whether offloading and intentional/directed forgetting rely on similar mechanisms by examining the dynamics of recall for offloaded information.

Serial position effects

Free recall tasks consistently produce serial position effects characterized by enhanced recall for beginning-of-list items (primacy) and end-of-list items (recency) relative to middle items (e.g., Glanzer & Cunitz, 1966; Murdock, 1962). Primacy is typically attributed to differential rehearsal of beginning-of-list items relative to items following (e.g., Fischler, Rundus, & Atkinson, 1970; Tan & Ward, 2008). For example, Fischler et al. (1970) showed that participants who freely rehearsed (could differentially rehearse initial list items) were significantly more likely to accurately recall beginning-of-list items (i.e., show primacy) than participants who only rehearsed the current item one at a time (i.e., not differentially). Primacy might also reflect differentially allocated attention to beginning-of-list items compared with later items (Azizian & Polich, 2007; Sederberg et al., 2006). Recency, however, has often been attributed to end-of-list items being retained in an activated, more accessible state, allowing for enhanced recall (e.g., items remain in *short-term memory*; Azizian & Polich, 2007; Davelaar, Goshen-Gottstein, Ashkenazi, Haarmann, & Usher, 2005; Glanzer & Cunitz, 1966; Shriffin & Atkinson, 1969). Alternatively, recency may also reflect a greater likelihood of retrieving the more similar temporal context associated with end-of-list items (compared with earlier items) during recall (Sederberg, Howard, & Kahana, 2008).

Intentional/directed forgetting instructions can affect the form of the serial position function in recall. Lee (2013) presented participants with lists of words and had each word in the list followed by a "remember" or "forget" cue. This was combined with a depth of processing manipulation where participants judged which of two Chinese characters had more strokes (shallow) or whether the word was good or bad (deep). We focus on the shallow processing condition as it is putatively more similar to an offloading scenario. At test, participants were told to recall as many words as they could. In the shallow condition, "forget" instructions were associated with a decreased primacy effect (no primacy for forget items), with recency intact (see also Bjork & Woodward, 1973). Thus, "forget" instructions appear to have a relatively selective negative effect on primacy, consistent with "forget" instructions discouraging rehearsal and/or attention.

Although "forget" instructions represent an explicit cue indicating that engaging in activities to enhance future recall is unnecessary, the ability to store information externally (i.e., offload memory) could also provide this cue, implicitly. Individuals may elect not to employ mnemonic activities (i.e., rehearsal) when storing information externally. If so, then recalling offloaded information (without the aid) should lead to a reduced primacy effect. The intact recency effect in Lee (2013) suggests that items activated most recently remained accessible at recall, despite "forget" instructions. Again, if offloading is similar to being told to forget, then we might expect an intact recency effect when we offload, suggesting that while individuals forego mnemonic activities such as rehearsal, the recently encountered information remains in a relatively active state.

Current Investigation

We manipulated the ability to offload in a free recall task to examine the serial position effect for offloaded information. Participants performed a series of trials on which they were presented with lists of to-be-remembered words and were told to write them down. On the first three trials, participants were instructed that they would have access to their external store (i.e., the paper on which they wrote the words) during the recall phase, which was, indeed, the case. This was essential for participants to develop trust/familiarity with the external store. The manipulation occurred at the beginning of the final trial: Half of the participants were notified that they would not be able to refer to the external store during recall, whereas the other half of participants were not. Critically, no participants were able to access their external store on the final trial. Thus, recall on the final trial contrasts memory for the final list when individuals knew that they had to rely on their internal memory (no-offloading) with memory for the final list when they could ostensibly offload those demands to an external store (offloading). Hence, our critical manipulation focuses on the expectations that participants had about their ability to rely on different memory stores (i.e., external vs. internal). To examine the serial position effects, we focused on the recall of the first two, middle two, and final two items (i.e., a subset of the list of items) across the offloading and no-offloading conditions.

Experiments 1-2

Experiments 1 and 2 were preregistered at https://osf.io/qwcxh/ and https://osf.io/2z6gt/, respectively. Experiment 1 used a fixed order of words within each list; Experiment 2 was a replication of Experiment 1 but with randomized word order over serial position. Otherwise, the experiments were identical and are described together.

Method

Participants. In both experiments, data from 64 participants were collected based on an a priori power analysis with a desired power of .80 (α = .05, two-tailed) to detect a Cohen's d of 0.80 for the interaction between offloading condition and the primacy effect (based on pilot work). Participants were undergraduate students in psychology participating for course credit.

Apparatus. Participants sat at individual workstations separated by occlusion screens. Each workstation had pens, a computer, a monitor, headphones, and a file folder.

Stimuli. We created four 20-item auditory word lists (available at https://osf.io/zjh25/) using the SenticNet4 word corpus (Cambria, Poria, Bajpai, & Schuller, 2016). Words were presented in the same position for each list in Experiment 1 but were randomized across positions in Experiment 2. Lists were counterbalanced across trial position (i.e., 1 to 4), though, in Experiment 1, two counterbalances (of the same offloading condition) were repeated.

Procedure. Participants sat approximately 50 centimetres in front of their monitors. Participants followed instructions given by the monitor and the researcher for the duration of the experiment (four trials). Each trial had three components: encoding, a 13.5 second period with the external store inaccessible, and recall. A researcher monitored participants to ensure that instructions were followed (e.g., that no participants used the external store on the final list).

Encoding. At the beginning of each trial, the participant was presented with an auditory list of to-be-remembered words. Words were presented one at a time, each separated by a 4-s pause. Participants were instructed to write down each word as they heard it onto provided paper. Once all words had been presented, participants placed their written lists into file folders at their stations so that the external store was out of view. Thirteen-and-a-half seconds was provided to participants to enclose their lists into the folders and to understand the on-screen instructions for the following recall task.

Recall. Participants were instructed to recall the words that they had heard into a text field on the computer. On the first three trials, they were instructed to refer to their external store (open the file folder to consult their list) to aid in recalling all of the words. Critically, on the fourth (final) trial, participants recalled without access to their external store (i.e., paper list), which was removed prior to recall. Half of the participants were given notice of this at the onset of the fourth trial by on-screen instructions and by the researcher. The other half of the participants were not given this instruction until after the encoding portion of the fourth trial had already finished. Instead, they saw the instructions right before the recall task stating that they were not to open their folder and therefore not to use their written list (unlike previous trials). Participants were given 150 seconds to complete this final free recall phase and were debriefed and excused when finished.

Results

Data from one participant from Experiment 1 and three participants from Experiment 2 were not analyzed, as they participated after the stopping rule (i.e., 64; data from multiple participants were collected at a time) had been reached. One participant in Experiment 1 was replaced because of technical issues. All other participants were included. Extra-list intrusions were not included in the analysis: There were 46 instances in Experiment 1 (76% during the final trials) and 35 instances in Experiment 2 (74% during the final trials) wherein participants "recalled" a word not on their list. For each relevant analysis, there were no violations of Levene's test of homogeneity or Mauchly's test of sphericity. Analyses are focused on final trial recall of the initial two (1, 2), middle two (10, 11), and final two (19, 20) positions across the offloading and no-offloading conditions. Focusing on this item subset facilitated direct comparisons of primacy and recency effects while keeping analyses relatively straight forward. For both Experiments 1 and 2, participants encoded > 99% of all words on each of Trials 1, 2, 3 and 4. Mean proportions of recall for the six positions of interest for the first three trials (when participants could rely on external stores) are presented in Table 1.[1] As expected, performance for these trials was near ceiling (Risko & Dunn, 2015). All confidence intervals reported are bias-corrected accelerated bootstrap 95% confidence intervals using 10,000 replications. Effect sizes reported are Cohen's *d* (*lsr* package in *R*; Navarro, 2015) and generalized eta squared (η_{G}^{2}; *ez* package in *R*; Lawrence, 2016). Figure 1 presents the mean proportions of recall by serial position and offloading condition for Experiments 1 and 2.

Table 1.

Mean proportions of recall across trials when participants could rely on their external memory stores

		Trial 1	Trial 2	Trial 3
Experiment 1	No-offloading	93.8	97.9	98.4
	Offloading	95.3	99.0	97.9
Experiment 2	No-offloading	88.0	99.5	99.5
	Offloading	89.1	95.8	96.9

[1]It is unclear why Trial 1 recall proportions were lower in each experiment. One explanation is that participants were less able to follow instructions during Trial 1 relative to trials following. Nevertheless, this highlights the importance of multiple offloading trials for participants to develop trust and familiarity with the external store, similar to how they may in nonlaboratory settings.

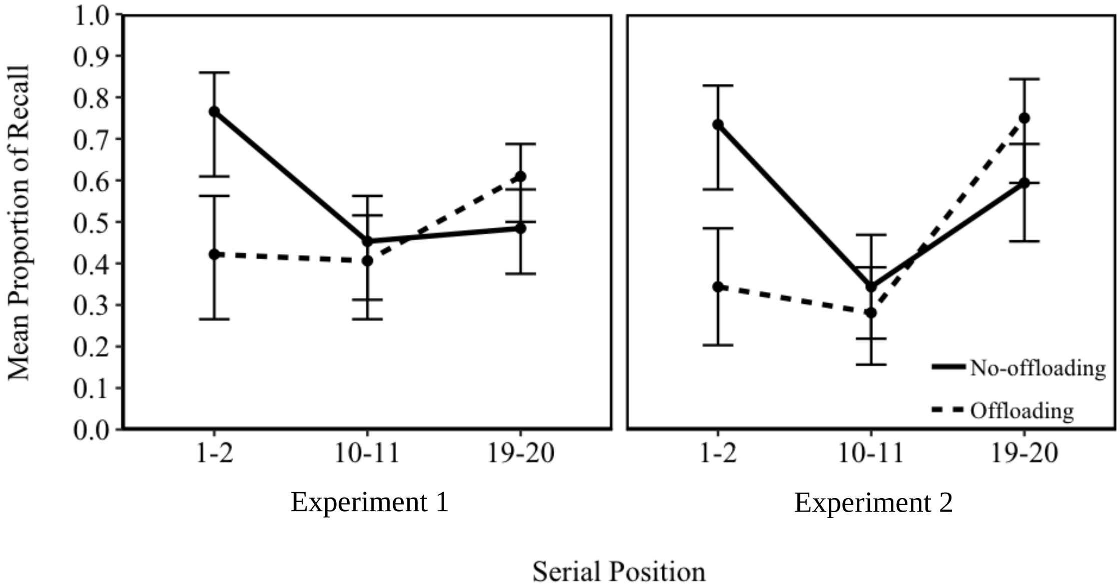

Figure 1. Mean proportions of recall by item position and offloading condition, shown separately for Experiments 1 and 2. Error bars are bias-corrected accelerated bootstrap 95% confidence intervals using 10,000 replications.

Experiment 1

A 2 (condition: no-offloading vs. offloading) × 3 (position: initial vs. middle vs. final) mixed ANOVA on the critical fourth list revealed no significant main effect of condition, $F(1, 62) = 3.63$, $p = .062$, $\eta_{G}^2 = .02$, but a significant main effect of position, $F(2, 124) = 3.52$, $p = .033$, $\eta_{G}^2 = .04$, qualified by an interaction between condition and position, $F(2, 124) = 6.92$, $p = .001$, $\eta_{G}^2 = .07$. This interaction was examined further with two 2 × 2 ANOVAs. The first 2 × 2 ANOVA assessed primacy by comparing initial versus middle position recall proportions across conditions. The second assessed recency by comparing middle versus final position recall proportions across conditions. The original preregistration of Experiment 1 to follow up on an interaction was ill considered, thus, we follow the preregistration for Experiment 2. Hence, these analyses were not preregistered.

