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Downstream Consequences of Collaborative Recall:

Testing the Influence on New Learning and Protection of Original Learning

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Code Availability: Code to reproduce all analyses is available on OSF: https://osf.io/3m2jk/?view_only=a132c0398c57453bb12523b2b2d35c9b

Abstract

Collaboration influences memory during group recall (e.g., collaborative inhibition) and downstream, impacting individual recall (e.g., retrieval gains) and memory convergence (e.g., collective memory) following the interaction. The current study tested the scope of this downstream reach as we examined whether prior collaborative recall, compared to individual recall, improves subsequent learning. Further, we assessed whether group recall protects original learning, that is, if collaboration helps individuals distinguish learning episodes and if post-collaborative effects persist even as new learning occurs. In two experiments, participants worked individually or in collaborative groups to recall a word list. Next, participants studied a new list of words that were semantically related to the original list before recalling the most recently studied list (non-cumulative recall; Experiment 1) or both lists (cumulative recall; Experiment 2). Interestingly, collaborative and individual retrieval influenced subsequent learning of new material similarly. However, collaboration protected original learning; former collaborators recalled fewer prior-list intrusions (Experiment 1) and they were better at identifying when words appeared on the original list (Experiment 2). Moreover, post-collaborative retrieval gains and collective memory for the originally studied material persisted as new learning occurred (Experiment 2). These novel findings suggest that while collaborative retrieval may not readily improve subsequent learning compared to individual retrieval, group recall confers a downstream source-monitoring advantage and post-collaboration effects are resilient in the face of subsequent learning. We discuss how these findings align with relevant theoretical accounts that emphasize the importance of contextual dynamics, and highlight the potential for more applied research on this topic.

Keywords: collaboration, testing effects, collective memory, intrusions, source-monitoring, new learning

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Life is replete with dynamic social interactions. In a single day, one might need to navigate a string of meetings and attend several classes before heading to a hands-on workshop and, if energy reserves allow, a lively book-club discussion. The interactions in this busy day are connected by at least two common threads. First, these interactions often include some form of collaborative retrieval; people may work together to recall some relevant material. Second, each of these situations may introduce new, to-be-remembered information. These common threads raise interesting questions about the nature of memory and learning in dynamic social contexts. On the one hand, questions arise relating to the impact collaborative recall has on what and how groups remember, both during and following the interaction. Considerable research has been directed to examine this set of questions (Rajaram et al., 2024). On the other hand, questions emerge about how the initial learning context – specifically when it involved collaborative recall – might influence subsequent learning, and how previously learned material is retained as one encounters new, to-be-remembered material. This latter set of questions motivated the current study.

Collaborative Recall Influences Memory

A collaborative memory experiment typically includes an individual study phase followed by one or more recall phases completed alone or in a group (B.H. Basden et al., 1997; Rajaram & Pereira-Pasarin, 2010; Weldon & Bellinger, 1997). For a fair comparison, collaborative group performance is compared to nominal "group" performance, computed by pooling responses from an equal number of participants that worked alone and counting the number of non-redundant targets recalled. For example, in a nominal group consisting of three participants (P1, P2, P3), if P1 and P2 both recall "apple," it is only counted once toward the group score. A well-replicated effect during group recall is collaborative inhibition; collaborating groups typically recall less than equal sized nominal groups. An intuitive explanation for this effect is *social loafing* (Latané et al., 1979) – participants within collaborative groups contribute less because they can rely on group members, with the net effect being reduced group recall. This explanation has been ruled out by tweaking design features and strongly incentivizing individual input (e.g., Weldon et al., 2000). Instead, *retrieval strategy disruption* is often invoked to account for this effect (see Marion & Thorley, 2016, for a meta-analysis; see Barber et al., 2014, and Abel & Bäuml, 2017, for additional accounts). This explanation posits that individuals have a preferred, idiosyncratic retrieval strategy, and in a group context, a strategy clash occurs across collaborators, lowering group performance. At the same time, the act of collaboration is a dynamic one – while group members work together, they may cue each other (i.e., cross-cueing; Meudell et al., 1995), though the extent to which this occurs can be difficult to quantify (see Rajaram et al., 2024, for a discussion).

In addition to the collaborative inhibition effect, two downstream consequences of collaboration are of interest here. First, following group recall, former collaborators typically experience a rebound, recalling more than their nominal counterparts (e.g., Blumen & Stern, 2011; Congleton & Rajaram, 2011; Weldon & Bellinger, 1997). Re-exposure to material during collaboration that would have otherwise been forgotten, combined with the freedom to rely more on their idiosyncratic retrieval strategy, provides this downstream advantage (see Marion & Thorley, 2016, for a meta-analysis). In this study, we will refer to this outcome as *retrieval gains.* Second, collaborative recall leads to the emergence of *collective memory*; former members of a collaborative group reliably recall more overlapping information, and they often do so by producing responses in more similar orders compared to nominal "group" members (e.g., Abel & Bäuml, 2023; Choi et al., 2017; Congleton & Rajaram, 2014; Greeley et al., 2022; Greeley et al., 2023; see Greeley & Rajaram, 2023, for a review). In essence, collaboration boosts later individual performance and has a synchronizing effect on later individual recall, homogenizing what people recall and aligning how memories are reconstructed.

The current study is concerned with three open questions relating to the downstream reach of collaborative recall. First, does prior collaborative recall influence the subsequent learning of new, related material? Based on the post-collaborative effects just noted, it is reasonable to predict some positive influence on the future learning of new, related information. We elaborate later on this reasoning. Second, does the process of collaboration confer source monitoring benefits that may aid in the discrimination of old and subsequently learned material? Rather than constituting a direct effect of collaboration on subsequent learning, such a possibility is more akin to *protection*; collaborative recall, compared to individual recall, may provide additional contextual cues that guard against interference and help one determine when material was actually learned. Third, do the established consequences in post-group-recall, specifically retrieval gains and collective memory, persist in the face of new learning? Once again, these effects are of interest not as a direct influence of collaboration on new learning; instead, evidence for retrieval gains and collective memory would highlight the *persistence* of post-collaboration effects that occurred in prior learning.

Collaborative Recall and Subsequent Learning: Potential Mechanisms

To address the questions just described, we draw inspiration from recent work on *test-potentiated new learning*. In individual recall, the classic testing effect refers to the finding that being tested on material, via recall or through some other means, generally leads to better long-term retention of that material than re-studying (McDermott, 2021; Roediger & Karpicke, 2006a; Roediger & Karpicke, 2006b). More relevant to the current study are the procedures and theoretical accounts associated with test-potentiated new learning, also known as the forward testing effect or the interim test effect (Szpunar et al., 2008; Wissman et al., 2011; see Chan et al., 2018, for a meta-analysis). Much ongoing work attempts to explain test-potentiated new learning effects with significant progress being made (Pastötter & Bäuml, 2014; Yang et al., 2018). Our own interest was not in examining this phenomenon, but we consider it here because it provides the control condition of individual recall in our methodology that we designed to test collaborative recall effects. Further, some theoretical insights to emerge from this literature provide useful reference points when considering the consequences of collaboration on subsequent new learning.

A typical experiment investigating test-potentiated new learning starts with a study phase. Next, depending on condition, participants may restudy the same material or receive a test of some kind (e.g., free recall). Then participants study some *new* material, which is likewise followed by a re-study phase or a test. The number of these study-test cycles varies, but the key is that new, to-be-remembered material is being introduced throughout the procedure. At some point, all participants, irrespective of condition, receive a critical test on the just studied material, with many experiments culminating in a final cumulative recall of all studied material encountered throughout the procedure (Yang et al., 2018; see Chan et al., 2018, for a meta-analysis). This growing literature suggests that retrieval practice boosts subsequent learning compared to re-study. As noted earlier, a full review of the theoretical accounts associated with test-potentiated new learning is beyond the scope of this investigation as the present study was not designed to interrogate test-potentiated new learning itself or the mechanisms associated with these effects.[1] However, as a test of our question about impact of prior collaborative recall on later new learning entails repeated study-test cycles in both the experimental and control conditions, two accounts from this literature are relevant to consider with respect to the potential cascading impact of collaborative retrieval.

First, Szpunar et al. (2008) explained test-potentiated new learning in terms of *context change*; testing affords a context shift between study phases, which largely releases participants from proactive interference. That is, previous items are less likely to interfere with the learning of new items when study phases are separated by a different (i.e., test) context compared to restudy. Applying this account in the current case of comparing collaborative recall to individual recall, collaboration ought to provide starker context shift which could benefit subsequent learning. Specifically, collaborating involves individual recall *and* processing responses produced by other people. While the underlying context is similar between conditions (i.e., retrieval is a shared feature), collaborating group members may benefit from the contextual specificity afforded by group recall. Similarly, if covert retrieval occurs during subsequent encoding, former collaborators could benefit from the additional social cues as new material is integrated, as this additional information could increase the contrast between old and new material (e.g., see Wahlheim, 2015, for a similar argument in a cued-recall paradigm). Covert retrieval, in contrast to overt retrieval, refers to silently retrieving previously studied material (see Smith et al., 2013, for an investigation of covert retrieval in the context of retrieval practice). In the current study, such covert retrieval (e.g., thinking of a previously studied word "dog" when later studying the word "cat") could occur following collaborative recall or individual

[1] A proper test-potentiated new learning experiment requires re-study controls, and current theoretical accounts of the phenomenon are not necessarily mutually exclusive (see Chan et al., 2018, for a review and a meta-analysis). As we were interested in comparing the influence of collaborative recall relative to individual recall, our study was not designed to test the comparisons focused on test-potentiated learning or aimed at interrogating their accounts.

recall, and could occur during subsequent study (e.g., when studying a new related list) or when engaging in overt retrieval (e.g., covertly retrieving but not reporting old material). However, former collaborators have access to social, contextual information to which nominal individuals are not privy, and could therefore bring that information to bear upon the task. Regarding our first question, this additional contextual specificity could potentially afford a better separation between study episodes and thus improve subsequent new learning. Regarding our second question, former collaborators could benefit from the social associations formed during group recall that provide source memory advantages for discriminating old and newly learned material (e.g., "My partner recalled *apple*, so *apple* was on the first list I learned"; also see Pierce et al., 2017). Practically speaking, this would aid in error-pruning downstream, with former collaborators recalling fewer prior-list and potentially extra-list intrusions (e.g., Ross et al., 2004; see Rajaram et al., 2024, for a review). That is, during collaboration, participants often benefit from explicit correction from group members – a response can be suggested to the group and filtered (pruned) out of the group recall product if caught. It is possible a similar process could unfold downstream – covertly retrieved material could be rejected prior to overt recall because it is associated with the more distinctive group recall.

