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Effects of Group Collaboration and Repeated Retrieval on Later Individual Memory

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Abstract of the Dissertation

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Exam preparation in groups is a common educational practice. Yet, the effects of group rehearsal and group retrieval (as involved in exam preparation in groups) on later individual memory (during exams) remain poorly understood. This dissertation examined the competing roles of benefits from *re-exposure* to study material during group collaboration and losses from *retrieval disruption* that accrue from the other group members' output. The goal was to identify the combinations of group and individual retrieval that optimize final individual memory performance. Experiment 1 examined the effects of repeated group recall, repeated individual recall or a combination of group and individual recall on later individual recall. Participants studied a list of words and then completed three recall trials in one of four recall sequence conditions – II**I** (individual-individual-**individual**), IC**I** (individual-collaborative-**individual**), CI**I** (collaborative-individual-**individual**) and CC**I** (collaborative-collaborative-**individual**). Results of Experiment 1 show that repeated group recall trials (CC**I**), and securing individual organization prior to group recall (IC**I**), benefit later individual recall more than repeated individual recall trials (II**I**). Experiment 2a and 2b examined the relationship between repeated group retrieval and the type of memory task that is used to asses retention (recall or recognition). In Experiment 2a, participants completed two group recall trials followed by an individual recall trial (C*Recall*-C*Recall*-**I*Recall***) or two group recognition trials followed by an individual recall trial (C*Recognition*-C*Recognition*-**I*Recall***). In Experiment 2b,

participants completed two group recognition trials followed by an individual recognition trial (C*Recognition*- C*Recognition*-***IRecognition***) or two group recall trials followed by an individual recognition trial (C*Recall*-C*Recall*-**I*Recognition***). Results of Experiment 2a and 2b show that the type of memory test used during repeated group retrieval (recall or recognition) is an important factor when final individual memory is assessed with a recognition task (C*Recognition*-C*Recognition*-***IRecognition*** **>** C*Recall*-C*Recall*-**I*Recognition***) but not when assessed with a recall task (C*Recall*-C*Recall*-**I*Recall*** ~ C*Recognition*-C*Recognition*-**I*Recall***).

To Peter

Table of Contents

List of Figures

List of Tables

The text of this dissertation in part is a reprint of the materials as it appears in (Blumen, H.M, & Rajaram, S (2008). Influence of Re-exposure and Retrieval Disruption during Group Collaboration on later Individual Recall, *Memory, 16*(3), 231-244). The co-author listed in the publication directed and supervised the research that forms the basis for this dissertation.

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Introduction

Study groups and group assignments are common educational practices. Students attend study groups in preparation for upcoming exams and teachers create group assignments to elucidate course material. Such group rehearsal or group retrieval is assumed to enhance comprehension and subsequent individual exam performance. Yet, the effects of prior group retrieval on later individual memory (or exam) performance are poorly understood and the scant findings on this issue have been mixed. While one study suggests that prior group retrieval enhances later individual memory performance (Weldon & Bellinger, 1997), another study suggests that prior group retrieval neither enhances, nor impairs, later individual memory performance (Finlay, Hitch, & Meudell, 2000). More importantly, there is currently no theoretical framework that explains how, or predicts when, prior group retrieval would enhance later individual memory. This dissertation was designed to fill this gap in the literature and to provide evidence-based recommendation for successful application to education. Specifically, the negative effects of *retrieval disruption* (that accrue from hearing the other group members' output during group retrieval) and the positive effects of *re-exposure* (to study material provided by other group members during group retrieval) were considered in two experiments.