For primacy, there were significant main effects of condition, $F(1, 62) = 8.06$, $p = .006$, $\eta_{G2} = .07$, and position, $F(1, 62) = 6.63$, $p = .012$, $\eta_{G2} = .05$, qualified by a significant interaction between condition and position, $F(1, 62) = 5.42$, $p = .023$, $\eta_{G2} = .04$. Paired t tests revealed a significant primacy effect in the no-offloading condition, $t(31) = 3.51$, $p = .001$, $d = 0.62$, but not in the offloading condition, $t(31) = 0.17$, $p = .865$, $d = 0.03$. For recency, there were no significant main effects of condition, $F(1, 62) = 0.46$, $p = .499$, $\eta_{G2} < .01$, or position, $F(1, 62) = 3.92$, $p = .052$, $\eta_{G2} = .03$, and no interaction between condition and position, $F(1, 62) = 2.11$, $p = .152$, $\eta_{G2} = .02$. A parallel set of mixed-effects logistic-regression analyses revealed qualitatively similar results.

Experiment 2

A 2 (condition: no-offloading vs. offloading) × 3 (position: initial vs. middle vs. final) mixed ANOVA on the critical fourth list revealed no significant main effect of condition, $F(1, 62) = 3.67$, $p = .060$, $\eta_{G2} = .02$, but a significant main effect of position, $F(2, 124) = 16.71$, $p < .001$, $\eta_{G2} = .15$, qualified by a significant interaction between condition and position, $F(2, 124) = 9.59$, $p < .001$, $\eta_{G2} = .09$. This interaction was examined with two 2 × 2 ANOVAs (preregistered). For primacy, there were significant main effects of condition, $F(1, 62) = 10.42$, $p = .002$, $\eta_{G2} = .09$, and position, $F(1, 62) = 15.38$, $p < .001$, $\eta_{G2} = .09$, which were qualified by a significant interaction between condition and position, $F(1, 62) = 8.07$, $p = .006$, $\eta_{G2} = .05$. Paired t tests found a significant primacy effect in the no-offloading condition, $t(31) = 4.88$, $p < .001$, $d = 0.86$, but not in the offloading condition, $t(31) = 0.751$, $p = .459$, $d = 0.13$. For recency, there was no significant main effect of condition, $F(1, 62) = 0.65$, $p = .422$, $\eta_{G2} < .01$, but the main effect of position was significant, $F(1, 62) = 31.12$, $p < .001$, $\eta_{G2} = .22$, such that recall proportion of the final items was significantly higher than of the middle items (final: 0.67 vs. middle: 0.31). There was no significant interaction between condition and position, $F(1, 62) = 2.88$, $p = .095$, $\eta_{G2} = .03$. A parallel set of mixed effects logistic regression analyses revealed qualitatively similar results.

Exploratory analyses

Overall effect of offloading. Our analyses focused on a subset of item positions; however, when considered across all positions, memory for offloaded items was significantly worse both in Experiment 1, $t(61.61) = 3.68$, $p < .001$, $d = 0.92$ (no-offloading: 0.49 vs. offloading: 0.36), and in Experiment 2, $t(60.97) = 4.79$, $p < .001$, $d = 1.20$ (no-offloading: 0.51 vs. offloading: 0.35). Mean proportions of recall across all positions for both experiments are presented in Figure 2.

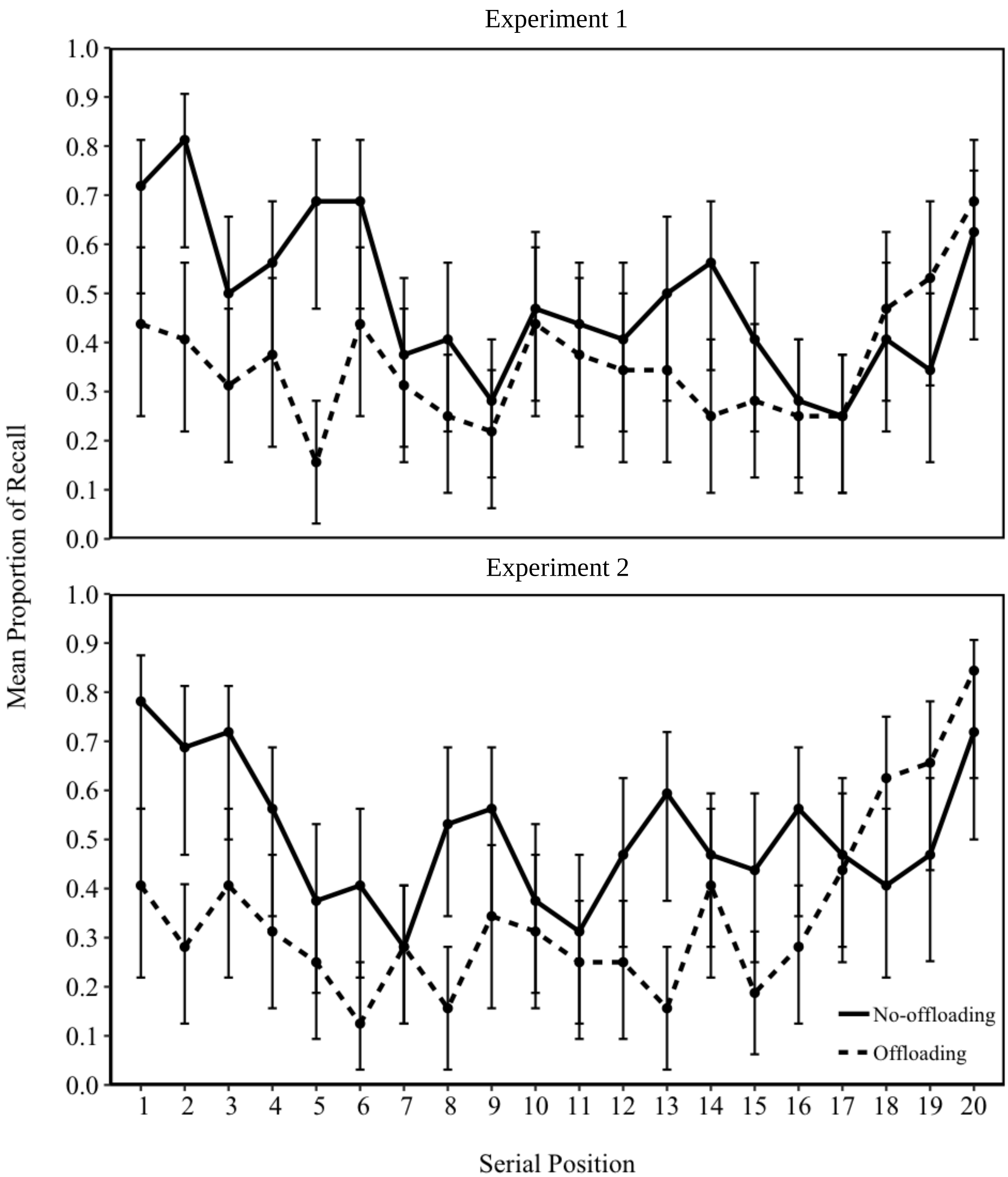

Figure 2. Mean proportions of recall by item position and offloading condition, shown separately for the two experiments. Error bars are bias-corrected accelerated bootstrap 95% confidence intervals using 10,000 replications.

Offloading on recency. In both experiments, there was a trend suggesting that the recency effect was larger in the offloading condition. This was unanticipated but was deemed worth examining closer (the following analyses were not preregistered). When combining across experiments, a 2 (Condition: No-offloading vs. Offloading) × 2 (Position: Middle vs. Final) mixed ANOVA revealed a significant interaction between offloading condition and position, $F(1, 124) = 4.65$, $p = .033$, $\eta_G^2 = .02$. Welch's two-sample t tests compared offloading with no-offloading recall proportions for middle and final items separately. The recall proportion of the final items was significantly higher in the offloading group than in the no-offloading group (offloading: 0.68 vs. no-offloading: 0.54), $t(125.83) = 2.49$, $p = .013$, $d = 0.44$. The recall proportion of the two middle items was not significantly different between offloading groups (offloading: 0.34 vs. no-offloading: 0.40), $t(125.80) = 0.85$, $p = .395$, $d = 0.15$.

Offloading on primacy versus recency. Although the main analyses show that offloading had a significant effect on primacy but not recency, a direct statistical comparison is needed to draw the conclusion that offloading influences the primacy effect more than the recency effect (Nieuwenhuis, Forstmann, & Wagenmakers, 2011; the following analyses were not preregistered). We conducted an additional 2 (Condition: No-offloading vs. Offloading) × 2 (Position: Initial vs. Final) mixed ANOVA for each experiment. When doing so for Experiment 1, we found a significant main effect of offloading condition, $F(1, 62) = 4.76$, $p = .033$, $\eta_G^2 = .03$, and no significant main effect of position, $F(1, 62) = 0.48$, $p = .493$, $\eta_G^2 < .01$, but a significant interaction between offloading condition and position, $F(1, 62) = 11.88$, $p = .001$, $\eta_G^2 = .11$. Further investigation of the interaction found that, in the first position, participants in the no-offloading condition had significantly higher recall than participants in the offloading condition (no-offloading: 0.77; offloading: 0.42), $t(58.94) = 3.60$, $p = .001$, $d = 0.90$. For the final position, participants in the no-offloading condition had lower recall than did participants in the offloading condition (no-offloading: 0.48; offloading: 0.61), though not significantly, $t(61.67) = 1.74$, $p =$

.087, $d = 0.44$. A parallel set of mixed-effects logistic-regression analyses revealed qualitatively similar results.

We also conducted the additional 2 (condition: no-offloading vs. offloading) × 2 (position: initial vs. final) mixed ANOVA for Experiment 2. We found no significant main effect of offloading condition, $F(1, 62) = 3.75$, $p = .057$, $\eta_{G}^{2} = .03$, and a significant effect of position, $F(1, 62) = 4.04$, $p = .049$, $\eta_{G}^{2} = .03$, qualified by a significant interaction between offloading condition and position, $F(1, 62) = 17.11$, $p < .001$, $\eta_{G}^{2} = .13$. Further investigation of the interaction found that in the first position, participants in the no-offloading condition had significantly higher recall than did participants in the offloading condition (no-offloading: 0.73; offloading: 0.34), $t(59.66) = 4.17$, $p < .001$, $d = 1.04$. For the final position, participants in the no-offloading condition had lower recall than participants in the offloading condition (no-offloading: 0.59; offloading: 0.75), though not significantly, $t(61.94) = 1.83$, $p = .072$, $d = 0.46$. A parallel set of mixed-effects logistic-regression analyses revealed qualitatively similar results.

General Discussion

We examined serial position effects (e.g., Glanzer & Cunitz, 1966; Murdock, 1962) for offloaded information as a test of whether offloading mirrors the recall patterns of intentional/directed forgetting. In both experiments, offloading led to significantly reduced primacy during free recall. Interestingly, offloading did not have any negative effect on recency and appeared (via exploratory analyses combining across experiments) to lead to greater recall of the final items. One potential explanation of this is that individuals were more likely to recall final items first, which could be investigated by analyzing output order.

Results are consistent with offloading influencing memory in a similar manner to that of "forget" instructions in intentional/directed forgetting. Critically, both offloading and being instructed to forget lead to a decreased primacy effect. If we take primacy to reflect differential rehearsal (e.g., Fischler et al., 1970; Sederberg et al., 2006; Tan & Ward, 2008) and/or attention (Azizian & Polich, 2007; Sederberg et al., 2006), this suggests that offloading discourages one or both of these processes. For example, individuals might encode information to the extent that they record it properly into their external store, but exert no mnemonic effort to remember that information thereafter, essentially carrying out no elaboration of "forget" items.

Consistent with Lee (2013), recency was intact when offloading was available. The magnitude of this effect was at least equivalent to that when offloading was unavailable. This suggests (depending on the account of recency) that the encoding of to-be-offloaded information is in an active enough state in memory to produce a robust recency effect (Azizian & Polich, 2007; Davelaar et al, 2005; Glanzer & Cunitz, 1966; Shriffin & Atkinson, 1969) and/or that offloading does not impair the encoding of the temporal context associated with the end-of-list list items (Sederberg et al., 2008). The unexpected finding that memory for the final items was greater in the offloading condition might reflect reduced within-list interference during the final trial when offloading compared with not offloading. If rehearsing beginning-of-list items hinders the encoding of end-of-list items and individuals who offload forego rehearsal, then we might expect greater memory for end-of-list items during offloading (see Storm & Stone, 2015). Offloading might also lead to a shift in strategic output order that emphasizes later list items.