Another test-potentiated new learning account argues that interim recall attempts enhance subsequent learning because these tests provide an opportunity to adapt encoding strategies (Chan et al., 2018) – the *strategy change* account. As it is well established that collaborative recall has a disruptive influence on individual retrieval strategies (B.H. Basden, 1997; Weldon & Bellinger, 1997; see Marion & Thorley, 2016, for a meta-analysis), this correspondence provides some basis for forming predictions about the persistence of classic post-collaborative recall findings in the face of new learning. Specifically, in the context of our third question, the strategy change account combined with recent research suggesting that collaborative recall synchronizes retrieval strategies (Greeley & Rajaram, 2023, for a review) points to the possibility that collective memory and collective organization would in fact persist and perhaps transfer to subsequently learned material. These possibilities are critical to consider when speculating about the advantages or disadvantages of collaborative recall in educational settings, within which learning episodes often occur in succession (e.g., back-to-back classes) and in collaborative settings (e.g., group learning exercises). Importantly, we drew inspiration from the strategy change account as it pertains to the transfer of collective memory and organizational outcomes to new learning. Whereas the possibility that collaborative recall provides a starker context shift than individual recall could fuel a downstream learning advantage, the notion of strategy change is relevant here because former collaborators could approach new, related material in a more similar fashion than nominal group members that never interacted. This could manifest in the way former group members gravitating toward overlapping new material (collective memory transfer). Critically, such synchronicity could arise independent of any potentiation in downstream recall. Likewise, the fact that collaborators may experience retrieval strategy disruption during collaboration may not necessarily be detrimental to subsequent learning; so long as retrieval still takes place, it is unclear whether disrupted retrieval strategies (induced by collaboration) would actually impair the learning of new material compared to the un-disrupted. On the contrary, we know from prior work that once group members leave the group, recall performance is recovered and often boosted, even though they retain elements of their group-level retrieval strategies (e.g., Congleton & Rajaram, 2014; Greeley et al., 2023).

To our knowledge, no research to date has ~~considered the theoretical accounts associated with test-potentiated new learning to~~ explored the effects of collaborative recall on new learning.

In taking this step, we draw inspiration from the theoretical mechanisms discussed above to develop informed, novel hypotheses regarding the topic of interest in this study - the relationship between collaborative recall and subsequent learning. Importantly, these mechanisms provide considerable value in terms of guiding predictions given the study-test cycles in both the experimental (collaborative recall) and control (individual recall) conditions.

The Present Study

The present study is concerned with two overarching possibilities. First, we examined whether collaborative recall has any direct influence on the subsequent learning of new, related material. Specifically, we were interested in two ways this influence could manifest – quantity and strategy. On the one hand, collaborative recall and the contextual shift it affords could provide an advantage over individual recall and improve subsequent learning. This is a question of downstream learning *quantity*. On the other hand, irrespective of whether or not collaboration confers a new learning benefit, the synchronizing effect collaboration has on retrieval strategies could transfer to new learning, giving rise to collective memory for the new material studied following group recall. This is a question of downstream learning *strategy*. While both these possibilities would constitute an effect on new learning, they are distinct in their influence.

Second, we examined the fate of what was originally learned. Whether or not prior collaborative recall impacts subsequent learning, the arrow-of-influence could just as well point in the opposite direction; learning new, related material following collaborative recall could have a unique impact on how well previously learned and newly encountered material is distinguished or retained. This is a question of original learning *protection*, a broad notion that underscores much research on the topic of retroactive interference (see Dewar et al., 2007, for a historical overview). Such a protective influence, like the new learning outcomes described above, could manifest in several ways. Specifically, collaborative recall could reduce downstream memory errors, especially prior-list intrusions, provided a non-cumulative final recall task is used. If former collaborators do prove more adept at such downstream error-pruning, this protection could be examined further by leveraging more direct tasks (e.g., source judgments). Related to notion of protection is the matter of whether post-collaborative retrieval gains and collective memory – for the originally learned material – continue to emerge as subsequent learning occurs. This is a question of original learning *persistence*. Rather than being tied to how well learning episodes are separated or partitioned, the notion of persistence in the current study relates to the integrity of the original learning, and specifically the durability of post-collaborative effects.

Across two experiments, we addressed each of the possibilities noted above. In Experiment 1, we examined the impact of prior collaborative recall on the subsequent learning of new, related information using a non-cumulative final recall task. In Experiment 2, we examined this possibility using a cumulative recall task, providing more room for collaborators to rely on strategies they may have adopted during group recall. We also examined whether collaborative recall protects original learning even as new learning occurs. In Experiment 1, we leveraged our use of a non-cumulative final recall task to assess the downstream error-pruning of prior-list and extra-list intrusions. In Experiment 2, given our use of the cumulative recall task and in light of Experiment 1 results, we included a source-judgment task to index how well former collaborators distinguish learning episodes. Finally, the inclusion of a cumulative recall task in Experiment 2 provided the ideal circumstance to examine whether retrieval gains and collective memory for original learning persist even as new learning occurs.

Experiment 1

In Experiment 1, we examined the extent to which collaborative recall – relative to individual recall – influences the subsequent learning of new, related material in a *non-cumulative* final recall context. In doing so, we aimed to replicate collaborative inhibition (e.g., Greeley et al., 2022) while assessing three novel questions. First, we asked whether prior collaborative retrieval attempts would affect subsequent learning, a possibility implied by the context change account drawn from test-potentiated new learning. Second, we examined the extent to which former collaborators converge on recalling more overlapping new information (studied and recalled after collaborating), essentially assessing whether collective memory effects transfer to subsequent learning contexts. This possibility, follows from the strategy change account drawn from test potentiated new learning and the collaborative recall consequences of synchronized strategies, together suggesting that subsequent learning may likewise be synchronized. Third, we examined memory intrusions, specifically whether prior collaborative retrieval attempts provide an advantage over individual recall attempts for rejecting (and not reporting) prior-list and/or extra-list intrusions when the new target material is learned following collaboration. Again, this pattern would be implied by the context change account often featured in work focusing on test-potentiated new learning.

Hypotheses

We formed a number of hypotheses relating to group and individual memory performance. ~~Core hypotheses are listed here while additional hypotheses are included in the Supplemental Materials.~~

1. *Replication*: Collaborative groups would recall less than nominal control groups (i.e., collaborative inhibition, although this effect may weaken with repeated collaborative recalls; e.g., see Congleton & Rajaram, 2014, and Blumen & Rajaram, 2008).

2. *Novel*: Initial collaborative retrieval, compared to individual retrieval, would benefit the subsequent learning of new, related material (as indexed by memory performance).
3. *Novel*: Former collaborators, compared to those that never collaborated, would collectively recall more overlapping new material (studied and recalled *after* collaboration, as indexed by collective memory scores).
4. *Novel*: Former collaborators, compared to those that never collaborated, would report fewer prior-list intrusions and fewer extra-list intrusions.

Beyond recall quantity, recall overlap, and error rates, we also probed synchronized retrieval strategies in a more exploratory fashion. Given the evidence that collaborative recall can disrupt individual retrieval strategies (Marion & Thorley, 2016, for a meta-analysis), for our categorized study lists it may influence item-specific and relational processing of exemplars within the studied categories (Wissman & Rawson, 2015). These influences can impact category clustering, that is, the extent to which participants recall semantically related words in succession. We examined this question in individual performance at Recall 3. It is possible such clustering could be influenced downstream, even as former collaborators study and recall new material. Recent research also suggests that collaborative recall synchronizes individual retrieval strategies (see Greeley & Rajaram, 2023, for a review). This synchronization is evident following collaboration, during follow-up individual recall phases, with former collaborators recalling more overlapping material and doing so in more similar sequences (Congleton & Rajaram, 2014; Greeley et al., 2023). If former collaborators go on to leverage their overlapping strategies when encoding, related material, we explored whether this new material could be retrieved in a similar fashion by former collaborators.

Method

Participants

Our final sample included 96 students, all of whom were undergraduates at Stony Brook University. Participants were recruited via the Psychology Department's experiment system (SONA) and received course credit for their time. All procedures were IRB approved. ~~Detailed~~ Demographics ~~and participant exclusions~~ are noted in ~~the **Supplemental Materials (**~~**Table 1**.

