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Influence of re-exposure and retrieval disruption during group collaboration on later individual recall

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This research examined the influence of prior group collaboration on later individual recall. We considered the negative effects of retrieval disruption and the potentially positive effects of re-exposure to additional items during group recall in the context of three hypotheses: the individual-strategy hypothesis, the combined-strategy hypothesis, and the group-strategy hypothesis. After a study phase and a brief delay, participants completed three successive recall trials in four different recall sequence conditions: III (individual-individual-individual), ICI (individual-collaborative-individual), CII (collaborative-individual-individual), and CCI (collaborative-collaborative-individual). Results show that repeated group recalls (CCI), and securing individual retrieval organisation prior to group recall (ICI), benefit later individual recall more than repeated individual recalls (III). These findings support the group-strategy hypothesis and the individual-strategy hypothesis, and have important implications for group versus individual learning practices in educational settings.

In educational settings, collaborative retrieval is often encouraged and sometimes assigned with the intent to improve subsequent individual exam performance. Some teachers assign discussion groups to elaborate and clarify the material discussed in class, while others create assignments or practice tests to be completed in small groups of two or three. However, the effects of such collaborative recall on later individual recall are not well understood and the scant findings on this issue have been mixed. More importantly, there is currently no theoretical framework that explains how, or predicts when, collaborative recall would enhance subsequent individual recall. As such, extant theories and findings are not sufficiently developed and, therefore, cannot be fruitfully applied to educational settings. The current research was designed to fill this gap in the literature.

In contrast to the limited literature on the effects of collaborative recall on subsequent individual recall, many recent investigations have focused on identifying the possible mechanism that might underlie *collaborative inhibition* that occurs during collaborative recall. Collaborative inhibition is the counterintuitive finding that groups retrieve fewer items than the non-overlapping items retrieved by the same number of individuals working alone, termed as nominal groups (B. H. Basden, Basden, Bryner, & Thomas, 1997; Weldon & Bellinger, 1997). The findings from these studies point to the disruption of individual retrieval strategies during group recall as the principal basis for reduced memory performance in collaborating groups relative to nominal groups (Andersson, Hitch, & Meudell, 2006; Andersson & Rönnberg, 1995, 1996, 1997; B. H. Basden et al., 1997; B. H. Basden, Basden, & Henry, 2000; Finlay, Hitch, & Meudell, 2000; Takahashi & Saito, 2004; Weldon & Bellinger, 1997; Weldon, Blair, & Huebsch, 2000).

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Disruption of individual retrieval strategies during group collaboration can potentially impair later individual recall. However, group collaboration also re-exposes an individual to additional study items recalled by other group members (that the individual him/herself did not retrieve). In this way, re-exposure can enhance individual recall after group collaboration. In this study, we examined how these distinct and opposite processes that occur during group collaboration modulate later individual recall.

In the next section we describe the retrieval disruption account of collaborative inhibition in more detail, followed by a section on the effects of repeated testing that show improvements in individual memory with repeated retrieval trials (Gates, 1917). These two phenomena will serve as springboards for testing the two critical mechanisms—retrieval disruption of studied information and re-exposure to studied information—that can determine when and how group collaboration can improve later individual memory.

COLLABORATIVE INHIBITION

The widely accepted account of the collaborative inhibition effect is that this phenomenon results from the disruption of individual retrieval strategies (B. H. Basden et al., 1997). This account is an extension of an explanation of the *part-list cueing inhibition* phenomenon, put forth by the same authors (D. R. Basden & Basden, 1995; D. R. Basden, Basden, & Galloway, 1977). Part-list cueing inhibition is the counterintuitive finding that individual recall is impaired when a subset of the to-be-remembered items are provided as cues during retrieval. According to D.R. Basden and colleagues (1977, 1995), the presence of cues disrupts individual retrieval plans and leads participants to adopt less organised (and less effective) retrieval strategies to recall only non-cued items. In the same way, cues provided by the other group members' output during group retrieval is thought to disrupt individual retrieval plans and result in less productive retrieval of the remaining items (B. H. Basden et al., 1997; Weldon & Bellinger, 1997).

The retrieval disruption account of collaborative inhibition is supported by the evidence that both part-list cueing inhibition and collaborative inhibition disappear when cues (or group members, respectively) are removed—presumably because individuals can return to their original retrieval plans (D. R. Basden & Basden, 1995; D. R. Basden et al., 1977; Finlay et al., 2000). Specifically, the items that are lost during recall when part-list cues are provided, reappear when participant are asked to subsequently recall the same items in the absence of cues (D. R. Basden et al., 1977). Similarly, the items lost during group retrieval reappear when participants are asked to subsequently recall the same items alone (Finlay et al., 2000). The retrieval disruption account of collaborative inhibition is also supported by the evidence that both part-list cueing inhibition and collaborative inhibition are more likely in situations where organisational retrieval strategies are particularly important for successful recall—as is the case when retrieving a categorised study list composed of many items from the same category. For example, D. R. Basden and Draper found that part-list cueing inhibition was greater for a categorised list composed of 15 instances from 6 different categories than for a categorised list composed of 6 instances from 15 different categories (D. R. Basden & Draper, 1973). Likewise, B. H. Basden and colleagues (1997) found collaborative inhibition for a categorised list composed of 15 instances from 6 different categories but did not find collaborative inhibition for a categorised list composed of 6 instances from 15 different categories. These parallel findings make sense, because a larger set of exemplars require more organisation than a smaller set that can be organised more easily within each category. For these reasons, collaborative inhibition is considered to be a function of retrieval strategy disruption.