Retrieval disruption is the typical explanation of *collaborative inhibition* – the counterintuitive finding that a collaborating group of individuals recalls less information than the non-overlapping responses of an equal number of individuals recalling alone – termed a *nominal group* (B. H. Basden, Basden, Bryner, & Thomas, 1997; Weldon & Bellinger, 1997). Each group members' individual organization of the to-be-remembered information is thought to be disrupted by hearing the other group members' output during group recall and lead to less efficient recall of the remaining information. It remains unclear if, and how, this retrieval disruption mechanism that occurs during group recall affects later individual memory performance. There are, perhaps, positive effects of prior group retrieval on later individual retrieval as well, because whenever you are trying to retrieve information in a group, you are also re-exposed to additional items recalled by the other group members - that you may not have recalled yourself (Weldon & Bellinger, 1997; Weldon, Blair, & Huebsch, 2000). This dissertation was aimed to identify conditions where such re-exposure can benefit later individual memory performance. Experiment 1 examined the effects of repeated group recall, repeated individual recall or a combination of group and individual recall on subsequent individual recall performance. Experiment 2a and 2b examined the relationship between repeated group retrieval and the type of memory task that is used to assess retention (recall or recognition).

This dissertation is organized as follows; first, the retrieval disruption account of collaborative inhibition will be considered in detail. Second, studies that show improvements in memory performance across repeated individual retrieval trials will be reviewed. These two topics establish the motivation for Experiment 1. Third, studies that examine the relationship between collaborative inhibition and different memory tasks will be considered in detail. Finally, studies that examine repeated individual retrieval with different memory tasks will be reviewed. These two topics establish the motivation for Experiment 2.

I. Experiment 1

Collaborative Inhibition

Researchers have repeatedly verified the familiar idiom "two heads are better than one" (Hinsz, 1990). However, recent research suggests that two heads working together are worse than two heads working alone (Basden, Basden, Bryner, & Thomas, 1997; Weldon & Bellinger, 1997). In other words, a collaborating group of individuals typically recalls more information than one individual recalling alone, but a collaborating group of individuals typically recalls less information than the non-overlapping responses of an equal number of individuals recalling alone. The non-overlapping responses that are pooled from the same number of individuals recalling alone are termed nominal group performance and the counterintuitive finding termed collaborative inhibition is that nominal group performance is better than collaborating group performance.

Imagine an experimental setting where a collaborating group of three individuals recalls five words from a larger list of words (*apple, banana, orange, chair* and *book*). One individual working alone recalls three of the words from this list (*apple, banana* and *monkey*) while another individual working alone recalls four of the words from this list (*book, orange, chair* and *monkey*). Finally, a third individual working alone recalls three of the words from this list (*banana, orange* and *table*). These hypothetical recall outputs show that the collaborating group outperforms each individual (i.e. five items are recalled by the collaborating group but only three or four items are recalled by the individuals that worked alone). However, these recall outputs also show collaborative inhibition - because nominal group recall performance is better than collaborative group recall performance (i.e. 7 unique items are recalled by the nominal group; *apple, banana, monkey, book, orange, chair* and *table* and five words are recalled by the collaborating group). The collaborative inhibition phenomenon suggests

that there is something about asking individuals to recall information in a group setting that is causing individuals to perform worse than they would if they had worked alone.

Collaborative inhibition is typically thought to be caused by retrieval disruption (B. H. Basden et al., 1997). In other words, hearing another group member recall the items *apple, banana, orange* is thought to disrupt one's own retrieval organization of the items (e.g. *apple*, *banana* and *monkey*) and lead to less efficient retrieval of the remaining items (e.g. forgetting the word *monkey*). This retrieval disruption account of collaborative inhibition is an extension of a popular account of *part-list cuing inhibition* (D. R. Basden & Basden, 1995; D. R. Basden, Basden, & Galloway, 1977). Part-list cuing inhibition is the finding that individual recall is impaired when a subset of the to-be-recalled items are provided as cues during recall compared to when no cues are provided during recall. The presence of cues is thought to disrupt individual retrieval organization and lead individuals to adopt less organized (and less efficient) retrieval strategies to recall the remaining (i.e. the non-cued) items. In a similar way, the cues provided by the other group members' output during group recall are thought to disrupt individual retrieval organization and lead to less efficient retrieval of the remaining items (Andersson, Hitch, & Meudell, 2006; Andersson & Rönnberg, 1995 , 1996 , 1997; B. H. Basden et al., 1997; B. H. Basden, Basden, & Henry, 2000; Finlay et al., 2000; Takahashi & Saito, 2004; Weldon & Bellinger, 1997; Weldon et al., 2000)