Our sample size was determined based on power analyses using a range of previously observed collaborative inhibition results from comparable designs drawing from the same stimuli pool (Congleton & Rajaram, 2011; $d = 1.84$) or using similar list lengths (Blumen and Rajaram, 2008; $d = 1.42$). Reliably detecting these collaborative inhibition effects with 80% power via a directional, independent-samples *t*-test at a .05 significance level would require between five and seven triads per condition (15-21 individuals). Detecting the overall collaborative inhibition effect reported in a recent meta-analysis ($d = 0.86$; Marion & Thorley, 2016) under the same testing assumptions calls for 18 triads per condition (54 individuals). Thus, our final sample of 16 triads (48 individuals) per condition was chosen to be within this range but on the conservative side, powering to detect a smaller effect due to a number of procedural considerations. Regarding our other effects of interest (e.g., individual recall of *subsequently* studied new material following collaboration), there are no other studies on which to base a reasonable effect size estimate. Thus, while we are well-powered for replicating key effects such as collaborative inhibition, we intend for the novel effects we report in this experiment series to help inform sample size estimates for future studies.

Table 1

Participant Characteristics Across Experiments 1 and 2

Variable	**Experiment 1**, N = 96	**Experiment 2**, N = 96	Across Experiments
Experiment Device			
Laptop	93 (96.88%)	89 (92.71%)	182 (94.79%)
Desktop	3 (3.12%)	7 (7.29%)	10 (5.21%)
Age			
Mean (SD)	19.60 (4.16)	19.15 (2.22)	19.37 (3.33)
Range	17.00, 48.00	17.00, 29.00	17.00, 48.00
Sex			
Female	66 (68.75%)	75 (78.12%)	141 (73.44%)
Male	30 (31.25%)	19 (19.79%)	49 (25.52%)
Other	0 (0.00%)	2 (2.08%)	2 (1.04%)
Race			
Asian	34 (35.42%)	45 (46.88%)	79 (41.15%)
White	34 (35.42%)	33 (34.38%)	67 (34.90%)
Black or African American	8 (8.33%)	11 (11.46%)	19 (9.90%)
Native American or Alaskan Native	3 (3.12%)	2 (2.08%)	5 (2.60%)
Native Hawaiian or Pacific Islander	1 (1.04%)	2 (2.08%)	3 (1.56%)
More Than One Race	13 (13.54%)	3 (3.12%)	16 (8.33%)
No Response	3 (3.12%)	0 (0.00%)	3 (1.56%)
Hispanic			
Hispanic	18 (18.75%)	16 (16.67%)	34 (17.71%)
Not Hispanic	78 (81.25%)	80 (83.33%)	158 (82.29%)

Note. Participant demographics across experiments, including information on the device used to complete the experiment. All participants were fluent in English. Categorical variables are summarized with counts, with percentages in parentheses. Across experiments, participants were excluded if they experienced one or more of these five possible issues: technical problems ($N =$

13 in Experiment 1, $N = 7$ in Experiment 2), use of a tablet or touchscreen device ($N = 3$ in Experiment 1, $N = 0$ in Experiment 2), delayed start in collaborative recall ($N = 15$ in Experiment 1, $N = 0$ in Experiment 2), failure to understand instructions ($N = 3$ in Experiment 1, $N = 3$ in Experiment 1), or providing incomplete data ($N = 8$ in Experiment 1, $N = 13$ in Experiment 2). Note that if a single participant within a collaborative group experienced one of these issues, the group as a whole was excluded. For example, if one person in a collaborative group joined on a touchscreen device, the data for the group would be invalid (resulting in $N = 3$ being excluded).

Materials

The full stimuli set consisted of 90 categorized targets drawn from the Van Overschelde et al. (2004) norms. These stimuli have been used in similar research on collaborative recall (Congleton & Rajaram, 2011, 2014). A full list of exemplars, along with their mean pleasantness ratings across experiments, is included in the Supplemental Materials (Table S2). The 90 selected targets came from 10 categories (nine exemplars per category). These targets were further split into three evenly sized sub-lists, such that each list contained 30 targets (we code these sub-lists as A, B, and C). These lists were formed by randomly assigning three exemplars from each category to each sub-list. Thus, each 30-target sub-list contained three exemplars stemming from each of the 10 categories, and critically, no targets appeared on more than one sub-list. Finally, each sub-list was randomized in order, with the exception that no two exemplars from the same category appeared in adjacent positions. With the sub-lists defined, the final study lists were formed by combining sub-lists to form study lists of 60 targets and 30 targets. This resulted in three balanced list combinations: AB-C, BC-A, and CA-B. Throughout the entire procedure, a given participant would study two lists, the first of which would consist of 60 targets (AB, BC, or CA) and next a corresponding list of 30 new but related targets (A, B, or C). Given the nature of the sub-lists, each 60-target list contained six exemplars from each of the 10 categories, and each 30-target list contained three exemplars from each of the same 10 categories (and a given exemplar was only ever studied once).[2]

Design

[2]Each study list also included two primacy and two recency buffers. These were drawn from categories *not* represented by the targets, and no two buffers belonged to the same category. This resulted in eight buffer words total (four per list). The same buffers were studied by all participants, irrespective of list order (i.e., AB-C, BC-A, or CA-B).

We used a two-condition, between-subject design and manipulated collaboration during a series of free recall attempts. This design follows a long history of collaborative memory studies (Basden et al., 1997; Blumen & Rajaram, 2008; Weldon & Bellinger, 1997). Participants in the nominal condition never collaborated and always recalled alone as many times as did participants in the collaborative condition. Participants in the collaborative condition worked in groups of three (triads composed of strangers) in a free-flowing fashion during the first two of three recall attempts (e.g., Weldon & Bellinger, 1997). Novel to the current study, after an initial study phase (List 1) and two recall attempts (Recall 1 and 2), participants were tasked with studying and recalling a set of new targets (List 2) that were semantically related to those that were studied in List 1 and thus recalled previously. This approach allowed us to determine if prior collaborative recall improves the subsequent learning of new material, and whether it modulates downstream intrusions (at Recall 3).

Procedure

The entire procedure is outlined in Table 2. The procedure was conducted synchronously online following protocols established by Greeley et al. (2022) to encourage effective online collaborative recall (also see Ahn & Chan, 2023, for an online implementation of the test-potentiated new learning paradigm). Participants completed all tasks in Qualtrics and Chatplat (e.g., Huang et al., 2017) using a laptop or desktop computer. Shortly before a given appointment, participants were emailed a link to a virtual "waiting room," which consisted of a Chatplat instant-messaging room in which the Experimenter could verify arrival. When all participants arrived, a study link was sent via email. After receiving the study link, all participants went through the consent process. The experimental procedures began with an initial study phase (List 1; 60 targets), which was always completed individually. Participants were informed of an upcoming memory test, but the nature of the test was unspecified. Each word appeared on the screen for six seconds, with a fixation between each word for one second. Critically, each participant within a given nominal or collaborative group saw the same words in the same order (i.e., the same AB, BC, or CA sub-list). While each word was presented, participants were tasked with rating it for pleasantness of meaning on a five-point Likert scale (1 = very unpleasant; 3 = neutral; 5 = very pleasant), an often-used task to encourage deeper processing (Craik & Lockhart, 1972). The screen advanced after six seconds whether or not a rating was provided. After this initial study phase, participants completed a distractor task which involved recalling as many U.S. cities as they could in three minutes.

Next, participants completed two free recall attempts for the previously studied words. During the first recall, which lasted seven minutes, participants in the nominal condition worked individually in a one-person Chatplat rooms while participants in the collaborative condition worked in triads in a three-person Chatplat room. Irrespective of condition, participants/groups received a message from the experimenter at the start of the recall phase that both reiterated the instructions and established that the experimenter was present to oversee the live procedure and address questions should they arise (see, e.g., Greeley et al., 2022). All participants were instructed to report one word at a time, in any order they preferred, and collaborative groups were told to monitor what words their partners were sending and to avoid sending duplicates. Participants in both conditions were able to scroll and see all previously submitted words, and collaborative groups were able to collaborate freely (e.g., contribute responses at any time, ask questions). Finally, all participants/groups received an automated message when they had one minute left to recall. After the first recall, participants were given a two-minute break (with a countdown on the screen), which was immediately followed by another recall. Nominal participants continued to work alone and collaborative participants again worked in triads with the same partners as the previous recall to report the items from the study list. All aspects of this recall (e.g., timing) were the same as the initial recall attempt.

After completing these two initial recall attempts, participants individually studied a new list of words (List 2; 30 targets). This list was shorter than List 1; a longer List 1 (60 targets) was chosen intentionally given the task entailed group recall (either collaborative or nominal), and a shorter List 2 was chosen to aid individual recall. Critically, these words were entirely *new*; they did not appear on the initial list, but were semantically related, that is, from the same categories, to those that did. For example, if a participant initially studied the AB list they would study the C list at this point, which would include three new exemplars from each of the 10 categories represented in the initial list. Again, each participant within a given nominal or collaborative group saw the same words in the same order (i.e., the same A, B, or C sub-list). The study procedure was the same as the initial list. That is, participants were informed of an upcoming (but unspecified) memory test, each word was to be rated for pleasantness of meaning, and each word appeared for six seconds. This study procedure was followed by a distractor task in which participants played the game of Snake for three minutes.