The retrieval disruption account of collaborative inhibition is also supported by the evidence that recall is lowered during group collaboration regardless of whether a free-for-all (Weldon & Bellinger, 1997) or a turn-taking procedure is encouraged during group recall (B. H. Basden et al., 1997). In addition, social loafing does not contribute significantly to lowered recall during collaboration because even when these factors are manipulated (or controlled), collaborative inhibition persists (Weldon et al., 2000). In contrast, collaborative inhibition disappears when participants are unable to see or hear the other group members' responses (Wright & Klumpp, 2004).

COLLABORATIVE INHIBITION AND SUBSEQUENT INDIVIDUAL RECALL

Group collaboration during first recall can potentially produce three different consequences on subsequent individual recall. Considering that group recall disrupts individual retrieval strategies and reduces individual output compared to nominal groups, it is possible that prior group recall also produces a negative effect on subsequent individual recall. In this case, subsequent individual recall would be worse after prior group recall compared to prior individual recall. There is currently little evidence to support this possibility. It is also possible that while individual organisation might not be recovered following collaborative recall, individuals carry benefits of re-exposure to additional stimuli produced by other group members to later individual recall. This offsetting process can result in comparable individual recall following collaborative or individual recall. Such comparable effects can also result from only the recovery of individual retrieval strategies and some evidence is taken as support for this latter possibility (Finlay et al., 2000). A third possibility is that while retrieval disruption during group retrieval impairs individual output and lowers group performance, individual retrieval strategies are recovered during subsequent individual recall and this is further augmented by the re-exposure benefits that accrued during previous group recall. On this reasoning, later individual recall can improve following prior group recall compared to prior individual recall. There is some evidence to support this possibility as well (B. H. Basden et al., 2000; Finlay et al., 2000; Weldon & Bellinger, 1997). However, while a couple of studies report benefits of prior group collaboration on later individual *cued* recall (B. H. Basden et al., 2000; Finlay et al., 2000), these findings have been observed in *free* recall in one study (Weldon & Bellinger, 1997) but not in another (Finlay et al., 2000).

In the present study we examined the effects of prior group collaboration on later individual memory using a free recall task because the negative effects of the retrieval disruption mechanism associated with group retrieval are usually smaller or nonexistent during cued retrieval (Clark, Hori, Putnam, & Martin, 2000; Finlay et al., 2000; Rajaram & Pereira-Pasarin, 2007). Thus, the free recall task is better suited for exploring the issues raised here. In light of the mixed findings noted above, we need to better understand whether prior group recall (and the collaborative inhibition therein) can impair, enhance, or have no effect on individual recall after group collaboration. These issues also have particular relevance in an educational setting because the ultimate test of learning almost always involves individual retrieval, regardless of whether a student participated in a study group or prepared for an exam alone. We addressed these issues by testing the differential effects of prior individual recall or prior group recall on final individual recall. We now turn to a review of the relevant studies on the effects of repeated individual retrieval on later individual memory.

REPEATED INDIVIDUAL RETRIEVAL: THE TESTING EFFECT AND HYPERMNESIA

In contrast to the scant and mixed effects of prior group retrieval on subsequent individual retrieval described above, the evidence regarding the effects of repeated individual retrieval are ample and consistent: An individual practice test or retrieval session clearly improves subsequent individual memory, a phenomenon that is typically referred to as a testing effect. This testing effect has been observed with words, pictures, and prose and is greater in free recall (the task we used in our study) than in cued recall and recognition (see Roediger & Karpicke, 2006a for a review). In the present study, we assessed hypermnesia (Payne, 1987; Weldon & Bellinger, 1997; Wheeler & Roediger, 1992), a related measure of increased recall across recall trials, to examine whether repeated testing led to an increase in recall. We will discuss this measure in more detail in the results section.

Interestingly, two recent studies (Roediger & Karpicke, 2006b; Wheeler, Ewers, & Buonanno, 2003) suggest that while repeated individual *studying* leads to better individual recall after a short delay (5 minutes), repeated individual *recall* results in superior memory relative to repeated individual studying after a 2-day and a 1-week delay (Roediger & Karpicke, 2006b; Wheeler et al., 2003). Prior individual retrieval may be more effective than prior individual studying because repeated studying promotes memory acquisition while repeated retrieval strengthens some aspects of the retrieval process itself (Wheeler et al.,

2003). In other words, prior individual retrieval might be more effective than prior individual studying because, consistent with the transfer-appropriate processing principle (Morris, Bransford, & Franks, 1977; Roediger, Weldon, & Challis, 1989), repeated retrieval employs similar cognitive processes as those engaged by the subsequent memory test (Roediger & Karpicke, 2006b).

An extension of the transfer-appropriate processing account to the effects of prior group retrieval on later individual retrieval implies that individual retrieval will benefit from prior group retrieval to the extent that the retrieval strategies developed during prior group retrieval are employed during final individual retrieval. From this perspective, prior group retrieval may not consistently enhance final individual retrieval unless the group product is first strengthened through repeated group retrieval. Note that this transfer-appropriate processing account is not a competing alternative to the retrieval disruption account of collaborative inhibition. Rather, it could provide a complementary explanation for the effects of prior group retrieval on subsequent individual retrieval.

Thus, mechanisms underlying group retrieval might not match or might even disrupt the mechanisms that guide individual retrieval. However, group retrieval when carried out more than once, has the potential to enhance subsequent individual memory. This is because under repeated group retrieval conditions, participants are exposed to additional stimuli produced by other group members more than once, and are thus in a better position to strengthen the benefits from collaboration compared to a single, prior group retrieval. Consistent with this prediction, preliminary evidence suggests that group retrieval strategies can be rapidly established and may be more stable and enduring than individual retrieval strategies (Weldon & Bellinger, 1997). In particular, when the recall of unrelated items is assessed across repeated retrieval trials, group recall (collaborative-collaborative) can be more consistently organised than individual recall (individual-individual) (Weldon & Bellinger, 1997). Thus, repeated individual retrieval can benefit individual memory for one set of reasons (securing one's own retrieval strategies) and repeated group retrieval can benefit later individual memory for another set of reasons (benefiting from re-exposure to others' output). Given the specific properties of group retrieval and individual retrieval, it might be possible to exploit the benefits from both types of retrieval in such a way as to optimise final individual memory. Little evidence is currently available on the relative benefits of repeated retrievals carried out by groups versus individuals, and the possible benefits of combining the two types of retrieval on final individual recall. Current research fills this important gap.