The present investigation focused on the memorial consequences of offloading as an available strategy. Requiring individuals to write down all words (rather than allowing a choice of what to record) seemingly removed the need to choose which items to offload. Removing this choice might introduce "unnaturalness" when considering that we typically decide what to offload. However, this seems a necessary compromise when considering those choices as unlikely to be random (see Siegler & Lemaire, 1997, for discussion). For example, Castel (2008) demonstrated that individuals have some metacognitive awareness of the influence of serial position on memory. If individuals' metacognitions drive their offloading decisions (Dunn & Risko, 2015; Risko & Gilbert, 2016), then we might expect serial position to influence offloading choices as well. However, this effect is likely to be small, considering that individuals tend to rely heavily on offloading, even if relying on internal memory would yield comparable performance (Risko & Dunn, 2015). This raises an interesting question for future research, both in terms of examining the effect of serial position on the choice to offload, and in terms of how providing choice influences one's internal representation of the offloaded (or not) information. Although our chosen form of offloading (writing) represents a common strategy, the emergence of massive digital forms of storage are quickly supplanting it. Previous research has used a mix of external storage types (e.g., digital files, paper and pencil; Eskritt & Ma, 2014; Hamilton, McIntyre, & Hertel, 2016; Hertel, 1988; Storm & Stone, 2015; Risko & Dunn, 2015; Sparrow et al., 2011). However, we are not aware of any direct comparisons across external store types, thus opening a door to another potentially fruitful line of research.

The present results support the suggestion that offloading memory may engage—or disengage—similar mechanisms as intentional/directed forgetting (Eskritt & Ma, 2014; Sparrow et al., 2011). Our results are also consistent with reduced top-down rehearsal during offloading, considering the link between primacy and rehearsal (Fischler et al., 1970; Tan & Ward, 2008). Although we think that decreased rehearsal fits with the current data, drawing parallels between intentional/directed forgetting and offloading raises the interesting question of whether offloading might also have a more active, inhibitory component as some have suggested for intentional/directed forgetting (e.g., Yang, Lei, & Anderson, 2015). However, when we offload information to an external store, it is likely guided by intentions to have that information for future use. Ostensibly, this is not the case when presented with “forget” instructions—thus, inhibiting offloaded information might be unnecessary.

Conclusion

The present work revealed that offloading information selectively impaired memory for initial list items and not for later list items. These results are consistent with previous work demonstrating analogous modulation of the serial position curve under “forget” instructions (Lee, 2013) and, therefore, supports the hypothesis that offloading and intentional/directed forgetting rely on similar mechanisms.

Chapter 2

The following work has been published in the *Journal of Applied Research in Memory and Cognition* (Kelly & Risko, 2019b). Note that wording in the main text, in addition to the numbering and referencing of experiments, figures, and tables have been adjusted from the published version of record to accommodate the structure of and technical feedback given regarding this thesis.

The use of artifacts to offload cognitive demands has long been an integral part of our day-to-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., 2018; Kelly & Risko, 2019a; Chapter 1; 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 occurs 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 is poor for offloaded information compared to information stored without the expectation that one can rely on an external store (e.g., Eskritt &

Ma, 2014; Kelly & Risko, 2019a; Chapter 1; Sparrow et al., 2011). Sparrow et al. tested memory for facts that individuals stored in a computer file. Half of the participants were told that their inputted information would be saved whereas 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, 2019a; Chapter 1).

One idea is that the cost of offloading with respect to memory is related to intentional/directed forgetting (Eskritt & Ma, 2014; Kelly & Risko, 2019a; Chapter 1; Sparrow et al., 2011). In a typical directed forgetting paradigm (item method), participants are given items one at a time that they are told either to remember or to forget (see MacLeod, 1998, for a review). 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 whereas they do not try to rehearse items that are cued as to-be-forgotten (Bjork, 1972; Sheard & MacLeod, 2005).

Support for the idea that offloading may involve disengaging top-down encoding strategies, like rehearsal, comes from recent work by Kelly and Risko (2019a; Chapter 1). 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; 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—better memory for items at the beginning of the list (Glanzer & Cunitz, 1966). In contrast, participants expecting access to their external store (offloading) demonstrated no primacy effect, but an intact recency effect. This pattern resembles that for 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 mechanisms (e.g., rehearsal, imagery), should remain even when we offload information to an external store. One such phenomenon is the isolation effect, which occurs when the recall of an isolated/distinct item is better than that of 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 additional rehearsal 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 the effect 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).

We examined the isolation effect in a cognitive offloading paradigm across two experiments using a method adapted from Kelly and Risko (2019a; Chapter 1). Participants were presented with to-be-remembered items (words) which they recorded 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); in the other trial, they did not (no-offloading). Both experiments used this within-participants design for condition (no-offloading vs. offloading) whereas Kelly and Risko had 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 4 was a replication of Experiment 3, 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 was to attempt to replicate findings that offloading predominantly influences the initial items in a list (Kelly & Risko, 2019a; Chapter 1).

Experiment 3

Method

Experiment 3 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 (2019a; Chapter 1). 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 15-s period with the external store out of view, and a recall phase. The researcher in the room monitored the participant to ensure that instructions were followed and that no participant 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 2.5-s pause. During the encoding phase, the participant was instructed to write down each item, as they saw them, onto provided paper. Once all items had been presented, the participant placed their written list into the file folder at their station, removing the external store from view. After the encoding phase, 13.5 s were provided to give the participant time to enclose their list in their folder 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 the participant, via onscreen instructions, that they could not use their list for recall, unlike during recall on 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, the participant 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) whereas the other time they were not (offloading): This was necessary for our within-participants design to be effective. The order in which these two trials occurred was counterbalanced. The recall components of the final two trials were free recall tasks and the participant was 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) having multiple individuals participating at once (although 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 inspecting 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 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 codes 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 0.95 to 0.99 and 0.98 to 1.00, respectively. When all items were considered, the mean proportions of items recalled during the first three trials ranged from 0.97 to 0.99. 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, 2019a; Chapter 1; 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, $b = -0.15$, $SE = 0.54$, $z = -0.27$, $p = .787$, $BF_{01} = 6.27$, 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, $F(1, 49) = 5.56$, $p = .022$, $\eta_{G2} = .02$, 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 item type (control vs. isolate) and condition (no-offloading vs. offloading) are presented in Figure 3.

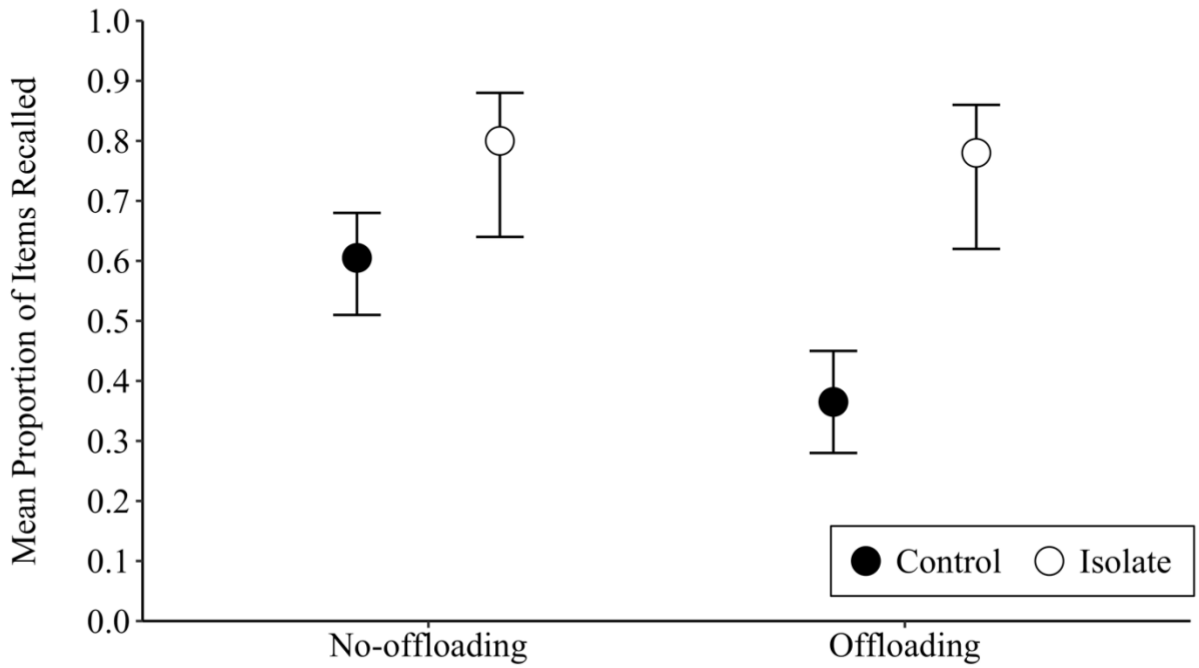

Figure 3. Mean proportions of items recalled in Experiment 3 by condition and item type. Error bars are bias-corrected accelerated bootstrap 95% confidence intervals using 10,000 replications.

Our offloading manipulation was implemented using a within-participants design. Therefore, we examined the influence of condition order by including condition order (no-offloading first vs. offloading first) as a between-participants factor 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 $|b|$s ≤ 1.69, *p*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.

Primacy and recency effects. Serial position analyses 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 no-offloading conditions for only the final two trials (i.e., the critical trials; similar to Kelly &

Risko, 2019a; Chapter 1). 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 were participants 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, $b = -0.09$, $SE = 0.21$, $z = -0.418$, $p = .676$. Qualitatively similar results were found using a 2 (condition: no-offloading vs. offloading) × 2 (position: middle vs. final) within-participants ANOVA. The mean proportions of items recalled by condition and position are presented in Table 2.

Table 2.

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

	Initial positions	Middle positions	Final positions	Primacy	Recency
Experiment 3					
No-offloading	0.87 [0.79, 0.92]	0.60 [0.48, 0.69]	0.53 [0.43, 0.61]	0.27	− 0.07
Offloading	0.55 [0.43, 0.66]	0.34 [0.24, 0.44]	0.37 [0.28, 0.46]	0.21	0.03
Experiment 4					
No-offloading	0.90 [0.75, 0.95]	0.57 [0.42, 0.68]	0.47 [0.32, 0.58]	0.33	− 0.10
Offloading	0.60 [0.42, 0.73]	0.35[0.20, 0.48]	0.35 [0.22, 0.48]	0.25	0.0
Trial 4 combined					
No-offloading	0.85 [0.77, 0.90]	0.54 [0.43, 0.62]	0.50 [0.40, 0.59]	0.31	− 0.04
Offloading	0.47 [0.35, 0.58]	0.33 [0.23, 0.42]	0.34 [0.25, 0.43]	0.14	0.01

Note. Trial 4 combined comprises data across Experiments 3 and 4 for Trial 4 only. For Experiments 3 and Trial 4 combined, middle positions comprised the 9th and 11th items; for Experiment 4, middle positions comprised 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 were participants in the offloading condition (no-offloading: 0.61; offloading: 0.38), $b = -0.98$, $SE = 0.10$, $z = -10.00$, $p < .001$. Qualitatively similar results were found using an analogous one-way ANOVA.

In addition to the comparison of primacy and recency effects as a function of condition (reported above), Kelly and Risko (2019a; Chapter 1) 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, 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, although the interaction between condition and position was not significant, $F(1, 49) = 2.82$, $p = .099$, $\eta_{G2} = .01$.

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 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 Chapter 1 (Kelly and Risko 2019a). Unlike Experiment 2 (but consistent with Experiment 1) of Chapter 1, 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 Chapter 1, the effect of offloading was greater on the initial items than on the final items. There were a number of differences between the present work and that of Chapter 1, 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 4 and the General Discussion.