Finally, all participants individually completed a *non-cumulative* final free recall attempt for the words on the most recently studied list (List 2). Irrespective of condition, participants worked in one-person Chatplat rooms and were allotted five minutes for the recall (reduced duration because there were half as many targets). Just like the previous recall attempts, participants received a message from the experimenter at the start of the recall that reiterated the instructions and established that they were watching live. All participants were instructed to send one word at a time, in any order they preferred. Participants were reminded to only send words they remembered from the most recent list. As before, participants in both conditions had in their view a subset of the words they had already recalled (with the ability to scroll and see all submitted words), and participants again received an automated message when they had one minute left to recall.

When this recall was complete, participants advanced into the survey portion of the experiment, which included demographic questions and a debriefing statement. The entire procedure lasted approximately 45 minutes.

Table 2

Procedure Across Experiment 1 and Experiment 2

	Experiment 1		Experiment 2	
Phase	**Nominal**	**Collaborative**	**Nominal**	**Collaborative**
1	Study *List 1 - 60 Targets*	Study *List 1 - 60 Targets*	Study *List 1 - 60 Targets*	Study *List 1 - 60 Targets*
2	Distractor - U.S. City Recall	Distractor - U.S. City Recall	Distractor - U.S. City Recall	Distractor - U.S. City Recall
3	Individual Recall *List 1 Targets*	Collaborative Recall *List 1 Targets*	Individual Recall *List 1 Targets*	Collaborative Recall *List 1 Targets*
4	Individual Recall *List 1 Targets*	Collaborative Recall *List 1 Targets*	Individual Recall *List 1 Targets*	Collaborative Recall *List 1 Targets*
5	Study *List 2 - 30 New Targets*	Study *List 2 - 30 New Targets*	Study *List 2 - 30 New Targets*	Study *List 2 - 30 New Targets*
6	Distractor - Snake Game	Distractor - Snake Game	Distractor - Snake Game	Distractor - Snake Game
7	Individual Recall *List 2 Targets Only*	Individual Recall *List 2 Targets Only*	Individual Recall *Targets from Both Lists*	Individual Recall *Targets from Both Lists*
8	–	–	List Judgement Task	List Judgement Task
9	Technology Questions	Technology Questions	Technology Questions	Technology Questions
10	Demographic Questions	Demographic Questions	Demographic Questions	Demographic Questions

Note. Procedures across experiments, from the initial study phase through the demographic procedure. Experiment 1 and Experiment 2 were identical through Phase 6. In Experiment 1, at Phase 7, participants were tasked with recalling as many targets as possible from only the most recently studied list (i.e., List 2 targets; noncumulative recall). In Experiment 2, this recall was cumulative, such that participants were free to recall any targets from either list, including those recalled previously. Another key difference in Experiment 2 was the inclusion of a list judgement task. Here, participants saw all targets (i.e., the 90 targets studied across both lists) in a random order and were tasked with making a forced-choice source judgement about where each target appeared (List 1 or List 2).

Results

All analyses were conducted in R version 4.4.2 (R Core Team, 2022). A number of additional packages were used to aid in analysis and visualization (Wickham et al., 2019). Data and code to reproduce our results are available on OSF (https://osf.io/3m2jk/?view_only=a132c0398c57453bb12523b2b2d35c9b). In line with our hypotheses, all *p* values were computed based on directional tests, unless otherwise noted. ~~See the **Supplemental Materials** additional analyses.~~

Recall 1 and 2: Collaborative Inhibition

At Recall 1, collaborative groups ($M = 0.56$, $SD = 0.13$, $N = 16$) recalled significantly less than equal sized nominal groups, $M = 0.64$, $SD = 0.13$, $t(30) = 1.92$, $p = .0319$, $d = 0.68$, d 95% CI [-0.06, 1.42]. This result, visualized in Figure 1A, supported our hypothesis regarding the replication of the collaborative inhibition effect (Greeley et al., 2022). At Recall 2, there was not a statistically significant difference, though collaborative groups ($M = 0.61$, $SD = 0.14$, $N = 16$) again recalled numerically less than equal sized nominal groups ($M = 0.68$, $SD = 0.14$), $t(30) = 1.33$, $p = .0967$, $d = 0.47$, d 95% CI [-0.26, 1.20]. This result adds to reports that the collaborative inhibition effect can sometimes become weaker across repeated retrieval attempts (see, e.g., Blumen & Rajaram, 2008; Congleton & Rajaram, 2014).

Recall 3: Individual Recall Performance

At Recall 3, during which targets consisted of only the words on the most recent list (i.e., List 2) in this experiment, former collaborators ($M = 0.41$, $SD = 0.19$, $N = 47$)[3], now recalling individually, and nominal participants ($M = 0.41$, $SD = 0.21$, $N = 48$) reported similar amounts,

[3] One collaborative participant recalled only a single buffer word at Recall 3 (so recall was 0%). This participant was removed from all individual Recall 3 analyses, and their group was excluded from the collective memory and collective organization analyses that follow. This exclusion does not change the interpretation of any results.

t(93) = -0.11, *p* = .4571, *d* = -0.02, *d* 95% CI [-0.43, 0.39]. This result suggests that previous collaborative recall does not improve the subsequent learning of new, related material. This pattern is depicted in Figure 1B.

Recall 3: Individual Recall Performance, Controlling for Individual Recall 1 and Recall 2

As just noted, we did not observe a strict new learning effect; former collaborators and nominal "group" participants (who recalled alone during Recall 1 and 2) performed similarly on the final, non-cumulative recall task. However, during Recall 1 ~~and 2~~, we replicated the collaborative inhibition effect, indicating that individuals *within* collaborative groups recalled less than they would have if they had worked alone (an effect that persisted numerically during Recall 2). ~~If participants who always recalled alone benefited from the retrieval practice (the standard test-potentiated new learning effect), the null result we observed suggests that collaborative retrieval provides a comparable benefit.~~ That is, while individuals within collaborative groups actually recall less than their nominal counterparts during initial retrieval attempts, subsequent new learning is similar between conditions. While this cannot be characterized as a test-potentiated new learning effect (because there is no re-study or similar control condition), to explore this further, we conducted a regression analysis assessing individual Recall 3 performance (List 2 target recall) as a function of condition, controlling for *individual* Recall 1 and Recall 2 levels. Interestingly, this analysis suggested that ~~when Recall 1 and 2 performance is held constant,~~ estimated Recall 3 performance is higher in the collaborative condition (*b* = .09, *p* = .0192); in essence, collaborative inhibition does not interfere with new learning despite the fact that it disrupts initial retrieval attempts. This is important to consider in the successive learning situations that characterize educational settings, and we elaborate on this finding in the General Discussion.

Recall 3: Collective Memory

A primary question of interest for Recall 3 related to the emergence of collective memory for subsequently studied, semantically related new targets. Specifically, we were interested in whether initial collaboration, disrupting individual retrieval strategies and potentially orienting participants to a joint strategy, would exert an influence on collective memory downstream for subsequently encountered, related material. In other words, would participants who collaborated to recall List 1 gravitate to learning and recalling similar items from List 2, even when working alone? This convergence did not occur in the recall of List 2 targets as former collaborators (M = 0.10, SD = 0.09, N = 15) collectively recalled similar amounts to nominal groups M = 0.09, SD = 0.07, N = 16, $t(29)$ = -0.35, p = .3631, d = -0.13, d 95% CI [-0.86, 0.61]. This relationship is depicted in Figure 1C.[4]

Recall 3: Prior-List and Extra-List Intrusions

We next examined downstream memory intrusions – specifically, whether prior collaboration insulated participants against prior-list and/or extra-list intrusions - and found this to be the case. Collaborators recalled significantly fewer prior list intrusions than nominal participants, *incident rate* = 0.37, *rate* 95% CI [0.21, 0.66], p = .0007. That is, on average, former collaborators report 63% fewer prior-list intrusions. The descriptive statistics are striking: 68% (N = 32) of collaborative participants recalled no prior-list intrusions, while 17% (N = 8) recalled only one, and no collaborative participant recalled more than three. On the other hand, only 38% (N = 18) of nominal participants recalled no prior-list intrusions, while 31% (N = 15) recalled one. The remaining nominal participants recalled between two prior-list intrusions

[4] ~~Additional analyses focusing on individual category clustering at Recall 3 (Roenker et al., 1971) and group-level collective organization at Recall 3 (Congleton & Rajaram, 2014) – for both Experiment 1 and Experiment 2 – are included in the **Supplemental Materials**.~~

(15%, $N = 7$) and six prior-list intrusions (4%, $N = 2$). An inspection of whether participants also reported extra-list intrusions (items reported that were neither on List 1 nor on List 2) was not statistically significant, *incident rate* = 0.54, *rate* 95% CI [0.21, 1.31], $p = .0912$. However, former collaborators reported 46% fewer extra-list intrusions on average than their nominal counterparts. Intrusion distributions are visualized in Figure 1D.