Specifically, the current study included three successive recall trials (Recall 1, Recall 2, and Recall 3) that were completed in one of four retrieval sequence conditions: the individual-individual-individual (III) condition, the individual-collaborative-individual (ICI) condition, the collaborative-individual-individual (CII) condition, and the collaborative-collaborative-individual (CCI) condition. We will articulate the relative efficacy of these recall combinations in the form of three different hypotheses.

The individual-strategy hypothesis

It is possible that strengthening one's own retrieval strategies through an initial individual retrieval trial protects against the disruptive effects associated with group retrieval. Such strengthened organisation can then be augmented with the benefits of group retrieval (hearing the other group members' output) during second, group recall. This is because recall of non-redundant items by other group members provides re-exposure to additional items. We will refer to this proposition as the *individual-strategy hypothesis* because it implies that individual retrieval strategies must be secured before individual memory can benefit from group collaboration. In this case, an individual recall trial followed by a group recall trial should enhance final individual recall performance (IC**I** condition > II**I** condition). This hypothesis also suggests that collaboration during first recall (before the individual strategy has coalesced) will produce poorer final individual recall (CII) compared to the final individual recall in the ICI recall sequence.

The combined-strategy hypothesis

Taking advantage of an initial group retrieval trial may also aid subsequent retrieval of the material in ways that may benefit subsequent individual recall. This is because re-exposure (or hearing the

other group member's output) can provide an increased set of retrieved items for later individual recall if Recall 1 takes place in a group setting. This augmented set can then be further strengthened when Recall 2 is individually completed. We will refer to this proposition as the *combined-strategy hypothesis* because it suggests that benefits from re-exposure to additional items (during Recall 1) have to be fed into the development of individual retrieval strategies (during Recall 2) for final individual retrieval to benefit from prior group collaboration. In this case, an initial group retrieval trial followed by two individual retrieval trials would generate better final individual memory performance compared to three individual retrieval trials (CI**I** condition > III condition). Note that both individual and group strategies are reinforced in the ICI and CII conditions but at different stages. Thus, our design allows us to directly evaluate the importance of the relative order of individual organisation versus re-exposure to be maximally effective (IC**I** condition vs. CI**I** condition).

Group-strategy hypothesis

Finally, it is possible that benefits of prior group discussion on later individual memory depend not only on being re-exposed to other group members' non-redundant responses but also being able to integrate this input with repeated collaboration. We refer to this proposition as the *group-strategy hypothesis* because it suggests that group strategies must be developed and strengthened before benefits of prior group collaboration can be observed on individual memory. From this perspective, repeated group retrieval provides a better opportunity for strengthening the group organisational strategy as well as for assimilating items from re-exposure and predicts best individual recall following repeated group retrieval trials compared to the other combinations of individual and group retrieval trials (CC**I** condition > IC**I** and CI**I** conditions). Further, repeated group retrieval is predicted to be better than repeated individual retrieval because participants are able to organise other group members' responses, and these additional processes generate benefits in recall over and above the retrieval match that operate in repeated individual retrieval (CC**I** condition > III condition). These considerations motivated the current research.

METHOD

Participants

A total of 192 undergraduates from Stony Brook University participated in this study for partial course credit. All participants provided written consent and were debriefed at the completion of the experiment.

Design

Type of retrieval sequence (III, ICI, CII, and CCI) was the between-subjects factor. There were 16 three-person groups in each retrieval sequence condition (i.e., total of 48 participants in each retrieval sequence condition). Participants were randomly assigned to a retrieval sequence condition as they arrived in the lab. Participants in the III condition were also randomly assigned to nominal groups as they arrived in the lab.

Materials

Study items were composed of 54 unrelated words (40 targets, 7 primacy buffers, 7 recency buffers) from Clark and Paivio's recent extension of the Paivio, Yuille and Madigan word norms (Clark & Paivio, 2004; Paivio, Yuille, & Madigan, 1968). Study items were concrete ($M = 6.76$) nouns with high imageability ($M = 6.43$) and a mean frequency of 1.67. Two randomly ordered study list sequences were created to avoid order effects. Study items were presented with an LCD projector.

Procedure

In the study phase, participants were asked to provide a pleasantness rating of the meaning of each word on a scale from 1 to 5 (*very unpleasant* to *very pleasant*). No mention of a subsequent memory task was made. Each word was displayed for 6 seconds. Immediately after the study phase, participants completed a distractor task for 7 minutes that involved recalling as many US cities as possible. In the retrieval stage that followed, Recall 1 and Recall 2 were completed either individually or in groups of three individuals depending on the retrieval sequence condition.

Recall 3 was always individually completed. Recall occurred in separate booths in the laboratory with closeable doors for each booth so that group responses could not be heard by participants outside the group. During an individual recall trial, participants were given 10 minutes to recall as many words as they could remember in any order. During a group recall trial, participants were given 10 minutes to collaboratively recall as many items as they could remember in any order, and all participants were encouraged to participate. One person was randomly asked to serve as the scribe for each group (Finlay et al., 2000; Weldon & Bellinger, 1997). A 5-minute break was given between Recall 1 and 2, and Recall 2 and 3.