Experiment 4

In Experiment 3, 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 4.

Method

Experiment 4 was preregistered at https://osf.io/5r3ap/.

Participants. Data from 60 participants (*n* = 30 per group) 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 3. Participants were undergraduate students in psychology participating for course credit.

The method for Experiment 4 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; 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. In all cases, words were randomized over positions, including the isolate position.

Results

Data from 26 participants were not analyzed because they participated after the stopping rule (i.e., 60) had been reached due to collecting data from multiple participants at once (although the tasks were performed individually). The data were collected for the same reasons outlined in Experiment 3. 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 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 3. Data and analysis codes 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 0.97 to 1.00 and 0.93 to

1.00 respectively. When all items were considered, the mean proportions of items recalled during these trials ranged from 0.95 to 0.98 for participants in the control condition and 0.95 to 0.99 for those in the isolate condition. As in Experiment 3, performance for these trials was near ceiling, as expected (Kelly & Risko, 2019a; Chapter 1; Risko & Dunn, 2015; Risko et al., 2019). As in Experiment 3, 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 3.

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 3, participants in the no-offloading condition were not more likely to recall items than were participants in the offloading condition, $b = -0.33$, $SE = 0.48$, $z = -0.70$, $p = .485$. Similar to Experiment 3, 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) are presented in Figure 4.

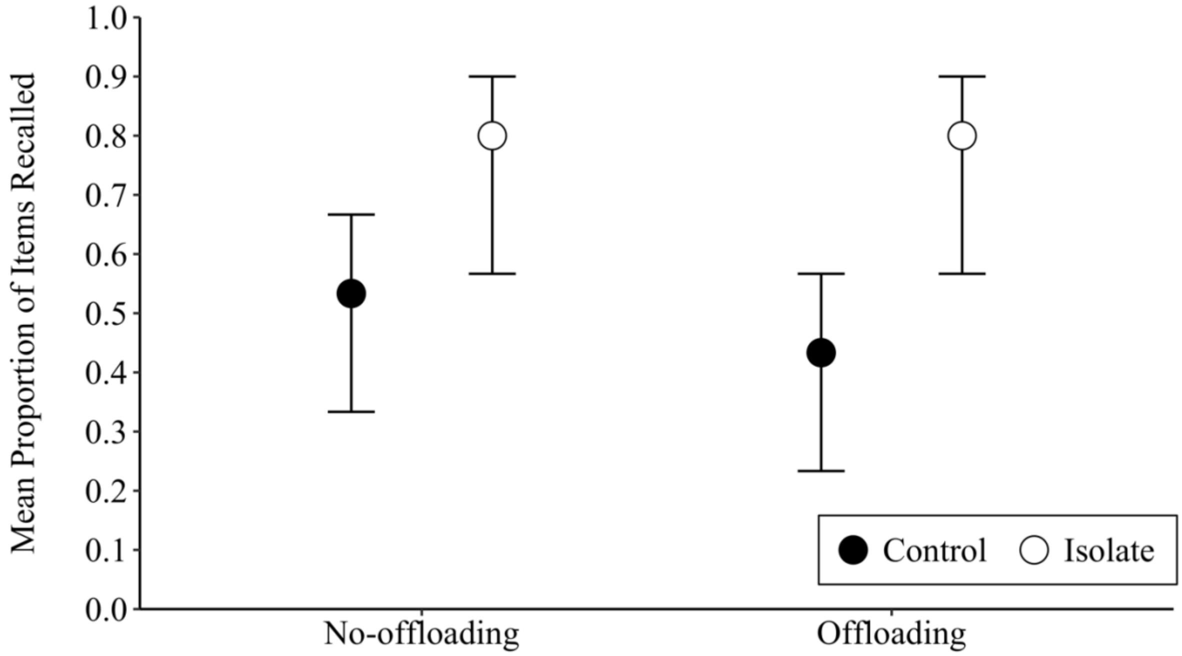

Figure 4. Mean proportions of items recalled in Experiment 4 by condition and item type. Error bars are bias-corrected accelerated bootstrap 95% confidence intervals using 10,000 replications.

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, however, 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 but we treated items in positions 8, 9, 11, and 12 as control items (as in Experiment 3), rather than just the item in position 10 as the single control item. 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 0.28; isolate: 0.80) than in the no-offloading condition (control: 0.59; isolate: 0.80). 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 3, there was no significant effect of offloading for isolates, $b < .001$, $SE = 0.69$, $z = 0$, $p = 1.00$, $BF_{01} = 5.14$ (this effect of offloading on isolates is the same as what would be found in the previous original analyses 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 3, 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 $|b|\text{s} \leq 1.59$, $p\text{s} \geq .054$). 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.

Primacy and recency effects. Serial position analyses 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 examined 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 2. 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, $b = -1.00$, $SE = 0.68$, $z = -1.47$, $p = .142$, so this interaction term was removed from the model. Participants in the no-offloading condition were more likely to recall items than were 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, $b = 0.48$, $SE = 0.58$, $z = 0.83$, $p = .406$, so this interaction term was removed from the model. Participants in the no-offloading condition were more likely to recall items than were 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 2.

Exploratory. The analyses in this section were not preregistered. As in Experiment 3, 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 were 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.

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 3 and Chapter 1 (Kelly & Risko, 2019a), 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 were 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 2).

Similar to Experiment 3, the analyses of primacy and recency effects were somewhat at odds with the findings of Chapter 1 (Kelly & Risko, 2019a). There was no recency effect in either condition, nor was there a significant interaction between condition and the primacy effect (although the pattern was similar, i.e., the primacy effect was somewhat smaller in the offloading condition). While in Experiment 3 this might have reflected the presence of an isolate, this was not the case in Experiment 4, 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 4. These discrepancies, instead, might have been caused by our use of a within-participant manipulation of offloading; recall that Kelly and Risko (2019a; Chapter 1) 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 examined the initial two (1 and 2), middle two (9 and 11), and final two (18 and 19) item positions for *N* = 110 participants (Experiment 3: *N* = 50; Experiment 4: *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

(2019a; Chapter 2), such that participants in the no-offloading condition had a larger primacy effect than did participants in the offloading condition. Participants were more likely to recall initial items over middle items in both the no-offloading, $b = -1.71$, $SE = 0.36$, $z = -4.80$, $p < .001$, and the 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, $b = -1.93$, $SE = 0.40$, $z = -0.48$, $p = .629$, so this interaction term was removed from the model. Participants in the no-offloading condition were more likely to recall items than were 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 (no-offloading vs. offloading) × 2 (middle vs. final) mixed ANOVA with offloading as the between-participants factor (see Table 2).

Last, we compared the effect of offloading on the initial and final items using this combined dataset. Condition and position interacted, $b = -1.32$, $SE = .46$, $z = -2.87$, $p = .004$, 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 than were participants in the offloading condition to recall 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 3 and 4 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 4 replicated the critical findings of Experiment 3. 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 3, the serial position effects across the two conditions were somewhat inconsistent with Experiments 1 and 2 (Kelly & Risko 2019a; Chapter 1). The effect of offloading on initial items was, again, larger than it was on final items, which is consistent with Experiment 3 and with findings by Kelly and Risko (2019a; Chapter 1). The exploratory analyses using only Trial 4 data provide some support for the notion that this inconsistency might be a product of the use of a within-participants 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 the external aid is not accessible, compared with when offloading is not an available strategy (e.g., Eskritt & Ma, 2014; Kelly & Risko, 2019a; Chapter 1; Sparrow et al., 2011). In the present investigation, we aimed to better understand the nature of this deficit. We investigated the isolation effect both for individuals expecting to use a memory aid (offloading) and for 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 3 and 4, offloading appeared to have no appreciable effect on the memory of the isolate. While offloading impairs memory overall, there clearly 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 occurs 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 poorer memory for the nondistinct items (rather than "special" processing of the isolate). They distinguish organizational processing (e.g., emphasizing similarities among 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, the nondistinct items 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 3, where 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) suggested 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 (e.g., distinct items would be relatively immune from *cue overload*, Watkins & Watkins, 1975). 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) whereas this is not the case for the nondistinct items. 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). Future work could examine whether this sufficient encoding of distinct information during offloading might vary with the type of "distinctiveness" employed, thus providing further insight into the effect of offloading on various types of information.

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 than on the recency portion of the serial position curve (Kelly & Risko, 2019a; Chapter 1). 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 2). Interestingly, this was not the case in the offloading condition, which is consistent with exploratory analyses reported by Kelly and Risko (2019a; Chapter 1; 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 (2019a; Chapter 1) 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 (2019a; Chapter 1) such that the primacy effect was larger in the no-offloading condition than in the offloading condition (although 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 (2019a; Chapter 1). Although 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 often considered to be delayed recall (e.g., Howard & Kahana, 1999). That said, the task was similar to that of Kelly and Risko (2019a; Chapter 1) wherein there were recency effects in the majority of conditions. More general differences in the memorial strategies might be being employed across the samples. Specifically, at the beginning of the within-participants version 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 and Risko, 2019a; Chapter 1). This instruction could encourage some participants to rehearse, thereby benefitting earlier items relative to later items. This might also explain the lack of recency effects in the within-participants design.

Indirect support for the potential effect of initial instructions encouraging rehearsal is that when comparing the no-offloading conditions (i.e., baseline for the offloading manipulation), the results differ slightly between the current work and that of Kelly and Risko (2019a; Chapter 1). Kelly and Risko (2019a; Chapter 1) found a recency effect for no-offloading in Experiment 2, whereas the current work did not find a recency effect. Instead, the current participants seemed to perform better on the initial and intermediate items. While speculative, recent work has demonstrated that in memory tasks similar to that employed here, strategies can vary between and within individuals, influencing 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 between-participants designs are best for investigating offloading.

Finally, we must address the fact that, in day-to-day life, offloading behaviour 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 under which we offload and yet, without the aid being accessible, we can still recall information as well as when we recall information from internal/biological memory. 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.

Chapter 3

In Experiments 1 and 2 (Kelly & Risko, 2019a; Chapter 1), we were particularly interested in how offloading affected the *primacy* effect, which is typically attributed to top-down memory mechanisms (e.g., rehearsal, imagery; Fischler, Rundus, & Atkinson, 1970; Tan & Ward, 2008). The primacy effect was indexed as the memory performance on initial-list items relative to middle-list items and there was a robust reduction in this primacy effect for those in the offloading condition. In contrast, the recency effect (indexed as memory performance for final items relative to that of the middle items) was not reduced in the offloading condition compared with the no-offloading condition. In Experiments 1 and 2, we also directly compared the effect of offloading on the recall of initial and final items and found that the effect of offloading was larger on the former than the latter items. We argued that these findings were consistent with the notion that the lower memory performance observed during offloading is driven by a reduced engagement in top-down memory strategies.

As discussed in Chapter 2, one prediction derived from the notion that offloading involves a reduction in top-down memory strategies is that phenomena which are not solely dependent upon such strategies should be observable even when individuals can offload memory demands to an external store (Kelly & Risko, 2019b). We tested this prediction in Experiments 3 and 4 by examining offloading's influence on the *isolation effect*—the enhanced recall of distinct items among a set of nondistinct items (often called the *von Restorff effect*; Köhler & von Restorff, 1995; von Restorff, 1933). While recall of an isolated item may be enhanced by top-down effort (e.g., rehearsal; Dunlosky, Hunt, & Clark, 2000; Rundus, 1971), it does not appear to be solely reliant on such top-down strategies (Dunlosky et al., 2000; Fabiani & Donchin, 1995). Experiments 3 and 4 (Kelly & Risko, 2019b; Chapter 2) used a within-participants design adapted from Experiments

1 and 2 wherein participants completed five trials, with the first three trials identical to those of Experiments 1 and 2 (Kelly & Risko, 2019a; Chapter 1). The latter two trials were both critical in that no participants had access to their external stores during these trials. On each of these two critical trials, half of the participants were given notice that their external store would be inaccessible (i.e., no-offloading) and the other half were not (i.e., offloading; the order of which were counterbalanced). Finally, to manipulate item isolation, the middle item of every list was perceptually isolated by font colour and size from the remaining set of items.