Recall 3: Category Clustering

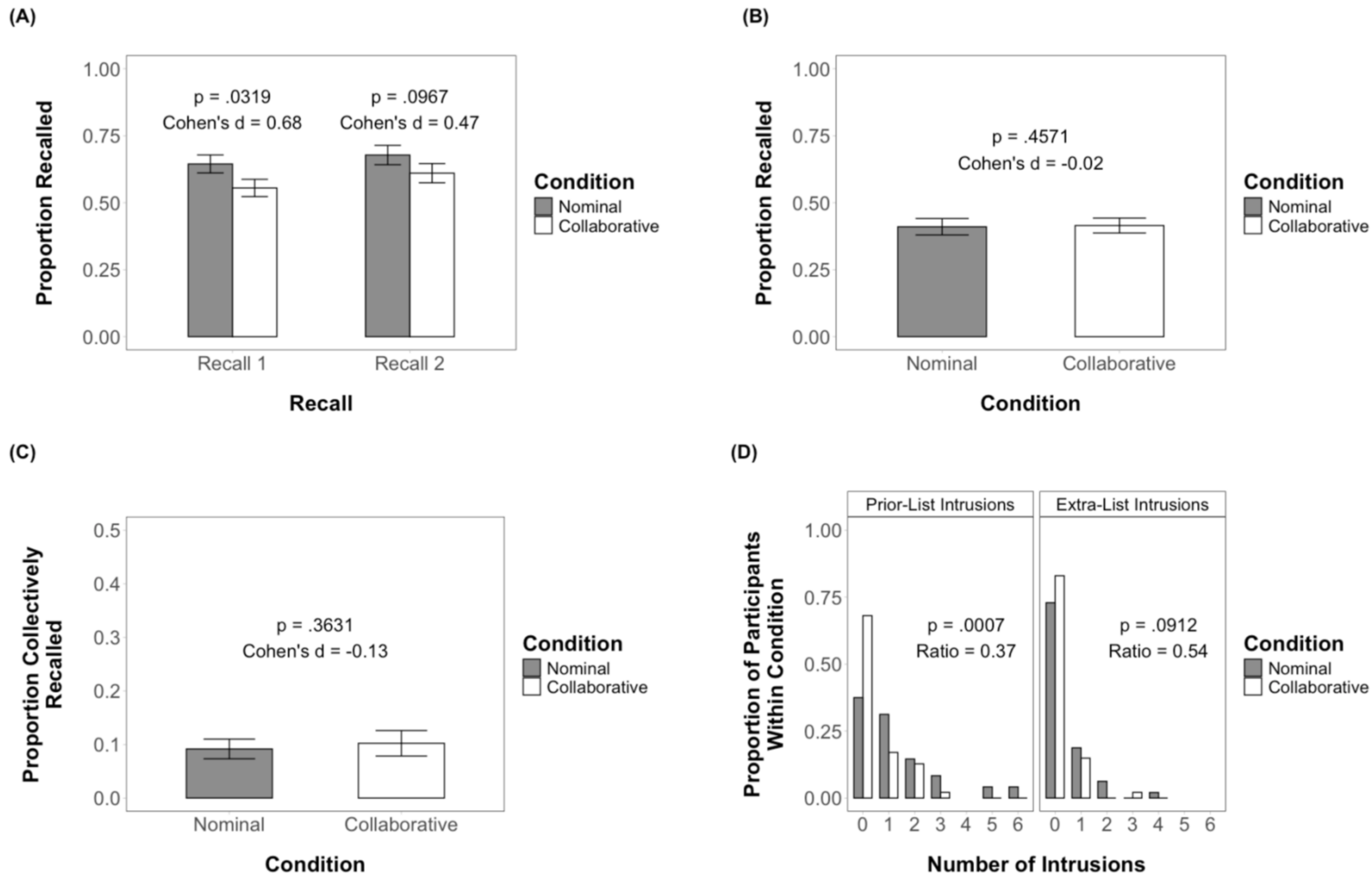
In this analysis, we were interested in category clustering in individual performance at Recall 3, during which there were 30 targets possible (stemming from 10 categories, with three words per category). We used the Adjusted Ratio of Clustering metric (ARC; Roenker et al., 1971) that characterizes category clustering, that is, the propensity to recall items belonging to the same category in succession. An ARC score of 0 indicates chance-level clustering, while a score of 1 indicates perfect clustering. Negative scores are possible when clustering is below chance, though scores are not necessarily bound to -1 and scores may be undefined if the number of words recalled is equal to the number of categories (i.e., no opportunity for clustering; see Roenker et al., 1971 for computational details). After removing undefined scores, former collaborators ($M = 0.31$, $SD = 0.40$, $N = 43$) had ARC scores that were very similar to nominal participants that never collaborated, $M = 0.32$, $SD = 0.45$, $N = 44$, $t(85) = 0.10$, $p = .9224$, $d = 0.02$, d 95% CI [-0.41, 0.45].

Recall 3: Collective Organization

We examined synchronized retrieval strategies (Greeley & Rajaram, 2023) by implementing the Shared Organization Metric Analysis (SOMA; Congleton & Rajaram, 2014) that characterizes retrieval similarity between people, in the current case, between members of a given nominal or collaborative group. Computationally, SOMA relies on the bidirectional pair frequency metric (PF; Sternberg & Tulving, 1977), a measure used to characterize within-subject retrieval similarity, specifically at the level of word-to-word transition pairs. Computing SOMA requires calculating PF scores between each pair of group members, with a group SOMA score provided by averaging the pairwise PF scores (see Congleton & Rajaram (2014) for computational details). A score of 0 indicates chance collective organization, while positive scores indicate above chance collective organization. SOMA scores were low across the board. Groups that collaborated previously (M = -0.03, SD = 0.46, N = 15) and nominal groups that never collaborated (M = 0.03, SD = 0.34, N = 16) both had average SOMA scores near chance, and the difference between conditions was not significant, $t(29) = 0.43$, $p = .6662$, $d = 0.16$, d 95% CI [-0.58, 0.89].

Figure 1

Experiment 1 Results: Recall Levels, Collective Memory, and Intrusion Rates



Note. Key results in Experiment 1; all bars are at mean, error bars are +/- 1 SE. **(A)** Collaborative inhibition was present at Recall 1, such that nominal groups recalled significantly more than equal sized collaborative groups (same pattern observed at Recall 2, but non-significant). **(B)** Initial collaborative recall did not benefit the subsequent learning of new, semantically related targets during Recall 3. **(C)** Initial collaborative recall did not contribute to the emergence of collective memory for *subsequently* studied, semantically related targets (List 2). **(D)** At the non-cumulative Recall 3, former collaborators recalled fewer prior-list intrusions than nominal participants that never collaborated.

Experiment 1 Discussion

Consistent with our hypothesis, we replicated collaborative inhibition at Recall 1 (Greeley et al., 2022). With respect to our first novel hypothesis, the influence of prior collaborative recall on subsequent learning of new material was limited. We did not find evidence for a boost in new learning following collaborative recall, but we saw that despite recalling less during collaboration (i.e., collaborative inhibition), former collaborators were not disadvantaged in their new learning. That is, they exhibited equivalent learning of new information compared to those who never collaborated. The hypotheses relating to this downstream impact followed from a number of theoretical accounts of collaborative inhibition and test-potentiated new learning. Specifically, prior collaborative recall may provide additional contextual specificity than individual recall (i.e., cues dependent on social context), perhaps contributing to a greater shift between study phases that further protects against proactive interference (Szpunar et al., 2008; also see Pierce et al., 2017). However, in our design, the impact of this shift on new learning was limited. With respect to our novel hypothesis concerning emergence of collective memory, we reasoned that the synchronizing effects collaborative recall has on retrieval organization may propagate forward to guide subsequent encoding and/or retrieval strategies, potentially giving rise to collective memory for new information (e.g., Chan et al., 2018; though see Ahn & Chan, 2023, and Boustani et al., 2023). However, we observed null results for the development of collective memory for new learning as well; similarly, we did not observe differences between conditions in the extent to which participants clustered their recall by category or synchronized this clustering in recalling the second list. We return to these points in the General Discussion. At the same time, for our novel hypothesis regarding prior-list intrusions we observed supporting evidence where former collaborators recalled significantly fewer prior-list intrusions than those who had previously worked alone.

With respect to new learning, it is possible that the context shift and strategy change mechanisms discussed earlier are not sensitive to whether prior retrieval was conducted individually or in a group. Because participants in both conditions engage in initial retrieval practice, the downstream impacts on new learning are roughly equivalent. Importantly, this does not necessarily mean both conditions experienced a benefit from testing – such a claim would require a non-tested control condition, and it was not a goal of the current study to explore this possibility. What these findings do suggest is that prior collaborative recall does not readily confer strong benefits on the quantity of new learning. At the same time, prior collaborative retrieval did reduce subsequent prior-list intrusions, a finding that is consistent with the idea that collaborative recall provides a contextual specificity not provided by individual recall (see Schwartz et al., 2014, for an example of how additional context can reduce downstream errors). In the current case, social-context is the key difference between conditions, demonstrating the power of collaboration where group members presumably add source information for differentiating between items recalled from the initial list versus the subsequently learned list. Because collaborative retrieval affords exposure to material recalled by partners, old material that gets covertly retrieved during a non-cumulative final recall may be more easily rejected (and thus not overtly reported). This prospect raises some interesting questions that we tested in Experiment 2.

If retrieval practice impacts subsequent learning of related information in roughly the same manner irrespective of whether it is performed individually or in a group, we should continue to observe null effects even when the final retrieval condition changes and allows for cumulative recall. In Experiment 2, we implemented this change, which provides additional room for the proposed mechanisms to operate. That is, former collaborators are free to recall new and old material together, affording them more of an opportunity to leverage the retrieval strategies they converged on during collaboration. Likewise, shifting to a final cumulative recall made it possible to assess the persistence of post-collaborative memory effects, namely retrieval gains and collective memory. Finally, we added a list judgment task that allowed a converging test of the Experiment 1 finding that former collaborators recalled fewer prior-list intrusions. If former collaborators are better at pruning prior-list intrusions because they are more effective at rejecting them as having been recalled in the previous collaborative context, they should also be more accurate at identifying target words from the initial list in a forced-choice list judgment task.