Both part-list cuing inhibition and collaborative inhibition disappear when cues (or group members, respectively) are removed. The items that are lost in the presence of cues reappear when participants are asked to recall the same items in the absence of cues (D. R. Basden et al., 1977) and the items that are lost during group recall reappear when individuals subsequently recall the same items alone (Finlay et al., 2000). Similarly, both part-list cuing inhibition and collaborative inhibition is more likely when organizational retrieval strategies are specifically important for successful recall – as is the case when retrieving a categorized list of words composed of many items from the same category. For example, part-list cuing inhibition is greater for a categorized list of words composed of 15 exemplars from 6 different categories than for a categorized list of words composed of 6 exemplars from 15 different categories (D. R. Basden, 1973). Likewise, collaborative inhibition is present for a categorized list of words composed of 15 exemplars from 6 different categories, but collaborative inhibition is absent for a categorized list of words composed of 6 exemplars from 15 different categories (B. H. Basden et al., 1997). These parallel findings support the retrieval disruption account of collaborative inhibition because a larger set of exemplars require more organization than a smaller set of exemplars that can be organized more easily within each category. Taken together, these findings

suggest that retrieval disruption is the mechanism that is responsible for collaborative inhibition.

Collaborative inhibition is a fairly persistent phenomenon that has been observed in free-for-all situations (Weldon & Bellinger, 1997) as well as with a turn-taking procedure (B.H. Basden et al., 1997). Furthermore, social loafing does not seem to significantly contribute to lowered recall during group collaboration, because even when these factors are manipulated or controlled, collaborative inhibition persists (Weldon et al., 2000). For example, when a collaborating group of individuals is given a monetary incentive to encourage optimal performance, overall group and individual performance increases, but collaborative inhibition persists (Weldon et al., 2000). Collaborative inhibition disappears, however, when individuals are unable to see or hear the other group members' responses (Wright & Klumpp, 2004). Thus, there is something about being exposed to the other group members' output – not the perceived group setting per se – that leads individuals to perform worse than they would had they been working alone. These findings provide further support for that collaborative inhibition is a function of retrieval disruption.

It is unclear if, and how, this retrieval disruption mechanism that occurs during group recall affects later individual memory performance. It is possible that the retrieval disruption that accrues during group recall persists and lowers later individual memory performance as well. If this is the case, individual memory performance would be worse following group recall compared to individual recall. However, there is currently very limited support for this possibility. It is also possible that individual memory performance is similar following group recall compared to individual recall. This finding can be generated either because the negative effects of retrieval disruption are offset by the positive effects of re-exposure during later individual retrieval, or because individual retrieval strategies are recovered during later individual retrieval. There is some support for this latter possibility (Finlay et al., 2000). A final possibility is that while retrieval disruption lowers group recall, individual retrieval strategies are recovered during later individual retrieval and are also augmented by the positive influence of re-exposure to additional items provided by the other members of the group. If this is the case, later individual memory would be better following group recall compared to individual recall. There is some support for 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 benefits have been observed in *free* recall in one study (Weldon & Bellinger, 1997) but not in another (Finlay et al., 2000). Experiment 1 examined the effects of prior group retrieval on later individual retrieval with a free recall task because the negative effects of retrieval disruption during later

group retrieval are smaller or absent during cued retrieval (Clark, Hori, Putnam, & Martin, 2000; Rajaram & Pereira-Pasarin, 2007). I will return to this issue when I establish the motivation for Experiment 2.