RESULTS AND DISCUSSION

The individual and group recall data were scored in four ways. First, correct recall scores were computed for each recall trial in each retrieval condition (III, ICI, CII, and CCI). Further, where appropriate, individual recall scores were used to compute nominal group recall scores by pooling the non-redundant items from three individual recall outputs into one score (B. H. Basden et al., 1997; Weldon & Bellinger, 1997). Second, changes in the levels of recall across recall trials were computed in the form of difference or hypermnesia scores for each participant. Third, hypermnesia scores were broken down into reminiscence (recovered items) and forgetting (lost items) from one recall trial to the next (Finlay et al., 2000; Payne, 1987; Weldon & Bellinger, 1997). Finally, where appropriate, paired frequencies were computed to assess subjective organisation across recall trials (Finlay et al., 2000; Weldon & Bellinger, 1997). Two-tailed significance tests with an alpha level of .05 were used for all comparisons, unless noted otherwise.

Our main goal in this study concerned the effects of prior group or individual recalls on final individual recall. However, we will first present the findings on the status of the collaborative inhibition effect to demonstrate the replications of key findings from previous studies. We will then proceed to the findings on final individual recall across the four retrieval conditions. Following this, we will present the effects of hypermnesia, reminiscence, and forgetting across recall trials within each condition to gain a finer-grained insight into the recall performance. We will conclude with findings on the organisational measure of paired frequency across recall trials.

Collaborative inhibition

The presence or absence of collaborative inhibition during Recall 1 and Recall 2 was assessed by contrasting collaborative group performance with nominal group performance (i.e., the pooled recall of non-redundant items produced by three individuals working alone) at each of the two recall stages. The proportions of correctly recalled items for the nominal groups where a direct comparison was possible with the collaborative groups are shown in Figure 1 and also noted in Table 1.

As predicted, collaborative inhibition was present during Recall 1 because collaborative group performance in the **C**II condition (.54) and the **C**CI condition (.56) was found to be significantly lower than nominal group performance in the **I**II condition (.70), $t(30) = 3.98$, $SE = .04$ and $t(30) = 3.87$, $SE = .04$, respectively. Collaborative inhibition was also observed when collaborative group performance in the **C**II condition and the **C**CI condition were compared to nominal group performance in the **I**CI condition (.68), $t(30) = 3.94$, $SE = .04$ and $t(30) = 3.89$, $SE = .03$, respectively. Consistent with our expectations, nominal group recall in the **I**II and **I**CI conditions did not differ ($t < 1$) and collaborative recall in the **C**II and **C**CI conditions did not differ ($t < 1$). The presence of collaborative inhibition in all four possible comparisons during Recall 1 nicely replicates prior research (e.g., B. H. Basden et al., 1997; Weldon & Bellinger, 1997).

During Recall 2 it was possible for both individual and group recalls to be modulated by the prior history of recall (individual or collaborative). Thus, assessment of collaborative inhibition during Recall 2 allowed us to see whether prior recall history can eliminate or even reverse this effect. In our first comparison we found that nominal group performance in the I**I**I condition (.74) was significantly higher than collaborative group performance in the I**C**I condition (.65), $t(30) = 2.89$, $SE = .03$. Thus, even when a prior individual recall trial enabled participants to secure their own organisation, this was not sufficient to eliminate collaborative inhibition during second group recall. We next compared nominal group performance in the I**I**I condition (.74) with collaborative group performance in the

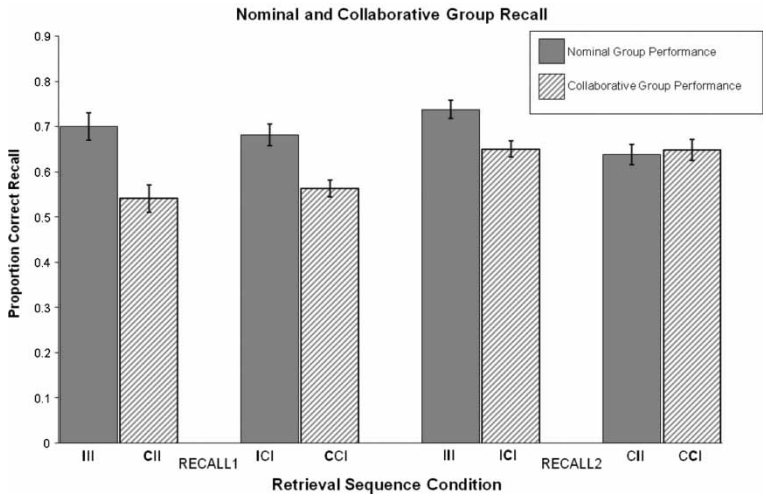

Figure 1. Mean proportion of correct recall for nominal and collaborative groups. Data from nominal and collaborative groups during Recall 1 in the **I**II and **I**CI condition were compared to the **C**II and **C**CI condition. Data from nominal and collaborative groups during Recall 2 are displayed when the prior history of recall was equated (i.e., I**I**I versus I**C**I and C**I**I versus C**C**I).

C**C**I condition (.65), and collaborative inhibition was once again significant, $t(30) = 3.25$, $SE = .03$. This finding suggests that collaborative inhibition is a robust phenomenon that cannot be offset with repeated group retrieval even when, as we will describe in detail in the next section, repeated group retrieval (CCI) improves final individual recall compared to the III and CII conditions. Interestingly, collaborative inhibition disappeared in one crucial comparison during Recall 2—between nominal group recall in the C**I**I (.64) condition and collaborative group recall in the C**C**I condition (.65), $t(30) = .44$, $SE = .03$. The absence of collaborative inhibition here is associated with lowered nominal group recall (C**I**I: .64) and not with higher collaborative group recall, as confirmed by a significant reduction of nominal group recall in the C**I**I condition compared to the **I**II (.74) condition, $t(30) = 3.31$, $SE = .03$ (see Figure 1). A similar pattern was reported in another study where category cued recall performance was assessed across two recall trials (B.H. Basden et al., 2000); nominal group performance during the second recall for participants that had recalled in a group previously (CI condition) was lower than nominal group performance for participants that had recalled individually (II condition).