Experiment 2

We designed Experiment 2 to provide a systematic replication of Experiment 1 by making two procedural changes. Specifically, we examined the extent to which collaborative recall influences the subsequent learning of new, related material in a *cumulative* final recall task and improves the ability to identify the initially learned material by including a forced-choice, list judgment task. We made these procedural changes to facilitate 1) a novel assessment of downstream new learning following collaborative recall, 2) a new look at the persistence of post-collaborative memory effects, and 3) a more explicit test of mechanisms underpinning the pruning of prior-list intrusions following collaborative recall observed in Experiment 1.

Hypotheses

Following Experiment 1, we hypothesized: ~~core hypotheses are listed here while additional hypotheses are included in the Supplemental Materials~~.

1. *Replication*: Collaborative groups would recall less than nominal groups, though the effect may weaken across retrieval attempts (e.g., Blumen & Rajaram, 2008).
2. *Novel*: Former collaborators, relative to those who recalled individually, would recall more subsequently presented words (i.e., List 2 targets). While this new learning effect was not observed in Experiment 1, the cumulative recall used in the current experiment provides an additional test. We also hypothesized that post-collaborative recall gains (i.e., for List 1 items) would persist, a result that would speak to the durability of collaborative influences. These list-specific hypotheses converge on the expectation that *overall* final recall performance on the cumulative recall task would be higher in the collaborative condition, an idea we explore that is of more applied interest (e.g., total learning).
3. *Novel*: Former collaborators, relative to those that never collaborated, would collectively recall more overlapping words from List 2 (collective memory for new material). Again, this was not observed in Experiment 1, though the cumulative recall task used here provides a new test. Echoing the hypothesis above that post-collaborative recall gains would persist, we hypothesized the same persistence for collective memory (i.e., for List 1 items). Finally, these list-specific hypotheses again converge on the expectation that overall collective memory would be elevated following collaboration.
4. *Novel*: Former collaborators would be better at correctly identifying targets from the initial list (List 1) than nominal participants in a forced-choice, list judgment task, offering a converging test of the reduced prior-list intrusions observed in Experiment 1.

Following Experiment 1, we again assessed several organization-based outcomes in a more exploratory fashion. With respect to category clustering assessed at the individual recall level, the inclusion of a cumulative final recall allows for old and newly learned material to be recalled in tandem. While we did not observe any influence on category clustering in Experiment 1, the change to a cumulative final recall provides more room for participants in both conditions to leverage their initial clustering strategies when integrating new material. In a similar way, while we did not find that prior collaboration synchronized retrieval strategies in a non-cumulative context, the switch to a cumulative recall means participants can continue to display strategies from earlier recall phases. As such, we examined collective organization to determine if the synchronization following collaboration persists even as new learning occurs.

Method

Participants

Our final sample included 96 participants, all of whom were undergraduates at Stony Brook. Recruitment procedures were identical to those in Experiment 1, all participants received course credit for their time, and all procedures were IRB approved. Detailed demographics are noted in Table 1.

Sample Size Rationale

The sample size for this experiment was motivated by the same power analyses that supported Experiment 1, with two important additions. Because participants would recall targets from *both study* lists during their final recall attempt, including targets previously recalled with group members, we could look to prior work that has assessed post-collaborative individual recall and post-collaborative collective memory. As noted in the Supplemental Materials, comparable studies often report large effects (i.e., $d > 1$). As such, a sample size of 16 triads (48 individuals) per condition is more than adequate for detecting collective memory in a new context while remaining a safe estimate for detecting the other effects previously discussed.

Materials

The stimuli and study lists were identical to Experiment 1.

Design

This experiment closely followed Experiment 1, with two procedural changes. In this experiment, the final recall (Recall 3) was *cumulative*. That is, participants, once again working individually at this point, were now tasked with recalling as many targets as they could from *both* study lists. Another change was the inclusion of a forced-choice, list judgment task following Recall 3, which probed source memory (forced choice; a List 1 or List 2 judgment) for the entire set of 90 targets.

Procedure

Most of the procedure for Experiment 2 was identical to Experiment 1 (see Table 1), that is, the initial study phase, the first distractor task, the first two recall phases, the second study phase (with new, related words), and the second distractor task were identical. The key changes to the procedure occurred during and just after Recall 3.

First, at Recall 3, participants were tasked with recalling as many targets as possible from *both* study lists. That is, we used a cumulative recall procedure. This allowed us to assess the downstream impact of collaboration in new ways (e.g., influence of prior collaboration on later new learning and the presence of post-collaborative memory gains for the initially studied items even when recalled among subsequently studied material). Because participants were tasked with recalling many more potential targets at this stage (up to 90, instead of 30 in Experiment 1; see Congleton & Rajaram, 2011, for a similar list-length), the recall duration was extended to 10 minutes. Another key change was the inclusion of a list judgment task, which followed Recall 3. During this source monitoring task, participants saw each of the 90 target words in a random order, and they made a forced-choice judgment about the list on which each word appeared (i.e., the initial list [List 1] or the subsequently studied list [List 2]). This afforded a more direct test of the source monitoring advantage we hypothesized following Experiment 1. Following the list judgment task, the rest of the procedure was identical to Experiment 1. Participants advanced to the survey portion of the experiment, just as in Experiment 1. The entire procedure lasted approximately one hour.

Results

All analyses proceeded in the same fashion as Experiment 1. At Recall 3, analyses that involve only one set of stimuli are indicated as such by referring to the initially studied list as "List 1" and the subsequently studied list as "List 2." ~~As before, additional analyses are included in the **Supplemental Materials**.~~

Recall 1 and 2: Collaborative Inhibition

At Recall 1, collaborative groups ($M = 0.56$, $SD = 0.14$, $N = 16$) recalled significantly less than equal sized nominal groups, $M = 0.70$, $SD = 0.14$, $N = 16$, $t(30) = 2.64$, $p = .0064$, $d = 0.93$, d 95% CI [0.17, 1.70]. This replicated Experiment 1. At Recall 2, collaborative groups ($M = 0.61$, $SD = 0.14$, $N = 16$) continued to recall less than nominal groups, $M = 0.72$, $SD = 0.12$, $N = 16$, $t(30) = 2.36$, $p = .0126$, $d = 0.83$, d 95% CI [0.08, 1.59]. This pattern of results is depicted in Figure 2A.

Recall 3: Individual Recall Performance

When focusing on List 2 target recall (30 possible words) to examine the impact of prior collaboration on later new learning, former collaborators ($M = 0.43$, $SD = 0.20$, $N = 48$) ~~actually recall slightly less than~~ and nominal participants ($M = 0.47$, $SD = 0.24$, $N = 48$) recalled a similar number of targets ~~though the difference was not statistically significant~~, $t(94) = 0.82$, $p = .7929$, $d = 0.17$, d 95% CI [-0.24, 0.57]. This result, combined with Experiment 1 results, provides converging evidence that initial collaboration does not moderate the subsequent learning of new material (at least in the context of word-list recall). Interestingly, when focusing only on List 1 targets (60 possible words), former collaborators (M = 0.42, SD = 0.17, N = 48) recalled significantly more than nominal participants, M = 0.36, SD = 0.17, N = 48, $t(94)$ = -1.78, p = .0390, d = -.36, d 95% CI [-0.77, 0.04] in the final individual recall. This suggests that post-collaborative retrieval gains, observed in single-list designs (e.g., Marion & Thorley, 2016), can occur even in the context of cumulative recall. These patterns are visualized in Figure 2B. Assessing whether there was an *overall* benefit of prior collaboration on cumulative recall (considering all 90 possible targets), former collaborators (M = 0.42, SD = 0.15, N = 48) and nominal participants performed similarly, M = 0.39, SD = 0.16, N = 48, $t(94)$ = -0.92, p = .1802, d = -0.19, d 95% CI [-0.59, 0.22].

Recall 3: Individual Recall Performance, Controlling for Individual Recall 1 and Recall 2

As just noted, and in line with Experiment 1, we did not observe a new-learning boost among former collaborators (compared to nominals), even in this new cumulative recall context. However, we again observed significant collaborative inhibition, indicating that collaborating group members recalled less than they would have if they had recalled alone. ~~Despite the initial disruption in the collaborative condition, individual Recall 3 performance was statistically similar between conditions (when focusing on List 2 recall). Echoing Experiment 1, this indicates that if individual retrieval practice was beneficial to subsequent learning, collaborative retrieval practice was similarly beneficial even though individuals within collaborative groups recalled less during the initial retrieval attempts.~~ As in Experiment 1, we assessed Recall 3 performance (specifically for List 2 target recall) as a function of condition, controlling for individual recall performance at Recall 1 and 2. This effect was null, b = .03, p = .4911, indicating that even though individuals within collaborative groups recalled less during Recall 1 and 2 (collaborative inhibition), predicted new learning was similar across conditions.