Repeated Individual Retrieval

Considering that a large number of studies suggest that prior individual retrieval benefits later individual retrieval, it is possible that repeated retrieval is an important factor that can determine when later individual memory will benefit from re-exposure, that accumulate during group retrieval. This increase in retrieval across individual recall trials is referred to as a *testing effect* when different study and test sequences are compared between subjects (Gates, 1917) and *hypermnesia* when the net improvement across recall trials is assessed within-subjects (Payne, 1987). The testing effect or hypermnesia has been observed with words (Allen, Mahler, & Estes, 1969; Carpenter, 2005; Carpenter & DeLosh, 2005; Darley & Murdock, 1971; Hogan & Kintsch, 1971; Izawa, 1967; Landauer & Eldridge, 1967; McDaniel & Masson, 1985; Payne, 1987; Slamecka & Katsaiti, 1988; Sternberg & Tulving, 1977; Wheeler, Ewers, & Buonanno, 2003), pictures (Wheeler & Roediger, 1992) and prose (Nungester & Duchastel, 1982; Petros & Hoving, 1980), and is greater for free recall than cued recall and recognition. In Experiment 1, repeated retrieval trials were used to examine the effects of prior group recall, prior individual recall, and combinations of group and individual recall on later individual memory performance.

Interestingly, two recent studies suggest that while repeated individual *studying* leads to better individual recall after a short delay (5 minutes), repeated individual *recall* leads to better individual recall after 2-day and 1-week delays (Roediger & Karpicke, 2006b; Wheeler et al., 2003). Repeated individual recall may be more effective than repeated individual studying because repeated recall employs the same processes as those engaged by the subsequent memory test (Roediger & Karpicke, 2006b). This proposition is consistent with the transfer-appropriate processing principle (Morris, Bransford, & Franks, 1977; Roediger, Weldon, & Challis, 1989). The transfer-appropriate processing principle states that memory will benefit to the extent that the cognitive processes employed at encoding overlap with those employed at retrieval.

An extension of the transfer-appropriate processing principle to the effects of prior group recall on later individual recall implies that later individual recall will benefit to the extent that the retrieval strategies developed during prior group recall overlap with those used during later individual recall. It is possible that prior group recall does not consistently benefit later individual recall because there is a mismatch between the retrieval processes developed as a group and

those used during later individual retrieval. Experiment 1 explored the possibility that repeated group recall trials aid the solidification of group recall strategies and, consequently, allow individuals to use these recall strategies during later individual recall. The transfer-appropriate processing principle is not a competing alternative to the idea that re-exposure and retrieval disruption play competing roles during group recall. Rather, it can provide a complementary framework for explaining the effects of prior group recall on later individual recall.

Rationale for Experiment 1

Thus, on one hand, the retrieval strategies that are employed during group recall might not match or might even disrupt the mechanisms that are employed during later individual recall. On the other hand, group recall, when carried out repeatedly, has the potential to enhance later individual memory. This is because during repeated group recall conditions, individuals are re-exposed to additional items provided by the other members of the group repeatedly, and are thus in a better position to solidify group retrieval strategies and incorporate the additional items provided by others during subsequent individual recall. Consistent with this prediction, preliminary evidence suggests that group retrieval strategies can be rapidly developed and may be more stable than individual recall strategies across recall trials. In particular, when the recall order of unrelated common words is assessed across repeated recall trials, group recall (collaborative-collaborative) is more consistently organized than individual recall (individual-individual) (Weldon & Bellinger, 1997). Thus, it is possible that repeated individual recall benefits individual memory for one set of reasons and repeated group recall benefits later individual memory for another set of reasons. Experiment 1 examined the benefits of both types of recall (individual and collaborative) with the intent to identify combinations of group and individual retrieval that optimize final individual memory performance. Little evidence is currently available on the relative benefit of repeated group recall and repeated individual recall and the possible benefits of combining the two types of retrieval in order to optimize final individual recall.

Design and Predictions

Experiment 1 involved 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. These recall sequence conditions were selected to test three hypotheses: the individual-strategy hypothesis, the combined-strategy hypothesis and the group-strategy hypotheses.

The individual-strategy hypothesis

It is possible that being given the opportunity to strengthen one's own retrieval strategies through an initial recall trial protects against the retrieval disruption that is associated with group recall. Such strengthened retrieval strategies can then, potentially, be augmented with the benefits of re-exposure during second, group recall. This proposition is termed the *individual-strategy hypothesis* because it implies that individual recall strategies must be secured before individual memory can benefit from prior group recall. If this is the case, an individual recall trial followed by a group recall trial should benefit final individual memory performance (IC**I** > II**I**). This hypothesis also suggests that group collaboration during first recall (CII) will generate poorer final individual memory performance compared to the ICI condition (IC**I** > CI**I)**. This is because individual retrieval strategies are not given the opportunity to coalesce prior to group recall in the CII condition.