TABLE 1
Proportions of correctly recalled items for individuals, collaborative groups and nominal groups

Recall condition	*Correct recall*	*Nominal recall*
Individual-Individual-Individual (III)		
Recall 1 (**I**II)	.40	.70
Recall 2 (I**I**I)	.45	.74
Recall 3 (II**I**)	.49	–
Individual-Collaborative-Individual (ICI)		
Recall 1 (**I**CI)	.37	.68
Recall 2 (I**C**I)	.65	–
Recall 3 (IC**I**)	.52	–
Collaborative-Individual-Individual (CII)		
Recall 1 (**C**II)	.54	–
Recall 2 (C**I**I)	.45	.64
Recall 3 (CI**I**)	.46	–
Collaborative-Collaborative-Individual (CCI)		
Recall 1 (**C**CI)	.56	–
Recall 2 (C**C**I)	.65	–
Recall 3 (CC**I**)	.55	–

A reduction in nominal group recall during Recall 2 in the CII condition implies that the initial group recall trial disrupted individual retrieval strategies and lowered subsequent individual recall. This possibility can be evaluated by comparing the levels of *individual* recall (i.e., not nominal group recall) during Recall 2 in the I**I**I condition (.45) with the C**I**I condition (.45) (see Table 1). These individual recall levels do not differ, even though we just considered the possibility that disruptive effects of initial group recall might have lowered nominal group recall during Recall 2 in the C**I**I condition. Instead, these equivalent levels of individual recall in I**I**I and C**I**I conditions suggest either only the recovery of individual retrieval strategies or the offsetting effects between impaired individual retrieval strategies and re-exposure benefits in Recall 2 of the C**I**I condition. When the individual recall

scores in the C**I**I condition (.45) (which did not go down compared to the **I**I**I** condition) are considered along with the nominal group recall scores (.64) derived from them (which did go down), lowered nominal group recall indicates the presence of fewer non-redundant responses in the individual recall protocols during Recall 2 in the C**I**I condition. In other words, during Recall 2 in the C**I**I condition, participants likely relied less on their individual retrieval strategies and more on the recall of the additional items produced by other group members previously. This resulted in the production of more redundant responses across group members, thereby lowering nominal group recall but retaining a similar level of individual recall in comparison to the **I**I**I** condition. Thus, these findings support the possibility that re-exposure to items during group collaboration can influence later individual recall.

Finally, we consider the size of the collaborative inhibition effect across Recall 1 and Recall 2. The lack of independence in recall responses between Recall 1 and Recall 2 precludes a statistical analysis of the size of collaborative inhibition across recall trials. But there is a numerical *decrease* in the size of collaborative inhibition from Recall 1 to Recall 2. Specifically, during Recall 1, nominal group performance was .70 in the **I**I**I** condition and collaborative group performance was .56 in the **C**C**I** condition producing a 14% collaborative inhibition effect. During Recall 2, nominal group performance was .74 in the **I**I**I** condition and collaborative group performance was .65 in the C**C**I condition, producing a 9% collaborative inhibition effect. This difference arises even though there was some increase in the nominal group performance from Recall 1 to Recall 2 (.70 versus .74). This trend in the *decrease* in collaborative inhibition from Recall 1 to Recall 2 suggests that repeated group recalls may reduce but not eliminate the retrieval disruption mechanism that is associated with group recall.

Together, the key findings concerning collaborative inhibition may be summarised as follows: (1) we observed robust replications of the collaborative inhibition effect during Recall 1; (2) collaborative inhibition persisted during Recall 2 despite the possibility that previous individual recall enabled the securing of one's own retrieval organisation; (3) collaborative inhibition was also not offset by the opportunity to integrate other group members output through repeated group collaboration; and (4) initial group collaboration reduced later nominal group recall during Recall 2, and this finding coupled with equivalent *individual* recall between the C**I**I and **I**I**I** conditions in Recall 2 suggests that re-exposure to additional items during collaboration can influence later individual recall. We now turn to the measure of main interest in our study—the effects of prior individual and/or group recall on final individual recall.

Final individual recall

The proportions of correctly recalled items in each condition are summarised in Table 1. A one-way ANOVA for final individual recall (Recall 3) in the four retrieval sequence conditions (III, ICI, CII, and CCI) was significant $F(3, 188) = 4.88$, $MSE = .63$. The specific differences between final individual recall performance in each pair of conditions was assessed in six contrasts and will be discussed in the context of the individual-strategy hypothesis, the combined-strategy hypothesis, and the group-strategy hypothesis.

First, we evaluated the individual-strategy hypothesis by comparing the proportions of correctly recalled items during final individual recall (Recall 3) between the **I**I**I** condition (.49) and the IC**I** condition (.52). Although recall in the IC**I** condition was higher than in the **I**I**I** condition, this advantage failed to be significant, $t(94) = 1.13$, $SE = .03$. Thus, the opportunity to secure individual retrieval strategies through an initial individual recall trial did not help participants to benefit from re-exposure during later group recall (Recall 2). Although the numerical trend here does not provide clear support for the individual-strategy hypothesis, support for this hypothesis does emerge in the direct comparison between the IC**I** condition (individual strategy) and the C**I**I condition (combined strategy) presented later in this section. In addition, the hypermnesia and reminiscence effects discussed in the next section provide further support for the individual-strategy hypothesis.