Recall 3: Collective Memory

With respect to collective memory for subsequently learned material (i.e., List 2 targets; 30 words), as in Experiment 1, we did not observe memory convergence – former collaborators (*M* = 0.10, *SD* = 0.11, *N* = 16) and ~~collectively recalled numerically less than~~ nominal groups (*M* = 0.14, *SD* = 0.12, *N* = 16) collectively recalled a similar number of words ~~However, the difference was not statistically significant~~, *t*(30) = 1.10, *p* = .8599, *d* = 0.39, *d* 95% CI [-0.34, 1.12]. Interestingly, when restricting the assessment to only List 1 targets (60 words), former collaborators (*M* = 0.14, *SD* = 0.09, *N* = 16) collectively recalled more than nominal group members, *M* = 0.06, *SD* = 0.07, *N* = 16, *t*(30) = -3.10, *p* = .0021, *d* = -1.10, *d* 95% CI [-1.87, -0.32]. This suggests that post-collaborative collective memory, often observed in single-list designs (e.g., Marion & Thorley, 2016), emerges even when targets are recalled in a cumulative context tapping memory for two different lists. Finally, this increased collective memory for List 1 targets is the driving force behind an overall collective memory effect; groups that collaborated previously (*M* = 0.13, *SD* = 0.06, *N* = 16) collectively recalled more overall than nominal groups, *M* = 0.08, *SD* = 0.07, *N* = 16, *t*(30) = -1.84, *p* = .0381, *d* = -0.65, *d* 95% CI [-1.39, 0.09]. These patterns are visualized in Figure 2C.

Recall 3: Recall Initiation by List

Turning to a more focused exploration of retrieval dynamics, it is possible that former collaborators could *initiate* retrieval differently than those that never collaborated. Specifically, we examined whether participants who collaborated earlier versus nominal participants who had not collaborated differed in their recall initiation strategies, by analyzing the source (List 1 vs.

List 2) of the first word recalled during Recall 3. We did not find that prior collaboration status influenced recall initiation in this context. When including only target words recalled in the first position (*N* = 72 valid first words), there was not a significant effect, $\chi^2(1) < 0.01, p = 1.$ This held when relaxing the inclusion requirements to allow for targets and buffer words to be recalled in the first position, *N* = 95, $\chi^2(1) = 0.26, p = .6112.$

Recall 3: Category Clustering

Following Experiment 1, we computed ARC scores to index category clustering in recall performance at the individual level. Here, because the recall task was cumulative, there were 90 targets possible (10 categories, each contributing nine exemplars). Despite the additional freedom to leverage prior clustering patterns (from Recall 1 and/or 2), former collaborators (*M* = 0.53, *SD* = 0.24, *N* = 48) and nominal participants that never collaborated once again clustered to a similar degree in Recall 3, *M* = 0.59, *SD* = 0.25, *N* = 48, *t*(94) = 1.27, *p* = .1043, *d* = 0.26, *d* 95% CI [-0.15, 0.67].

Recall 3: Collective Organization

Just as in Experiment 1, we assessed the emergence of collective organization, that is, synchronized retrieval strategies, with SOMA scores, this time for the combined recall of Study List 1 and Study List 2. Former collaborators (*M* = 1.67, *SD* = 1.03, *N* = 16) and nominal group members that never collaborated had similar SOMA scores, *M* = 1.29, *SD* = 1.35, *N* = 16, *t*(30) = -0.89, *p* = .1900, *d* = -0.31, *d* 95% CI [-1.04, 0.41].

List Judgement Task: Source Monitoring Performance

Our primary interest in the list judgement task was whether former collaborators were better at identifying List 1 targets, as would be expected if the process of collaboration provides additional context specificity (i.e., social cues) that aid downstream source monitoring. As such, we analyzed these data similarly to old/new recognition data, treating List 1 items as targets and List 2 items as foils[5]. That is, responding "List 1" when the word shown was indeed a List 1 target counted as a hit while responding "List 1" when the word shown was actually a List 2 target was counted as a false alarm.

As predicted, former collaborators had a better List 1 hit rate (M = 0.76, SD = .011, N = 47) than their nominal counterparts, M = 0.70, SD = 0.11, N = 46, t(91) = -2.32, p = .0112, d = -0.48. This pattern, visualized in Figure 2D, suggests that prior collaborative recall provides a downstream source monitoring benefit. Turning to false alarms, former collaborators (M = 0.18, SD = 0.13, N = 47) did not differ significantly from nominal participants that never collaborated, M = 0.18, SD = 0.14, N = 46, t(91) < .01, p = .4985, d < 0.01. Given the different hit rates and similar false alarm rates, corrected recognition (hits – false alarms) followed the same pattern but did not reach statistical significance, t(91) = -1.33, p = .0930, d = -0.28.

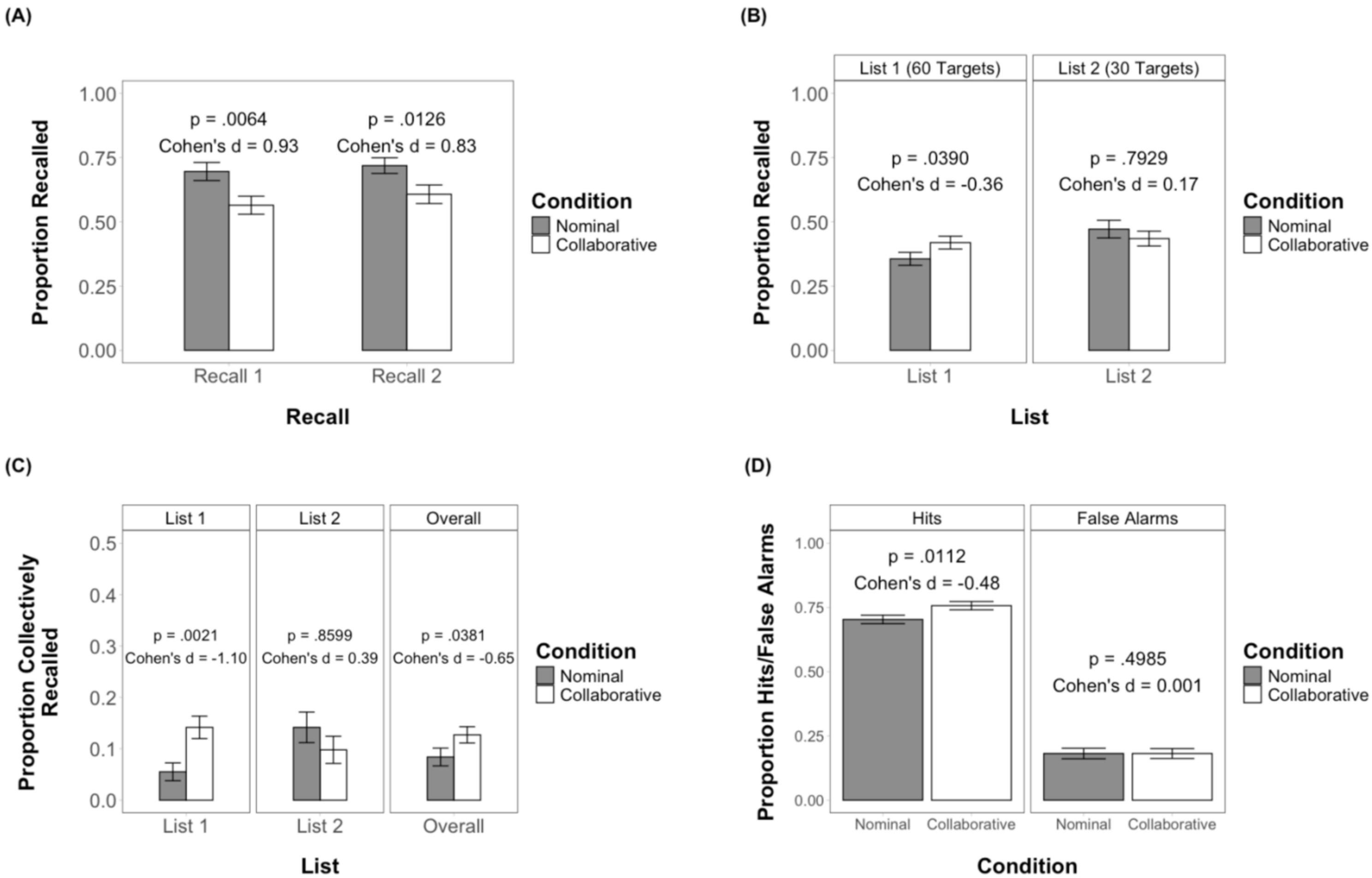
To explore this result further, we partitioned the corrected recognition analysis based on whether words were recalled or not recalled during the cumulative Recall 3. Because performance should be quite high for recalled words (in both conditions), we were especially interested in source monitoring when words were *not* recalled. We found that prior collaboration (M = .78, SD = .21) did not influence source monitoring performance compared to nominal controls (M = .78, SD = .22) when focusing on previously *recalled* words, t(87) = -0.07, p = .9419. Interestingly, prior collaborative recall did confer a downstream benefit during source monitoring when focusing on words that were *not* recalled. Former collaborators (M = .42, SD = .22) significantly outperformed their nominal counterparts, M = .33, SD = .15, t(79.03) = -2.31, p

[5] Note that all words shown during this task were technically targets as they were presented at some point during the task (either during List 1 or List 2 study phases). The treatment of List 1 words as targets and List 2 words as foils was for the purposes of analysis only; the separation provides a broadly interpretable way to characterize list discrimination, specifically List 1 target identification.

= .0234. This indicates that the process of collaboration provides additional information on which to base source judgements, but only when words were not reported during cumulative individual recall following group recall.