The combined-strategy hypothesis

It is also possible that an initial group recall trial aids subsequent individual recall in ways that can benefit later individual memory performance. This is because re-exposure can provide an increased set of items for later individual recall, if Recall 1 takes place in a group setting. This increased set of items can then be strengthened when Recall 2 is individual completed. This proposition is termed the *combined-strategy hypothesis* because it implies that benefits of re-exposure to information provided by the other members of the group (during Recall 1) have to be fed into the development of individual recall strategies (during Recall 2) before final individual memory can benefit from prior group recall. If this is the case, an initial group recall trial followed by an individual recall trial should enhance final individual recall performance (CI**I** > II**I**). Both individual and group retrieval strategies are reinforced in the ICI and CII condition but current design allows a direct evaluation of the importance of the

relative order of individual organization versus re-exposure to be maximally effective (IC**I** vs. CI**I**).

The group-strategy hypothesis

Finally, it is possible that benefits of prior group recall on later individual recall depends not only on being re-exposed to the other group members output but also on being able to integrate this input during repeated group recall. This proposition is termed the *group-strategy hypothesis* because it suggests that group strategies must be strengthened through repeated group recall trials, before final individual memory can benefit from prior group recall. If this is the case, two group recall trials should generate better final individual recall performance compared to other combinations of individual and group recall trials (CC**I** condition > IC**I** and CI**I** condition). Repeated group recall is also predicted to be better than repeated individual recall because participants are able to organize other group members' responses (because of transfer-appropriate processing), and these additional processes generate benefits in recall over and above the retrieval match that operate during repeated individual recall (CC**I** > II**I**).

Method

Participants

One-hundred and ninety-two 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 a between-subjects factor. There were 16 three-person groups in each retrieval sequence condition (or a 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 et al., 2000; Paivio, Yuille, & Madigan, 1968). Study items were concrete (M = 6.76) nouns with high imageability (M = 6.43). 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*). There was no mention of a subsequent memory task. Each word was displayed for six seconds. Immediately after the study phase, participants completed a distracter task for seven minutes that involved recalling as many U.S. 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 of 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 different ways. First, correct (individual and group) recall scores were computed for each recall trial in each retrieval sequence condition (III, ICI, CII and CCI). Second, when appropriate, individual recall scores were used to compute nominal group recall scores by pooling the nonredundant responses from three individuals working alone (B. H. Basden et al., 1997; Weldon & Bellinger, 1997). Third, changes in the levels of recall across recall trials were computed in the form of difference or

hypermnesia scores for each participant. Hypermnesia scores were also 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, paired frequencies were computed to assess the stability of subjective organization 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.

This experiment was designed to explore the effects of repeated group recall, repeated individual recall or combinations of group and individual recall on final individual recall performance. However, the findings on the status of the collaborative inhibition effect will be presented first in order to demonstrate the replications of key findings from previous studies. Final individual recall scores for each condition will be presented next followed by hypermnesia, reminiscence and forgetting scores across recall trials. The findings from the paired frequency measure of the stability of retrieval organization across recall trials will conclude the results section.

Collaborative Inhibition

The presence or absence of collaborative inhibition during Recall 1 and Recall 2 was assessed by contrasting collaborative group recall with nominal group recall (i.e. the pooled recall of nonredundant 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 expected, collaborative inhibition was present during Recall 1 because collaborative group recall in the **C**II condition (.54) and the **C**CI condition (.56) was lower than nominal group recall 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 recall in the **C**II condition and the **C**CI condition were compared to nominal group recall in the **I**CI condition (.68), t (30) = 3.94, SE = .04 and t (30) = 3.89, SE = .03, respectively. Note that nominal group recall in the **I**II and **I**CI conditions did not differ ($t < 1$) and collaborative group recall in the **C**II and **C**CI conditions did not differ ($t < 1$). The presence of collaborative inhibition in all four comparisons during Recall 1 nicely replicates prior research (B. H. Basden et al., 1997; Weldon & Bellinger, 1997).