Using a design adapted to examine the isolation effect (isolate recall minus nonisolate recall) in Experiments 3 and 4, we tested whether the isolation effect was still present for those in the offloading condition. There were robust isolation effects both when individuals expected to rely on internal memory (no-offloading) and when they expected to be able to rely on external memory (offloading). Moreover, there was a trend suggesting that the isolation effect was even larger in the offloading condition than in the no-offloading condition (this finding was significant in one exploratory analysis). Furthermore, there was no appreciable effect of offloading on recalling the isolate, specifically. This is consistent with the notion that phenomena not solely reliant on engagement of top-down memory strategies are less affected by offloading. To approximate the conditions of Experiments 3 and 4 (Kelly & Risko, 2019b; Chapter 2), we include the manipulation of item isolation in the current work and extend the previous work by using a fully between-participants design.

In Experiments 3 and 4 (Kelly & Risko, 2019b; Chapter 2), we also aimed to replicate the observation that offloading led to a reduced primacy effect (indexed in the same manner as in Experiments 1 and 2; Kelly & Risko, 2019a; Chapter 1). However, in each of Experiments 3 and 4, we did not find a robust reduction in the primacy effect (i.e., memory performance for initial items minus that of the middle items) in the offloading condition. However, in an exploratory analysis that examined Trial 4 data, specifically (which approximated the between-participants design used in Experiments 1 and 2), there was a reduction of the primacy effect in the offloading condition (though not as stark a reduction as in the original work of Experiments 1 and 2). In this combined analysis, the offloading manipulation had a larger effect on initial items than on final items (as reported in Experiments 1 and 2). While the overall pattern of results of Experiments 3 and 4 was similar to that of Experiments 1 and 2, it was clearly less robust in Experiments 3 and 4. Thus, further work is needed to put the effect of offloading as a function of serial position on stronger footing. To this end, in the present investigation, we returned to the between-participants design used in Experiments 1 and 2 and examined both the serial position effects and the isolation effect as a function of offloading. Thus, the present investigation provides an attempted replication of Experiments 1 and 2 and extends the examination of the influence of offloading on the isolation effect to a between-participants design.

In extending the previous four experiments (Kelly & Risko, 2019a; Chapter 1; 2019b; Chapter 2), we also wanted to examine the idea that offloading memory demands is unlikely to be an all-or-none phenomenon. That is, the use of an external store does not preclude storing information internally as well. Indeed, this fact reveals a potentially important asymmetry present in extant investigations of offloading memory demands. Specifically, when an external store is unavailable, individuals have to rely solely on their internal memory. In contrast, when the external store is available (the typical offloading condition) individuals can rely on both the external and internal stores, although in practice they likely rely more on the external store. Individuals in the offloading condition need not engage in the behavior of interest (i.e., offloading memory demands) at all. The lower overall memory performance when offloading, observed across investigations, suggests that this is not the case. However, understanding individual differences in the reliance on external stores when available, the factors that influence that reliance, and the resultant influence on memory represent a potentially valuable new direction in research on distributed memory.

In the present investigation, we included a self-report measure at the end of the experiment wherein individuals were asked two questions about their chosen memory strategies throughout the study. Participants were asked: (i) the extent to which they relied on the external store (versus their internal memory) during the first three trials, wherein they had access to the external store and (ii) the extent to which they had *expected* to rely on the external store (versus their internal memory) in the final trial, wherein they had no access to the external store. Inherent in the phrasing of these two questions is a difference in the nature of what they each ask. The paradigm affords what could be interpreted as offloading at encoding/storing (i.e., storing words into the external store for future use and foregoing efforts to remember the items internally) and at retrieval/test (i.e., using the external store to "remember" items to forego efforts to recall items from internal memory). The first question would allow participants to respond while considering their strategies at both of these time points. The second question, focused on the critical fourth trial, prompts participants to report their strategy during encoding only. That is, the emphasis is on how much they had expected they would be able to rely on the external store. Of course, no participants on this trial could rely on the external store at retrieval.

Responses to each of these questions should be differentially related to memory performance. First, provided that relying on an external store represents an effective memory strategy when that store is available (Kelly and Risko 2019a; Chapter 1; 2019b; Chapter 2), reliance on the external store should be positively correlated with memory performance. Those who refer to their external store at retrieval give themselves more opportunity to recall the entire set of items, which is challenging to do if relying on an internal-based memory strategy at retrieval. On the critical fourth trial (i.e., when the external store was actually unavailable), on the other hand, those whose strategy involved relying more strongly on the external store should perform more poorly than those reporting an encoding/storing strategy of internal memory reliance. This prediction falls out of previous findings suggesting that the availability of an external store is associated with the disengagement of intentional efforts at encoding.

In understanding how one allocates memory demands internally and/or externally when external storage is available, we consider different strategies in the use of the external store. One such strategy emerged unexpectedly in Experiments 3 and 4 (Kelly & Risko, 2019b; Chapter 2). Specifically, during encoding, a number of participants indicated in their external store when an item was distinct. They did so by denoting the isolate specifically (e.g., adding an asterisk, indicating its distinct colour—"*red*", etc.). This behavior could reflect an attempt to remember that the isolate was distinct from the other items. This would be an interesting strategy, given that participants were never instructed to remember which item was the isolate or tested on which item was the isolate. This account of their behaviour makes a straightforward prediction on the critical fourth trial: If participants are denoting the isolate within the external store in an effort to enhance the information available to them upon future use of that store, then doing so should be sensitive to the expectation that one will or will not have such access. That is, from this perspective, denoting the distinctiveness of the isolate should be more prevalent when they expect to have access to their external store (i.e., those in the offloading condition).

Alternatively, participants may denote the distinctiveness of the isolate in the store as an effort to enhance future recall, as recording the distinctiveness may act as an elaborative encoding technique by adding additional routes to retrieval (Graf & Mandler, 1984) or increasing the total time of processing for the isolate (Cooper & Pantle, 1967). On this type of account, the expectation of future access to the external store (manipulated on the critical fourth trial) could arguably have the opposite effect to that outlined above. Namely, individuals might be more likely to record the distinctiveness (i.e., engage in more elaborative retrieval) when they know they have to rely on their internal memory (on the critical trial; i.e., those in the no-offloading condition).

To test these hypotheses, we compared whether participants recorded the distinctiveness of an item into their external store as a function of offloading condition. In addition, when considering whether participants denote the isolate in their store as a strategy to enhance encoding, this raises the question of how denoting the distinctiveness of the isolate in the store influences memory for the isolate or other items. To answer this, we investigated whether the recording of distinctiveness in one's external store influences recall of the isolated and nonisolated items (separately analyzed for each offloading condition).

Method

This investigation was preregistered at osf.io/59g3y and we report any deviations from this preregistration.

Participants

Data from 192 participants taking part for course credit were collected and analyzed. This was based on power using proportion tests in R (power.prop.test() function; R Core Team, 2018) and GPower (the Z proportions test: difference between two independent proportions; Erdfelder, Faul, & Buchner, 1996) to detect an isolation effect based on that of earlier work for the no-offloading condition specifically (Experiments 3 and 4; Kelly & Risko, 2019b; Chapter 2).

Stimuli

The five 19-item word list set (available at https://osf.io/e5wrh/) used in Experiments 3 and 4 (Kelly & Risko, 2019b; Chapter 2) was used here. Items were presented randomly within each list, with the 10th item as the isolate (i.e., randomly determined) for half of the participants. Control items were the 10th items for the other half of the participants. Isolates were perceptually distinct (red, size 28 font) from all other items (white, size 18 font). Isolates appeared during each trial for participants in the isolate condition. Lists were counterbalanced across trial position (i.e., first through fourth) such that each list appeared in each trial position equally often. Words were randomized across item positions in each list, including the 10th (isolate) position such that the word serving as the isolate varied.

Procedure

Participants were seated at their own stations, occluded from one another. Stations were equipped with pens, computer with corresponding monitor and keyboard, and a file folder. Participants sat approximately 50 cm in front of their computer monitors and were directed to follow instructions given by the monitor and researcher during the session. Each of the four trials comprised three phases: an encoding phase, a 15-s period without access to their external store, and then a recall phase. A researcher in the room monitored participants to ensure that experimental protocols were properly followed (e.g., that no participants used the external store on the final trial, wherein doing so was not permitted).

Encoding phase. At the start of each trial, participants were presented visually with the list of to-be-remembered words on the monitor. Words were presented one at a time for 3 s with an interstimulus interval of 2.5 s. In the encoding phase, participants were instructed to write down each item as they saw them onto a provided sheet of paper. After the final item, participants placed the written lists into the file folders to remove the external store from their view. Fifteen seconds were given to participants to enclose their written lists in the file folder and to read the instructions for the upcoming recall phase.

Recall phase. In the recall phase, participants were instructed to type the items that they were originally presented in the encoding phase into a text field on the computer with their list as a resource. Participants had access to during the recall phases of the first three trials but not during the fourth trial. Half of the participants were told of this after they completed Trial 3 (no-offloading condition); the other half of participants were not given notice (offloading condition).

Post-task questionnaire. The final task of the study was a short questionnaire consisting of two questions asking participants about their memory strategy during the study. Upon completing the questionnaire, participants were told that "*When we refer to 'your memory' below we are referring to information (i.e., words) stored in your own mind (i.e., not the written list).*" They then proceeded to answeri each question. Question 1 asked: "Please select the option that best describes your recall strategy during the FIRST THREE trials of this study (when you were ABLE to refer to your written lists):". Participants responded by selecting one option from the following scale: (1) I relied EXCLUSIVELY on my written lists, (2) I relied MOSTLY on my written lists, (3) I relied ABOUT EQUALLY on both my written lists and my internal memory, (4) I relied MOSTLY on my internal memory, (5) I relied EXCLUSIVELY on my internal memory, (6) None of the above. Question 2 asked "Please select the option that best describes your recall strategy during the FINAL TRIAL of this study (when you were NOT able to refer to your written list):". Participants responded in the same manner as for Question 1, but with the answers framed in the context of planned memory strategy. For example, Option (1) above was "I *planned to rely* EXCLUSIVELY on my written list".

Results

Data from 22 participants were excluded because they did not follow instructions and/or participated after the preregistered stopping rule (i.e., 192) had been reached. These data were collected partially as a result of the collecting data from multiple participants at once (although participation was individual) in combination with a desire to retain equal counterbalancing (offsetting data loss in the event that a participant needed to be excluded upon viewing their responses). There were 234 instances (across all trials and conditions) wherein participants recalled an item not on their list. 38% of these instances involved participants recalling items from other lists within the study. All confidence intervals reported (included in figures) are bias-corrected accelerated 95% bootstrap confidence intervals (CI_{95}) using 10,000 replications. Effect sizes are reported in terms of generalized η^2 (η_{G}^2; *ez* package in R; Lawrence, 2016) and Cohen's *d* (*lsr* package in R; Navarrow, 2015). Data and analysis code are available at https://osf.io/e5wrh/.

The preregistration specified the use of both ANOVA (*ez* package in R; Lawrence, 2016) and mixed effects logistic regression (logit link function, binomial distribution; *lme4* package in R; Bates, Maechler, Bolker, & Walker, 2015), We opt to foreground the latter in the following reports which include random intercepts for both participant and trial word (noting any deviations from this structure). The results of these two types of analyses are qualitatively the same except when specified otherwise.

The mean proportion of control items and isolates recalled from critical position 10 during the first three trials (wherein participants could rely on their external memory store) were from .97 to 1.00, and .99 to 1.00, respectively. When all items were considered, the mean proportion of items recalled during these initial trials ranged from .98 to .99.

The effect of offloading

A one-way ANOVA was conducted to investigate the effect of offloading (offloading vs. no-offloading) collapsed across all Trial 4 items. There was a significant effect of offloading, such that the mean proportion of items recalled was significantly lower when offloading than when not (offloading: .30; no-offloading: .54), $F(1, 190) = 98.22$, $p < .001$, $\eta_{G2} = .34$.