As a test of the combined-strategy hypothesis, we compared recall in the C**I**I condition (.46) with recall in the **I**I**I** condition (.49) during Recall 3 and found that this difference also failed to be significant, $t(94) = 1.00$, $SE = .03$. If anything, recall in the C**I**I condition was numerically lower than recall in the **I**I**I** section. This finding refutes the combined-strategy hypothesis and suggests that the group strategies (and re-exposure) that

accrued during the initial group retrieval trial were not readily integrated with subsequent individual retrieval strategies in the CII condition.

While considering the efficacy of combining individual and collaborative recalls prior to the final individual recall, we also compared the ICI condition (.52) and the CII condition (.46) to evaluate the relative benefits of the individual retrieval strategy (securing individual organisation *before* receiving input from others during the second, collaborative recall) versus the combined retrieval strategy (re-exposure from others first and then incorporating them in the second individual recall) hypothesis. This comparison showed significantly superior final individual recall (Recall 3) in the ICI condition compared to the CII condition, $t(94) = 2.34$, $SE = .02$ (Cohen's $d = .48$; Cohen, 1992). This finding supports both the idea that securing one's own organisation prior to group collaboration is beneficial for later individual memory and the idea that initial collaboration can be harmful to retaining one's own individual organisation. This is because in Recall 3, the recall in the ICI condition (.52) was numerically, though not statistically, higher than in the III condition (.49), and because recall in the CII condition (.46) was numerically, though not statistically, lower than the III condition (.49). Together, these findings provide some evidence in favour of the individual-strategy hypothesis but little evidence for the combined-strategy hypothesis.

We now discuss findings to evaluate the group-strategy hypothesis. The proportion of correctly recalled items during Recall 3 was .55 in the CCI condition. A follow-up contrast revealed that final individual recall performance was significantly greater in the CCI condition than in the III condition (.49), $t(94) = 2.48$, $SE = .03$ ($d = .51$). This finding suggests that repeated group recall trials are important for taking advantage of the re-exposure benefits of group recall during final individual recall. In other words, the benefit in final individual recall in the CCI condition (relative to the III condition) but not in the CII condition (as discussed above during the consideration of the combined-strategy hypothesis) supports the group-strategy hypothesis, and suggests that group strategies must be secured and integrated before benefits of prior group discussion can be observed on subsequent individual memory.

The above analyses indicate that repeated group retrieval trials generate benefits on final individual recall that are greater than those associated with repeated individual retrieval trials (III condition). In order to directly compare the benefits from repeated group retrieval trials on final individual retrieval with the benefits from a single group retrieval trial, we compared Recall 3 in the CCI versus the CII conditions and the CCI versus the ICI conditions. The contrast between the CCI condition and the CII condition was significant, $t(94) = 3.87$, $SE = .02$ ($d = .79$), and while a trend in this direction was also observed for the comparison between, the CCI condition and the ICI condition, this difference failed to reach significance, $t(94) = 1.46$, $p = .15$.

Together, a lack of a difference in final individual recall (Recall 3) between CII versus III conditions and ICI versus III conditions described earlier, and the statistically significant superiority of the final individual recall in the CCI condition compared to the III condition and CII condition, provide converging support for the group-strategy hypothesis. In fact, in the CCI condition, final *individual* recall (.55) came quite close to initial *group* recall (.56), a finding we will discuss again in the next section on hypermnesia. These patterns together support a novel finding in group memory research—repeated group recall is an important factor for observing benefits of prior group recall on subsequent individual recall.

Hypermnesia

As noted in the introduction, benefits of prior retrieval on later retrieval—known as the testing effect in some cases and hypermnesia in other cases—constitute one of the most replicable effects in memory research. To assess improvement in performance across recall trials, we calculated the difference (or hypermnesia) scores for Recall 1 to Recall 2, Recall 2 to Recall 3, and finally for Recall 1 to Recall 3. The hypermnesia scores are shown in Table 2. Experiments that are specifically designed to examine the testing effect typically compare a repeated retrieval condition to a repeated study condition (or one retrieval sequence is compared to different type of retrieval sequences, e.g., Roediger & Karpicke, 2006a). However, our design (see also Weldon & Bellinger, 1997) involved repeated recall trials where the same set of participants attempted recall of the same set of studied items in all three recall trials. Thus, improvement across recall trials was

TABLE 2
Proportions of hypermnesia, reminiscence, and forgetting across recall trials

Recall condition	*Recall 1 to Recall 2*	*Recall 2 to Recall 3*	*Recall 1 to Recall 3*
Individual-Individual-Individual (III)			
Hypermnesia	.04	.05	.09
Reminiscence	.08	.08	.13
Forgetting	.04	.03	.04
Individual-Collaborative-Individual (ICI)			
Hypermnesia	.28	−.13	.15
Reminiscence	.31	.05	.20
Forgetting	.03	.18	.05
Collaborative-Individual-Individual (CII)			
Hypermnesia	−.09	.01	–.08
Reminiscence	.04	.05	.06
Forgetting	.13	.04	.14
Collaborative-Collaborative-Individual (CCI)			
Hypermnesia	.09	−.10	−.01
Reminiscence	.11	.04	.10
Forgetting	.02	.13	.11

assessed in terms of hypermnesia, or the net increase in recall from one recall trial to the next.

The significance in improvement across individual recall trials (III condition) was first assessed in three single-sample t-tests, Recall 1 to Recall 2, Recall 2 to Recall 3, and Recall 1 to Recall 3 (**III**, **III** and **III**). As expected, hypermnesia was significant from Recall 1 to Recall 2, $t(47) = 5.19$, $SE = .01$, Recall 2 to Recall 3, $t(47) = 5.45$, $SE = .01$, and Recall 1 to Recall 3, $t(47) = 7.90$, $SE = .01$. This pattern nicely replicates previous research (Payne, 1987; Roediger & Karpicke, 2006a).