Figure 2

Experiment 2 Results: Recall Levels, Collective Memory, and List Judgement Performance



Note. Key results in Experiment 2; all bars are at mean, error bars are +/- 1 SE. **(A)** Collaborative inhibition was present at both Recall 1 and 2. **(B)** During the cumulative Recall 3, prior collaboration boosted recall for List 1 targets, even in the context of cumulative recall, although there was no recall difference for the (subsequently studied) List 2 targets. **(C)** At Recall 3, former collaborators collectively recalled more overall, an effect driven by greater collective memory for List 1 targets, with no significant difference in collective memory for List 2 targets. **(D)** At Recall 3, former collaborators are better at identifying List 1 targets, suggesting that collaboration provides lasting source monitoring benefits.

Experiment 2 Discussion

Consistent with our expectations, we replicated the collaborative inhibition effect. However, prior collaborative retrieval, relative to individual retrieval, did not have a significant influence on the subsequent learning of new material. In this new cumulative recall context, former collaborators did not recall significantly more overall, nor did they recall more subsequently studied (List 2) targets than their never-collaborating counterparts. This pattern replicated Experiment 1 findings.

At the same time, collaborative retrieval did have a notable presence downstream. Consistent with our hypotheses, former collaborators recalled more initially studied material (i.e., List 1 targets) than those that never collaborated. Likewise, former collaborators collectively recalled more initially studied material (and more overall) than nominal groups that never collaborated. This demonstrates the persistence of post-collaborative retrieval gains and collective memory, respectively, highlighting the robustness of these social memory phenomena in the face of potential retroactive interference from new learning. These results, combined with the findings of Experiment 1, provide converging evidence that collaborative recall – relative to individual recall – does not have a clear impact on the subsequent learning of new, semantically related material, but its initial effects of memory gains and collective memory emergence hold up for the former collaborators in the face of processing new, incoming information. ~~This is interesting in light of the predictions that follow from accounts of test-potentiated new learning.~~

Turning to the list judgement task, the significantly elevated hit rate for initially studied material in the collaborative condition suggests that group recall aids in source monitoring, helping distinguish between material that was studied and recalled in the group context from material learned later on. This result, combined with the reduction in prior-list intrusions observed in Experiment 1, supports the notion that the contextual specificity afforded by collaborative provides a source monitoring advantage (see Schwartz et al., 2014, for another perspective on how context can support recognition in a different paradigm). This has implications, which we discuss below, for learning in multiple study-test situations that characterize educational settings.

General Discussion

In Experiment 1, we asked whether prior collaborative recall has an impact on subsequent new learning, and whether prior collaboration helps filter out memory intrusions as subsequent material is studied and recalled in a non-cumulative final recall context. Experiment 2 provided a converging assessment of whether collaborative recall influences subsequent new learning in a new testing context (cumulative final recall), and the addition of a list-judgement task allowed us to further examine the protective benefits of prior collaboration, specifically whether former collaborators could more effectively judge the source of studied material. Finally, the use of a cumulative final recall task in Experiment 2 allowed us to investigate whether the post-collaborative recall effects of retrieval gains and collective memory persist in the face of subsequent learning. In both experiments, we replicated the standard collaborative inhibition effect, setting the stage for testing our novel questions.

Three novel findings emerged. First, we did not find that collaborative recall, relative to individual recall, benefited the subsequent new learning. Whether participants collaborated during initial recall attempts or they worked individually, new learning as well as collective memory for newly learned information were similar on a non-cumulative final recall task (Experiment 1) and cumulative final recall task (Experiment 2). Second, collaborative recall did provide an advantage over individual recall for filtering out prior list intrusions in noncumulative recall (Experiment 1), and former collaborators were better at correctly identifying words as having occurred on the initial list (Experiment 2). These related results suggest that the act of collaborative recall can provide individuals with additional, useful information that may be used to qualify or disqualify potential responses as erroneous and to distinguish learning episodes. Third, post-collaborative findings such as retrieval gains and the emergence of collective memory for initial learning did persist even as group members parted ways to study and recall new material in a cumulative testing context (Experiment 2).

While both experiments suggest that collaborative recall does not benefit subsequent learning, we find no evidence that collaborative recall impairs subsequent learning compared to individual recall. This is important to note, considering that collaborative recall impairs individual recall output during collaboration (i.e., the collaborative inhibition effect). Despite this, subsequent learning is similar between conditions. However, these findings do not address whether collaborative and individual recall exert a similar benefit, as this assessment requires an additional, re-study (or similar) condition, a comparison that was not the goal of the study. But this novel result, collaboration producing no detriment in subsequent new learning, provides a step for exploring this possibility in the future. ~~supporting the idea that collaborative and individual retrieval practices exert a similar benefit. We suggest this implication with caution given it is indicated via performance equivalency but note that future research exploring this further may be warranted~~.

The novel effects we did observe speak to the contextual value collaboration can provide and to the persistence of post-collaborative effects. First, both experiments demonstrate that collaborative recall helps individuals separate learning episodes. We attribute these findings to the additional social information available to collaborating participants, which can be used subsequently to disqualify covertly retrieved items as errors and appropriately qualify potential responses as correct. This contextual specificity explanation incorporates elements of the context change account described earlier (Szpunar et al., 2008); while the rich collaborative recall context may not be sufficient to boost subsequent learning under the conditions of this study, it does afford the formation of associations that can be used to isolate learning episodes (also see Wahlheim, 2015). In addition to being generally consistent with the context change account of test-potentiated new learning, our explanation has some overlap with the postretrieval monitoring account of how testing can reduce proactive interference via context change (Pierce et al., 2017). In brief, this account posits that testing can reduce proactive interference by providing distinctive episodes that can be used during the critical test to edit-out previously recalled non-target material. Pierce et al. (2017; Experiment 1) found support for this account; compared to non-tested participants, participants that were tested (via recall) during initial recall trials were better at attributing non-target words as old during a final free recall test. Our novel findings show that collaborative recall amplifies context change as indexed by greater protection from proactive interference following collaborative recall compared to individual recall.

Despite the reduction in prior list intrusions (Experiment 1) and improved source monitoring (Experiment 2), former collaborators did not experience downstream recall benefits compared to their nominal counterparts. How can we reconcile these findings with the context change account noted above? One possibility is that the surface-level features of these two retrieval conditions were similar enough that collaborative retrieval is valuable only insofar as it provides additional source information, rather than a completely different context or experience per se. With recall in both conditions facilitated by typing responses into an instant messaging platform, the retrieval interface was identical; the only contextual difference was the inclusion of unseen collaborative recall partners sending responses that must be monitored. It appears that this difference was enough to provide collaborators with useful source information downstream, but not enough to prompt recall potentiation. While speculative at this point, this explanation essentially puts “context change” on a spectrum, with the current design residing closer to context augmentation (different retrieval conditions) than to an all-out context shift (retrieval vs. re-study). Future research could test this idea by comparing retrieval conditions that vary in more or less extreme ways. For instance, in-person, face-to-face collaborative recall could provide a starker contextual divide between learning episodes.

Finally, the current results suggest that a subsequent encounter with semantically related material does not offset re-exposure benefits, that is, post-collaborative retrieval gains, or the formation of collective memory for the *originally studied* material. Both of these findings highlight the resilience of post-collaborative effects in the face of potential retroactive interference, adding a new dimension to a recent work documenting the persistence of post-collaborative effects across time in single-list designs (e.g., Blumen & Stern, 2011; Wei et al., 2024). At the same time, we did not observe any influence on subsequent learning – whether or not people collaborated to recall List 1 words, group members did not converge on recalling more of the same List 2 words (collective memory transfer). Moreover, prior collaborative retrieval did not influence category clustering downstream, nor did it influence collective organization transfer. This held across non-cumulative (Experiment 1) and cumulative recall (Experiment 2) contexts. As noted earlier, the expectation that prior collaboration would influence these particular outcomes was motivated by elements of the strategy change account. Based on the absence of any transfer effect, support for this account is lacking, at least in the context of the current study. Future research will be required to bolster this claim.

While the present study leveraged theoretical considerations, procedures, and materials rooted in a basic research tradition, this work has implications in more applied domains (e.g., see Kim et al., 2023, for a review on the relationship between cognitive and educational psychology). For example, educators often encourage collaboration (including collaborative recall) among students, who throughout a given day are encountering new, to-be-remembered material. Our results suggesting that collaborative recall provides individuals with information that can aid source monitoring may apply in such a context, especially if to-be-learned content shares overlapping features. Based on these results, for related study lists, we could also speculate that collaborative retrieval practice might provide advantages over individual retrieval practice, particularly in cases where old and new material may be difficult to disentangle but it is important to do so (e.g., learning important historical events that preceded WWI vs. WWII). This possibility underscores the value of focusing specifically on individual and collaborative retrieval conditions – independent of whether or not new learning is being potentiated by retrieval practice (vs. re-studying), individual and collaborative retrieval could exert different effects downstream.

Our findings regarding the resilience of post-collaborative retrieval gains and collective memory for original learning even in the face of new learning also raise interesting possibilities in educational domains and other settings (e.g., social networking sites). For example, if a collaborating group or small online community develops a highly homogenized but biased representation of the past, the collective may be resistant to change even as the constituent individuals encounter new but related material. Conversely, the persistence of post-collaborative retrieval gains could be a useful outcome to harness in classroom settings. Given the range of forces at play during collaboration (e.g., error pruning, cross-cueing), the influence of different retrieval conditions in such contexts could vary substantially as students engage with old and new material. These exciting prospects await further research.

Open Practices Statement

These experiments were not pre-registered. Data and code are available on OSF: https://osf.io/3m2jk/?view_only=a132c0398c57453bb12523b2b2d35c9b

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