Isolation effects

We conducted a mixed effects logistic regression with offloading condition (offloading vs. no offloading) and item type (isolate vs. control) as predictors on recall performance. Offloading and isolation did not interact, $b = 0.51$, $SE = 0.70$, $z = 0.73$, $p = .466$, so the interaction was removed from the model. In the model without the interaction, having random intercepts for participants led to a singular fit, therefore we only included random intercepts for trial word. Participants in the offloading condition were not significantly less likely to recall items than were participants in the no-offloading condition (offloading: .49; no-offloading: .63), $b = –0.58$, $SE = 0.36$, $z = –1.63$, $p = .103$. The isolate was significantly more likely to be recalled than the control item (isolate: .74; control: .38), $b = 1.90$, $SE = 0.45$, $z = 4.25$, $p < .001$. While the interaction between offloading condition and item type was not significant, we continue with the preregistered plan of simple effects analyses and, for consistency, we only include random intercepts for trial word. The isolation effect was significant in both the offloading, $b = 1.88$, $SE = 0.51$, $z = 3.70$, $p < .001$, and no-offloading, $b = 1.39$, $SE = 0.57$, $z = 2.45$, $p = .014$, conditions. The mean proportions of recall for isolates and control items by offloading condition are presented in Figure 5. Though not preregistered, the offloading effect was significant in the case of control items, $b = –0.91$, $SE = 0.44$, $z = –2.06$, $p = .039$, but not isolates, $b = –0.33$, $SE = 0.53$, $z = –0.63$, $p = .531$, $BF_{01} = 3.77$. An analogous ANOVA revealed qualitatively the same results, except that those in the offloading condition were significantly less likely to recall items, $F(1, 188) = 4.15$, $p = .043$, $\eta_{G2} = .02$.

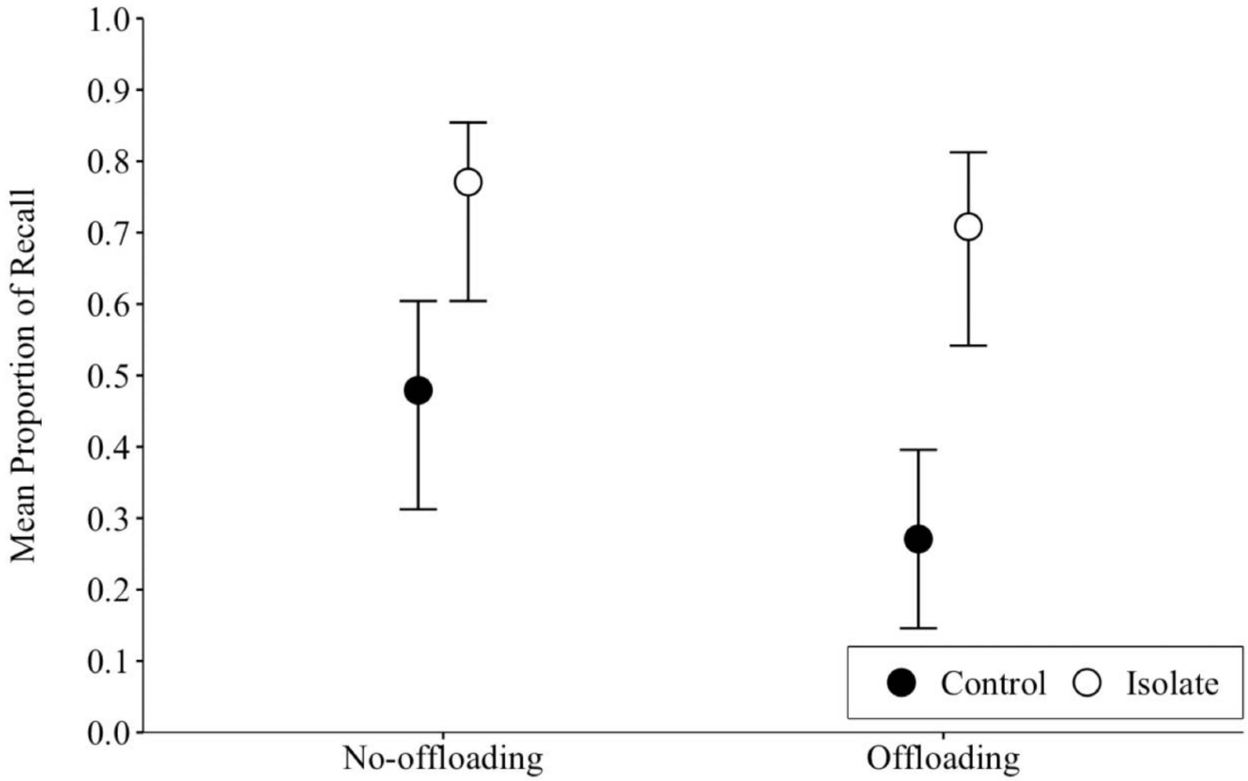

Figure 5. Mean proportions of items recalled by offloading condition and item type. Error bars are bias-corrected accelerated bootstrap 95% confidence intervals using 10,000 replications.

Recording distinctiveness into the store

Forty-eight participants spontaneously indicated that the isolate was distinct when encoding the items into their external stores. We examined the frequency at which participants in the isolation condition indicated the distinctiveness of the isolate on Trial 4 as a function of offloading condition using logistic regression with offloading condition (offloading vs. no-offloading) as a fixed effect. Between offloading conditions, participants were equally likely to indicate the distinctiveness of the isolate in their external store (offloading: .38; no-offloading: .38), $b < .01$, $SE = 0.42$, $z = 0$, $p > .999$.

We also investigated the effect of recording distinctiveness into the external store on recall of the isolate on Trial 4 using logistic regression. There was no effect of indicating the distinctiveness on the likelihood of recalling the isolate (indication: .75; no-indication: .73), b = 0.09, SE = 0.48, z = 0.18, p = .857. We also conducted parallel analyses using logistic regression separately for each offloading condition. This revealed that the recall of words that were not the isolate was also unaffected by whether participants indicated the isolate within their external stores in the offloading condition (indication: .27; no-indication: .26), b < 0.01, SE = 0.06, z = 0.075, p = .940, and no-offloading condition (indication: .50; no-indication: 0.53), b = –0.03, SE = 0.05, z = –0.52, p = .605.

Serial position effects

The following analyses focus on data from participants in the control (nonisolate) condition. Specifically, we examined the recall of the initial two (1 and 2), middle two (10 and 11), and final two (18 and 19) item positions across offloading and no-offloading conditions for only the final two trials (i.e., the critical trials). Note that the preregistration incorrectly specified that serial position analyses would be conducted only on data from the no-offloading-control condition combination. This was in error as we are specifically interested in investigating the effect of offloading on primacy and recency effects. Figure 6 presents the mean proportion of recall as a function of offloading condition and serial position for participants in the control condition.

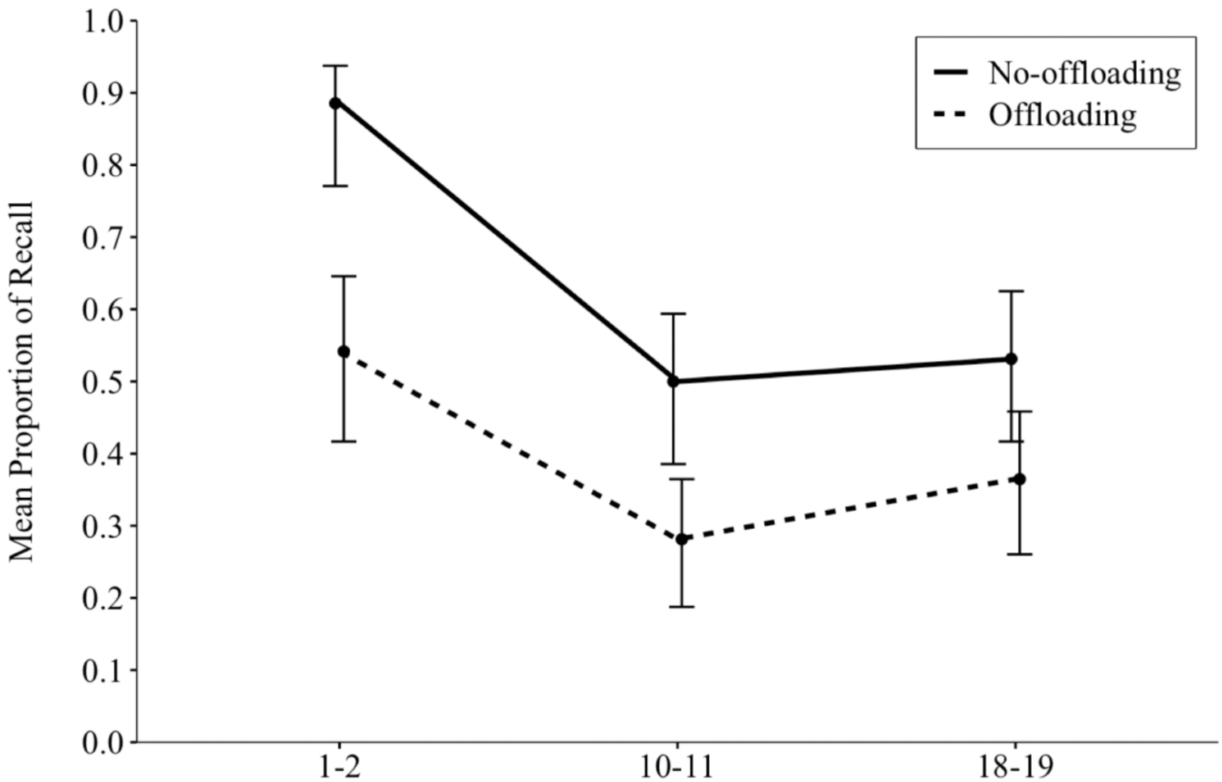

Figure 6. Mean proportions of recall by item position and condition. Error bars are bias-corrected accelerated bootstrap 95% confidence intervals using 10,000 replications.

Primacy. To investigate primacy, we included offloading condition (offloading vs. no-offloading) and position (initial vs. middle) as fixed effects on recall performance. There was a significant interaction between offloading condition and position, $b = –1.07$, $SE = 0.54$, $z = –1.98$, $p = .048$, such that the effect of offloading was larger on initial items than middle items (initial: .34; middle: .22; consistent with the previous experiments; Kelly & Risko, 2019a; Chapter 1; 2019b; Chapter 2). Simple effects analyses determined that the effect of offloading was significant on the recall of both initial and middle items, $b = –2.69$, $SE = 0.81$, $z = –3.32$, $p = .001$; $b = –1.00$, $SE = 0.35$, $z = –2.88$, $p = .004$. In the middle item analysis, the random effect of trial word had to be excluded from the model to prevent a singular fit. An analogous mixed ANOVA with offloading as the between-participants factor found no significant interaction between offloading and position, $F(1, 94) = 1.89$, $p = .172$, $\eta_G^2 = .01$.

Recency. To investigate recency, we used offloading condition (offloading vs. no-offloading) and position (middle vs. final) as fixed effects on recall performance. Offloading condition and position did not interact, $b = 0.26$, $SE = 0.43$, $z = 0.60$, $p = .549$, so the interaction term was removed from the model. Participants in the offloading condition were significantly less likely to recall items than those in the no-offloading condition, $b = –0.81$, $SE = 0.22$, $z = –3.71$, $p < .001$. There was no significant difference in recall performance of middle-list items and final-list items, $b = 0.25$, $SE = 0.21$, $z = 1.16$, $p = .244$.