Next, we assessed the relative benefits of the intervening trials—individual recall or collaborative recall in Recall 2—by conducting a planned comparison of difference scores between Recall 1 and Recall 3 across the **III** condition and the **ICI** condition. Hypermnesia was significantly higher in the **ICI** (.15) than in the **III** (.09) condition), $t(94) = 3.77$, $SE = .02$. Higher levels of hypermnesia in the ICI condition compared to the III condition might seem inconsistent with the lack of a difference in final individual recall performance between the II**I** condition and the IC**I** condition, reported earlier in the Final individual recall section. These two findings can be reconciled by examining the non-significant, albeit numerical, difference in individual recall during Recall 1 (.40 in **III** condition and .37 in the **ICI**), $t(94) = 1.33$, $SE = .02$. In other words, intervening collaboration seems to improve final individual recall to a greater extent (likely because of the re-exposure effects during group recall) if individual retrieval strategies have been secured through an initial individual recall trial prior to group collaboration.

In the previous section on final individual recall, we reported the beneficial effects of repeated group retrieval on final individual recall (the CCI condition). These benefits can also be viewed in terms of the hypermnesia effect by comparing the change in correct recall from Recall 1 to Recall 3 in the **CII** condition (−.08) with the **CCI** condition (−.01); this difference was statistically different, $t(94) = 4.97$ $SE = .02$. In other words, final individual recall was worse than initial group recall in the **CII** condition but final individual recall was similar to initial group recall in the **CCI** condition. As noted earlier, individual performance during Recall 3 in the **CCI** condition (.55) was similar to group performance during recall 1 (.56). Together, these hypermnesia findings further support the group-strategy hypothesis.

We also assessed one particular contrast in the difference scores for Recall 1 to Recall 2—between **CCI** and **III**—although it was not of a priori interest. This contrast showed that groups exhibit more hypermnesia (.09 in the **CCI** condition) than did individuals (.04 in the **III** condition), $t(94) = 3.58$, $SE = .01$. To our knowledge, this is the first direct empirical evidence for cross-cueing (i.e., that group collaboration facilitates additional recall) during group recall because groups benefited from repeated retrievals more than individuals working alone (Finlay et al., 2000; Meudell, Hitch, & Boyle, 1995; Meudell,

Hitch, & Kirby, 1992; Weldon & Bellinger, 1997). The notion of cross-cueing is different from the mechanism of re-exposure we have tested, in that group collaboration not only provides re-exposure of the items recalled by the other members of the group (the re-exposure effect) but can also trigger recall of other items in response to having heard the mention of an item by another group member (the cross-cueing effect). Weldon and Bellinger (1997) failed to find this effect under similar experimental conditions although hypermnesia effects in their study were smaller, making it difficult to detect possible differences. We are currently exploring the reliability of this effect.

In sum, the hypermnesia analyses support the group-strategy hypothesis—group responses strengthened by repeated retrieval can benefit later individual memory. In addition, these analyses suggests that a single group recall trial can also benefit final individual recall provided that it is preceded by an initial individual recall trial. This finding is consistent with the individual-strategy hypothesis, which suggests that an initial individual recall trial protects against the disruptive effects associated with group retrieval and permits individuals to benefit from re-exposure during intervening group recall.

Reminiscence and forgetting

We further examined the pattern of change in the levels of recall across recall trials by breaking down the difference scores into items that were recovered (reminiscence) and items that were lost (forgotten) from Recall 1 to Recall 2, from Recall 2 to Recall 3, and from Recall 1 to Recall 3 (see Table 2). In cases where we observed hypermnesia, reminiscence was higher than forgotten items, resulting in a net increase in recall across recall attempts. The interesting comparisons here document how collaboration modulated reminiscence and forgetting across different retrieval conditions.

We examined the effects of intervening collaboration on the changes in individual recall by conducting a planned comparison between the lost items (forgetting) on one hand and recovered items (reminiscence) on the other hand from Recall 1 to Recall 3 in the **ICI** condition compared to the **III** condition. This comparison is of interest because the intervening collaboration in the **ICI** condition can improve final individual recall by providing re-exposure to additional items (leading to an increase in reminiscence). But items produced during the intervening collaboration can also disappear in final individual recall for various reasons (such as the individual contributions did not fare well during collaborative recall). These potential changes in the **ICI** condition were compared to the baseline changes in the **III** condition where no collaboration intervened. As suggested by the net increase in hypermnesia in the **ICI** condition over the **III** condition from Recall 1 to Recall 3, reminiscence was also significantly higher in the **ICI** condition (.20) than the **III** condition (.13), $t(94) = 4.93$, $SE = .01$. In other words, while reminiscence increased in the baseline **III** condition replicating previous studies (see Payne, 1987 for a review); it increased significantly more in the **ICI** condition (see also Finlay et al., 2000).

Next, we examined whether the intervening collaboration also led to possible pruning of individual responses, in which case forgetting in the **ICI** condition from Recall 1 to Recall 3 would be greater than the **III** condition. We obtained some forgetting in the **ICI** condition (.05) but, interestingly, this did not differ from the baseline rate of forgetting in the **III** condition (.04), $t(94) = 1.27$ $SE = .01$. Together, these findings show that the disruptive effects of collaborative processes do not necessarily lead to a change in final individual forgetting, and are also consistent with the group-strategy hypothesis in that re-exposure during second, collaborative recall increased final individual recall in the ICI condition compared to the III condition. Furthermore, these findings also provide support for the individual-strategy hypothesis, in that if the individual recall organisation is first secured (as was the case in the ICI condition), forgetting per se of items does not exceed the rate of forgetting that occurs in the baseline condition of retrieval attempts without any collaborative intervention (as in the **III** condition.).