Self-reported memory strategy

Trials 1-3 versus Trial 4 strategy. Table 3 presents the proportion of individuals by offloading condition for each of the levels of self-reported memory strategy associated in Trials 1–3 and Trial 4. For reference, the response rating ranged from 1: an exclusively external-based memory strategy to 5: an exclusively internal-based memory strategy, with the midpoint response of 3 representing an equal reliance on external- and internal-based memory (see *Method* section for exact wording). One participant in the offloading condition was excluded from the analyses of this section (and Table 3) for not providing a reported strategy for Trial 4 (analyses of this section are not preregistered). We first investigated the effect of offloading on the expected recall strategy of Trial 4 and found that those in the offloading condition were significantly more likely to report an external-based strategy (no-offloading: 4.39; offloading: 2.06), $t(181.90) = 15.04$, $p < .001$, $d = 2.18$. During Trials 1-3, wherein there was no offloading manipulation, there was no effect of offloading condition on reported strategy (no-offloading: 1.80; offloading: 1.69), $t(188.39) = 0.93$, $p = .352$, $d = 0.14$, as expected.

To investigate the relation between the reported strategy during Trials 1-3 and the reported encoding/storing strategy during Trial 4, we conducted three Spearman correlation analyses (not preregistered). The first revealed that, overall, the associated strategy (either reported as their encoding or retrieval/test strategy) during Trials 1-3 was related to the encoding/storing strategy during Trial 4, $r_s = .25$, p < .001, such that those who were more inclined to rely on an external-based memory strategy during Trials 1-3 were also more inclined to do so on Trial 4. The remaining two correlation analyses revealed that the observed overall association between strategies was driven by the offloading condition, $r_s = .56$, $p < .001$, as the no-offloading condition did not show a significant relation between the reported strategy of Trials 1-3 and the expected strategy of Trial 4, $r_s = .06$, $p = .586$.

Trial strategy predicting memory performance. We tested the relation between offloading condition (offloading vs. no-offloading) and self-reported expected memory strategy on Trial 4 (1: exclusively external to 5: exclusively internal) on the recall performance on Trial 4, using logistic regression. Offloading condition and memory strategy interacted, such that the participants in the offloading condition had a stronger relation between reported strategy and recall performance than did those in the no-offloading condition, $b = 0.04$, $SE = 0.02$, $t = 2.16$, $p = .032$. Specifically, for participants in the offloading condition, those reporting a greater reliance on the external store were less likely to recall items, $b = 0.07$, $SE = 0.01$, $t = 5.42$, $p < .001$. This relation was not as robust for participants in the no-offloading condition, $b = 0.03$, $SE = 0.02$, $t = 1.69$, $p = .094$.

We also examined the relation between self-reported memory strategy in the first three trials (1: exclusively external to 5: exclusively internal) and recall performance in the first three trials. Note that the first three recall trials are those wherein participants had access to their external stores at recall. The relation between self-reported memory strategy and performance was significant, such that those reporting less reliance on the external memory store had significantly lower recall performance on the first three trials, $r_s = -.27$, $p < .001$.

Table 3.

Proportion of individuals self-reporting each level of memory strategy used in Trials 1-3 (Question 1) and expected to use in Trial 4 (Question 2).

	Trials 1-3					Trial 4				
	1	2	3	4	5	1	2	3	4	5
Offloading	.48	.38	.09	.03	0	.41	.36	.09	.07	.06
No-offloading	.39	.46	.13	.04	0	.02	.08	.05	.22	.64

Note. The scale is: 1: exclusively external, 2: mostly external, 3: equally external and internal, 4: mostly internal, 5: exclusively internal. For Trials 1-3, participants in the offloading condition would not be expected to differ in their responses from those in the no-offloading condition, as no manipulation of offloading had occurred. Proportions may not add to 1.00 due to rounding.

Exploratory

The analyses to follow were not preregistered.

Overall. The following analyses include data from all participants, including those in the isolation condition. To do so, the middle items are considered to be items in the 10^{th} and 11^{th} positions of a list (rather than those in the 9^{th} and 10^{th} positions; c.f. the main analyses). The mixed effects logistic regression analyses to follow include random slopes for presented word and participant on recall performance, and only deviations from this structure due to singular model fits are mentioned. Each analysis was followed up with an analogous ANOVA. Only cases where the results of the ANOVA did not qualitatively align with those of the regression are stated.

Primacy. When including all participants, a mixed effects logistic regression with offloading condition (offloading vs. no-offloading) and item position (initial vs. middle) as fixed effects on recall performance revealed a significant interaction, $b = –.87$, $SE = 0.35$, $z = –2.48$, $p = .013$. Specifically, the effect of offloading was significantly larger for initial items than for middle items, which is consistent with the previous experiments (Kelly & Risko, 2019a; Chapter 1; 2019b; Chapter 2). The effect of offloading on recall performance was significant for both initial items, $b = –2.34$, $SE = 0.44$, $z = –5.34$, $p < .001$, and middle items, $b = –1.07$, $SE = 0.25$, $z = –4.23$, $p < .001$ (these latter two analyses contained random intercepts for participants only to prevent singular fitting).

Recency. When including all participants in examining recall performance using mixed effects logistic regression, with fixed effects of offloading condition (offloading vs. no-offloading) and item position (middle vs. final), there was no significant interaction between condition and position, $b = 0.46$, $SE = 0.31$, $z = 1.47$, $p = .141$, so this was removed from the model. There was a significant main effect of offloading condition, $b = –0.81$, $SE = 0.17$, $z = –4.86$, $p < .001$, but no main effect of position, $b = –0.19$, $SE = 0.16$, $z = 1.24$, $p = .215$,

Initial versus final. We also directly compared the recall performance of initial items and final items using mixed effects logistic regression with item position and offloading condition as fixed effects. The interaction between offloading condition and item position was significant such that the effect of offloading was larger for initial items than for final items, $b = 1.32$, $SE = 0.34$, $z = 3.90$, $p < .001$. There was an effect of offloading in initial, $b = –2.34$, $SE = 0.44$, $z = –5.34$, $p < .001$, and final items, $b = –0.65$, $SE = 0.25$, $z = –2.62$, $p = .009$.

Comparing findings across investigations. Given the similarity in methods across the current investigation and Experiments 3 and 4 (Kelly & Risko, 2019b; Chapter 2) in examining the effect of offloading on isolate recall, Figure 7 presents the mean recall proportion as a function of item type and offloading condition for Experiments 3 and 4, the current investigation, and collapsing across these two investigations. The presented data are only those of the critical trials, wherein participants did not have access to their lists upon recall. Isolates presented in Figure 7 were always of the 10th word position within each list. In Experiment 3, control items were those in positions 8, 9, 11, and 12. In Experiment 4 and the current work, both control and isolate items were those presented in word position 10. In the current investigation, the interaction between offloading manipulation and item type did not reach statistical significance. This was also the case in Experiments 3 and 4 (although this interaction was significant when adjusting the control items used in an exploratory analysis). However, the results are qualitatively consistent across the different investigations (see Figure 7). That is, there is a clear isolation effect in both the no-offloading and offloading conditions with the effect appearing slightly smaller in the latter condition.

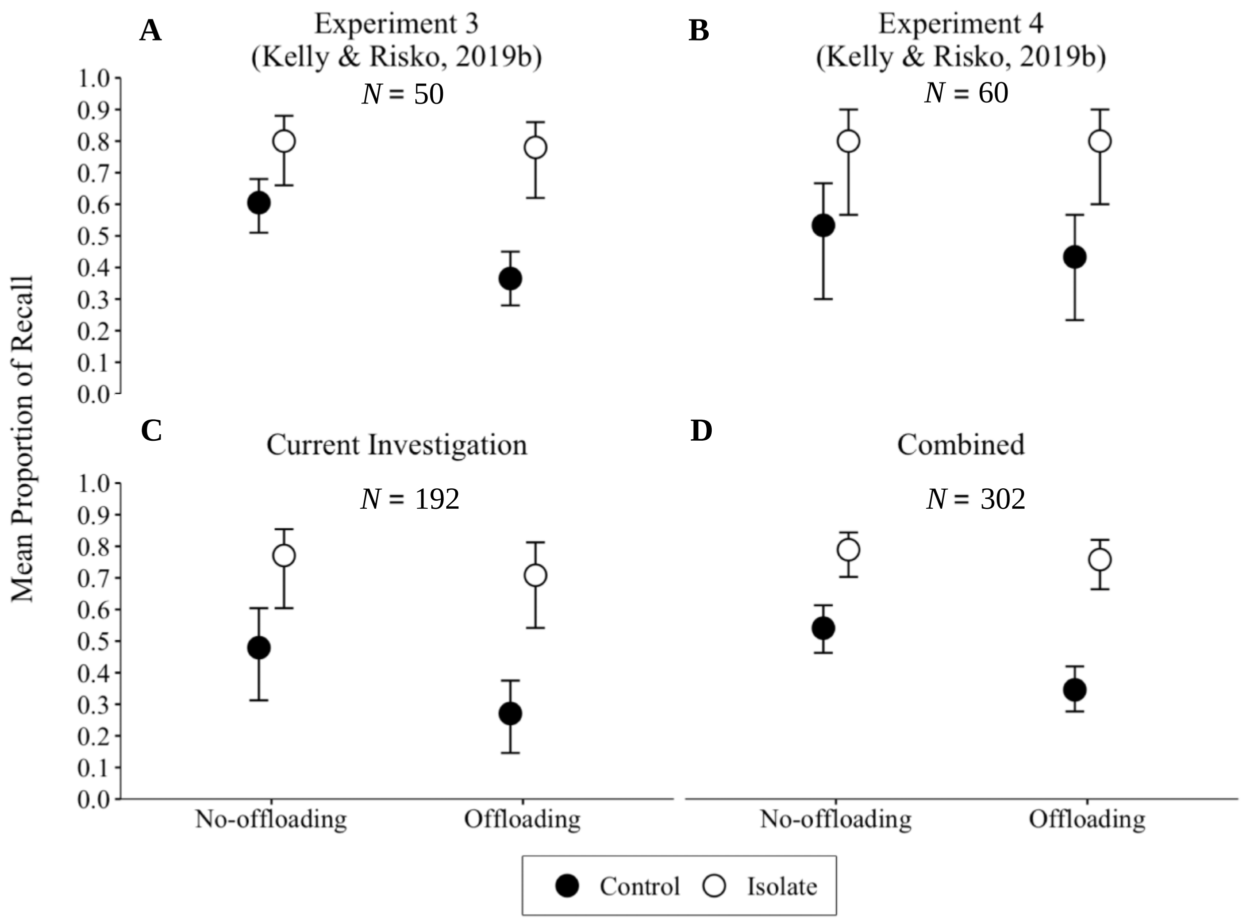

Figure 7. Mean proportions of items recalled by offloading condition and item type, by investigation (Panels A through C) and collapsed across investigation (Panel D). Error bars are bias-corrected accelerated bootstrap 95% confidence intervals using 10,000 replications.

Figure 8 presents the mean recall proportion as a function of item position and offloading condition across Experiments 1 and 2 (Kelly & Risko 2019a; Chapter 1), Experiments 3 and 4 (Kelly & Risko 2019b; Chapter 2), the current investigation, and collapsing across these investigations. Additionally, Figure 8 presents the difference in the mean recall proportion between the offloading and no-offloading conditions as a function of item position for each investigation. Overall, the patterns across experiments are relatively consistent. In the no offloading condition, there is a pronounced primacy effect and no recency effect. In the offloading condition, overall memory performance is clearly lower and the effect is more pronounced in earlier serial positions. The serial position curve in the offloading condition appears to have a less pronounced primacy effect and unlike the no offloading condition, possibly a small recency effect overall. The latter was particularly pronounced in Experiments 1 and 2. These trends are made even clearer by the mean difference between offloading and no-offloading, which generally decreases as item position increases. This is a consistent pattern across the investigations but was much more pronounced in Experiments 1 and 2.