The effects of intervening collaboration can also be assessed by comparing reminiscence and forgetting from Recall 1 to Recall 3 across the **CII** condition and the **CCI** condition. Put another way, this comparison will show how reminiscence and forgetting contribute to the beneficial effects of repeated group retrievals on final individual recall discussed in the previous sections on final individual recall and hypermnesia. From Recall 1 to Recall 3, reminiscence in the **CCI** condition (.10) was significantly higher than in the **CII** condition (.06), $t(94) = 2.94$, $SE = .01$. These findings are

consistent with the group-strategy hypothesis and suggest that repeated group recall trials allow participants to recover more items from an initial group recall trial during later individual recall. Converging on this pattern, forgetting from Recall 1 to Recall 3 was .14 in the **CII** condition and .11 in the **CCI** and this difference was also significant, $t(94) = 2.38$, $SE = .02$. These findings suggest that repeated group recall trials lead to less forgetting and more reminiscence from the initial group recall trial than from a combination of a single group recall following by a single individual recall. These findings together suggest a role of re-exposure (as indicated by higher reminiscence) as well as transfer of group responses to final individual recall (as indicated by lower forgetting) in mediating the benefits of repeated group retrieval in the CCI condition.

Paired frequency

We now turn to a discussion of the organisation measure of paired frequency to assess whether a match in recall organisation mediated the benefits of prior recalls on final individual recall. A paired frequency measure of subjective organisation (Sternberg & Tulving, 1977) was used to assess the similarity of organisation across recall trials. Paired frequency measures the frequency with which pairs of items (e.g., apple, child) are recalled consecutively across recall trials, regardless of the order (apple, child or child, apple). The paired frequency measure of subjective organisation has been used in prior collaborative memory studies (Finlay et al., 2000; Weldon & Bellinger, 1997). Although this measure yields a clearer picture of organisation when pictorial or more organised study material is used, rather than unrelated words, it is nevertheless useful for examining trends in the subjective organisation across trials even with unrelated words (Weldon & Bellinger, 1997). It should be noted that unlike the other measures of organisation such as the ARC scores (used on categorised lists) that can be used on recall responses *within* a recall trial (Roenker, Thompson, & Brown, 1971), the paired frequency measure—appropriate for assessing organisation of unrelated information—requires comparisons *across* recall trials.

First, as expected, we observed an increase in organisation with repeated *individual* recall in the III condition such that the paired frequency measure across the last two recalls (1.71) exceeded the measure across the first two recalls (1.13), $t(47) = 2.05$, $SE = .29$, $p = .05$. Next, we assessed whether repeated group retrieval during the first two recalls in the CCI condition led to improved organisation. To this end, we compared paired frequencies for the first two recalls in the **CC**I and the **II**I conditions to determine whether group retrieval is more consistently organised across recall trials than individual retrieval. The paired frequency measure from Recall 1 to Recall 2 was higher in the **CC**I condition (1.51) than the **II**I condition (1.13), but this trend did not become significant, $t(94) = 1.33$, SE .02, $p = .18$. Weldon and Bellinger (1997) also found a marginally significant difference under similar conditions. Consistent with this trend, the paired frequency measure for the first two recalls in the **CC**I condition (1.51) was also higher than in the **CI**I condition (1.16) that involved a switch from group recall to individual recall. However, this pattern was also not significant, t $(94) = 1.28$, $SE = .01$. Together, these trends suggest that repeated group retrieval leads to better organisation.

Although the lack of statistical differences (noted for the paired frequency measure in other research as well) makes these trends only suggestive, these are consistent with the conclusions about the benefits of repeated group retrieval emerging from the overall body of findings reported in this article. Finally, we compared the PF measures across the first two recalls in the ICI (.50) and the CCI (1.51) conditions because final individual recall did not differ across these two conditions. As expected, this difference was significant, $t(94) = 3.63$, $SE = .01$. This finding suggests that collaboration benefits final individual recall regardless of whether collaboration was preceded by individual or collaborative recall first. However, the process that underlies this benefit varies across the two combinations of recall (CCI and ICI). Further research on this issue is needed to evaluate the similarities and differences in the eventual improvement from collaboration as a function of prior history of recall.

CONCLUDING COMMENTS

In conclusion, the findings from this study support both the group-strategy hypothesis and the individual-strategy hypothesis but do not provide any support for the combined-strategy hypothesis. Thus, these findings show that both the harmful effects of retrieval disruption and the beneficial

effects of re-exposure to other members' input modulate final individual recall. While an initial group recall trial disrupts later individual recall (CII condition), both repeated group recall trials (CCI condition) and an individual recall trial prior to group collaboration (ICI condition) protect against retrieval disruption and allow individuals to benefit from re-exposure during group recall. The conditions of this experiment and the findings therein pinpoint the process by which retrieval disruption and re-exposure shape later individual recall, and also reveal the conditions under which group collaboration can maximally benefit later individual recall. Isolating the processes that shape, and the factors that can enhance or impair, individual memory following group collaboration in small groups of two or three may also be important for mapping out the features of memories that are shared within larger groups or cultures (see Harris, Paterson, & Kemp, 2008 this issue; Wang, 2008 this issue).

In addition to the theoretical significance of these findings for better understanding the interactions between group and individual memory, these findings propose straightforward suggestions for successful application to educational settings. While group collaboration prior to individual studying may impair later individual exam performance, repeated group collaboration, or individual studying prior to group collaboration, may enhance later individual exam performance. To make these findings even more amenable to educational applications and apply the principles derived from the basic research reported here, we are currently testing these hypotheses with more educationally relevant prose material.

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