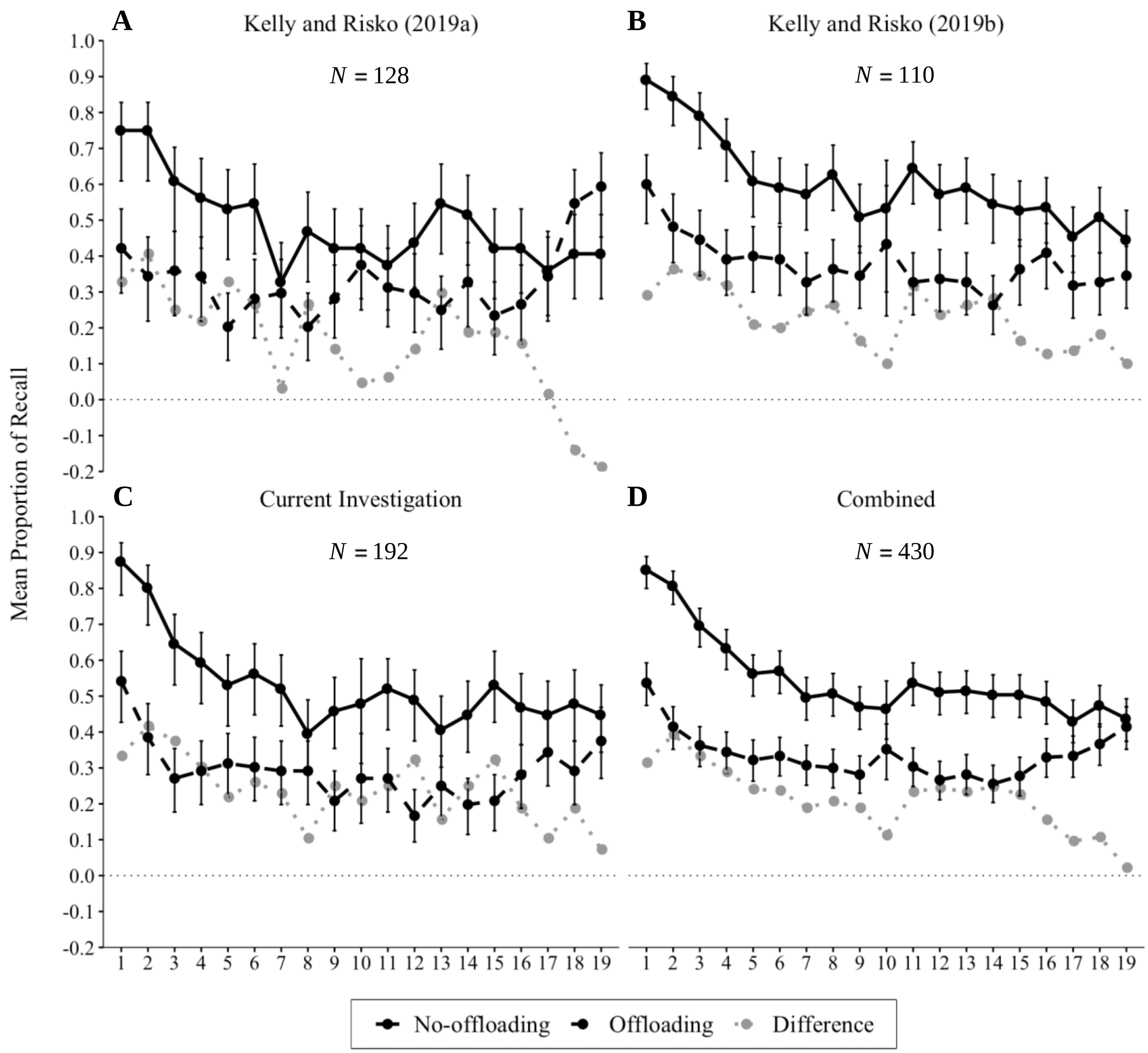

Figure 8. Mean proportions of items recalled by offloading condition and item position and the offloading effect by item position by investigation (Panels A through C) and collapsed across investigation (Panel D). For uniformity, item position 20 is excluded (only applicable to Experiments 1 and 2; Kelly & Risko 2019a; Chapter 1). Isolate recall was also excluded, thereby reducing the number of observations for item position 10 by 80 in Panel B, 96 in Panel C, thus by 176 for Panel D. Error bars are bias-corrected accelerated bootstrap 95% confidence intervals using 10,000 replications.

General Discussion

A number of investigations have found that when we have the ability to offload information to an external store, we later show poorer internal memory for that information, in general (Eskritt & Ma, 2014; Kelly & Risko 2019a; Chapter 1; 2019b; Chapter 2; Sparrow, Liu, & Wegner, 2011). In the current work, we sought to deepen our understanding of this poorer memory performance by replicating and extending the research of the previous four experiments. To this end, we examined the influence of offloading on memory for distinct information (via the *isolation effect*; e.g., Dunlosky et al., 2000) and on serial position effects. We also examined the frequency of participants spontaneously denoting the distinctiveness of the isolate within their store at encoding, determining whether this frequency differed by offloading condition and whether denoting the isolate affected the recall of the isolate or of the nonisolated items. Finally, we investigated whether offloading affected the reported memory strategy used at recall, in addition to whether the reported recall strategy affected memory performance. We discuss these findings in turn.

Offloading and the Isolation effect

The isolation effect on recall performance was robust in both the offloading and the no-offloading conditions, as also reported in Experiments 3 and 4 (Kelly & Risko, 2019b; Chapter 2). In fact, we found that the magnitude of the isolation effect on recall was statistically no different between the offloading and no-offloading conditions. This is also what was found in both Experiments 3 and 4. The current investigation is consistent with the previous findings, and this general trend has been present in each experiment conducted to date (see Figure 7). Thus, the same general pattern has been reported across a completely within-participants (i.e., Experiment 3), mixed (i.e., Experiment 4), and completely between-participants design (the current investigation). These results are consistent with the notion that the mechanisms underlying the enhanced recall of distinct information are relatively immune to the effects of offloading. Indeed, there was an isolation effect under offloading conditions that was at least as large in magnitude as when relying on internal memory.

We also extended the examination of isolation effects during offloading by investigating why individuals denoted the distinctiveness of the isolate within their external stores. Of the participants in the isolate condition (n = 96), 50% recorded the distinctiveness of the isolate within their store at encoding. The rates of such behaviour were equal between offloading and no-offloading conditions, despite differing in their expectations of later using the external store during recall. Our results are inconsistent with both hypotheses articulated in the introduction—that is, that participants denoted the isolate in the external store for future reference, in which case this behaviour should be more prevalent in the offloading condition, or that they did so as a kind of elaborative encoding strategy, in which case it should be more prevalent in the no-offloading condition. In addition, while not a prediction of the latter account, there were no differences in recall performance between those who denoted the isolate and those who did not.

Although we found no evidence supporting the hypotheses outlined in the introduction, it remains possible that different subsets of individuals are each engaging in the strategies described, but that the opposing effects cancel out at the aggregate level. Another alternative, consistent with the present results, is that participants interpreted the task as requiring that they denote the isolate in their external store. From this perspective, denoting the isolate would not be expected to be related to whether the participant was expecting future access to their external store (i.e., be sensitive to the offloading manipulation). More insight for why participants denoted the isolate in their store could be obtained by asking them in a post-task question.

Offloading and Serial Position Effects

In general, our current findings are consistent with the view that individuals are less inclined to engage in top-down memory strategies under offloading conditions. We tested the effect of offloading on the primacy effect by investigating the interaction between offloading condition (offloading vs. no-offloading) and item position (initial vs. middle). We found a reduced primacy effect in the offloading condition compared with the no-offloading condition, as reported in previous experiments (Kelly & Risko, 2019a; Chapter 1; 2019b; Chapter 2). However, this effect is not as robust as originally found in Experiments 1 and 2 (Kelly & Risko, 2019a; Chapter 1). There was a significant interaction when using the mixed effects logistic regression, but not with the analogous mixed ANOVA. This interaction was also significant in the exploratory comparison of primacy effects as a function of offloading condition (i.e., when all participants were included, even those in the isolate condition), such that the primacy effect was smaller for those in the offloading condition. If we consider the true size of the effect of offloading on memory to be that which is approximated by the majority of investigations, then it seems more plausible that the effect of offloading on the serial position curve is more similar to that found in the current report, which is more consistent with Experiments 3 and 4 (Kelly & Risko, 2019b; Chapter 2; see Panels B and C of Figure 8). Moreover, these consistencies are observed despite the methods of the current investigation being identical to those of Experiments 1 and 2, as both involved fully between-participants designs.

When examining the potential influence of offloading on the recency effect, there was little evidence of a recency effect, even when considering all participants in the exploratory analyses. When comparing this result to that of Experiments 1 and 2 (Kelly & Risko, 2019a; Chapter 1); see Panel A of Figure 8), our current findings differ. Experiments 1 and 2 found that there was a recency effect across most of the conditions, and even reported a small benefit of offloading on the recency effect when collapsing across both experiments. Interestingly, virtually no recency effects or trends of offloading benefitting final items were found in Experiments 3 and 4 (Kelly & Risko, 2019b; Chapter 2), nor supported statistically in the current report (although, Figure 8 seems to suggest a recency effect might be present). Given that the time between the final item encoded and the onset of free recall is ~14 s, it might be surprising by some standards that there were recency effects at all in Experiments 1 and 2 (e.g., Howard & Kahana, 1999).

One potentially significant difference between Experiments 1 and 2 and the remaining experiments are the manner in which stimuli were presented during study/encoding. Specifically, Experiments 1 and 2 involved the presentation of auditory stimuli and an interstimulus interval of 4 s. In contrast, Experiments 3, 4, and 5 involved the presentation of visual word stimuli with an interstimulus interval of 2.5 s. The combination of the different modes of delivery of stimuli with the varied interstimulus intervals could contribute to the discrepancy between studies. For example, it is recognized by many that auditory stimuli often enhance recency effects during recall—known as the *modality effect* (e.g., Watkins, Watkins, & Crowder, 1974). That being said, it seems unlikely that the mode of stimulus presentation can explain why a large reduction of the primacy effect under offloading conditions was found only in Experiments 1 and 2 because in all investigations, participants wrote down each study word in order to offload. The differential recency effects and varied influence of offloading on the primacy effect across investigations are possibly indicative of varied offloading strategies across investigations. Offloading behaviour may vary between and within individuals, much like other memory strategies, affecting the observed serial position curves (e.g., Unsworth, Brewer, & Spillers, 2011).

If we consider the magnitude of the primacy effect as an index of the degree to which one engages in intentional top-down memory strategies and consider the recency effect as relatively independent from such engagement, then the present findings suggest that offloading specifically affects this engagement in intentional efforts at remembering. This is consistent with the previous findings of Experiments 1 through 4 (Kelly & Risko, 2019a; Chapter 1; 2019b; Chapter 2) and, taken together, the experiments suggest that when we are able to offload memory demands, we are less likely to make intentional efforts to store the offloaded information internally.

Self-reported strategy

Consistent with the previous idea that offloading may vary within and between participants is the simple fact that offloading is unlikely to be an all-or-nothing strategy (see Table 3). As alluded to in our introduction, participants in our paradigm are able to store the to-be-remembered information both internally and externally when offloading is an available strategy (i.e., in the offloading condition). We found on Trial 4, consistent with the manipulation, that participants in the offloading condition were significantly more likely to expect to use an external-based strategy than were those in the no-offloading condition. In a similar vein, on Trials 1-3, individuals reported relying heavily on the external store in general. Also consistent with the manipulation on Trial 4, participants in the offloading condition tended to report the same strategy when reporting their encoding strategy for Trial 4, and their strategy of Trials 1-3. Critically, for participants in the offloading condition on Trial 4, reporting an encoding strategy consisting of a greater reliance on the external store was associated with lower recall performance. This is consistent with the notion that when offloading is an available strategy, there is a reduction in the ability to recall the offloaded information when unexpectedly without the store, compared to when not expecting to offload (Eskritt & Ma, 2014; Kelly & Risko 2019a; Chapter 1; 2019b; Chapter 2; Sparrow, Liu, & Wegner, 2011).

Conclusion

In the present investigation, we found that the effect of offloading was larger for initial than final items with the isolation effect remaining intact. This is consistent with the explanation that offloading leads to a reduction in top-down intentional efforts to remember while seemingly unaffecting phenomena not solely dependent on such top-down mechanisms.

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