During Recall 2 both individual and group recall performance could be modulated by the prior history of recall (individual or collaborative). Nominal group recall in the I**I**I condition (.74) was greater than collaborative group recall in the I**C**I condition (.65), t (30) = 2.89, SE = .03. This finding suggests that even

when participants were given the opportunity to secure individual retrieval organization through an initial individual recall trial, collaborative inhibition persists during second group recall. Nominal group recall in the I**I**I condition (.74) was also greater than collaborative group performance in the C**C**I condition (.65), *t* (30) = 3.25, *SE* = .03. This finding suggests that collaborative inhibition is a robust phenomenon that is not offset by repeated group recall - even when (as will be discussed in the next section) repeated group recall (CCI) enhances final individual recall performance compared to the III and CII conditions.

Collaborative inhibition disappeared, however, in one crucial comparison during Recall 2 – that 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**I**I condition, *t* (30) = 3.31, *SE*=.03 (see Figure 1). A similar pattern has been reported in another study where category cued recall performance was assessed across two recall trials (B.H. Basden et al., 2000). In this study, nominal group performance during the second individual recall was lower for participants that had recalled in a group previously (C**I** condition) than nominal group performance for participants that had previously recalled individually (I**I** condition).

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 further 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 equivalent levels of individual recall in I**I**I and C**I**I conditions during Recall 2 suggest either the recovery of individual retrieval strategies or an offsetting effect of impaired individual retrieval strategies and re-exposure in the C**I**I condition. When individual recall in the C**I**I condition (.45) (that did not go down compared to the I**I**I condition) are considered along with nominal group recall (.64) derived from them (that did go down), lowered nominal group recall signifies the presence of fewer nonredundant responses in the individual recall protocols during Recall 2 in the C**I**I condition compared to the I**I**I condition. In other words, participants in the C**I**I condition relied less on their individual retrieval strategies and more on the recall of the additional items produced by the other group members – 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. These findings support the possibility that re-exposure to items during group recall influence later

individual recall, even when an overall benefit of prior group recall compared to prior individual recall is not observed.

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 in the CCI condition. However, there is a numerical *decrease* in the size of collaborative inhibition from Recall 1 to Recall 2. During Recall 1, nominal group performance was .70 in the **I**II condition and collaborative group performance was .56 in the **C**CI 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 trend in the *decrease* in collaborative inhibition from Recall 1 to Recall 2 suggests that repeated group recalls can reduce, but not eliminate, the retrieval disruption mechanism that is associated with group recall.

The key findings concerning collaborative inhibition can be summarized as follows: 1) collaborative inhibition was observed during Recall 1, 2) collaborative inhibition remained during Recall 2, even when an initial individual recall trial enabled the solidification of individual retrieval organization prior to group recall 3) collaborative inhibition was also not offset by the opportunity to integrate other group members output through repeated group recall and 4) initial group recall 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 even when an overall benefit of prior group recall compared to prior individual recall is not observed.

Final individual recall

The proportions of correctly recalled items in each condition are summarized 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.

The individual-strategy hypothesis can be evaluated by comparing the proportions of correctly recalled items during final individual recall (Recall 3) in the II**I** condition (.49) with the IC**I** condition (.52). Although recall in the IC**I** condition was numerically greater than in the II**I** condition, this advantage failed to be significant, $t(94) = 1.13$, $SE = .03$. This finding suggests that the opportunity to secure individual retrieval strategies through an initial individual

recall trial did not allow participants to benefit from re-exposure during group recall (Recall 2) during final individual recall (Recall 3). 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 CI**I** condition (combined strategy) presented later in this section. The hypermnesia and reminiscence measure discussed in the next section also provide further support for the individual-strategy hypothesis.

The combined-strategy hypothesis can be evaluated by comparing the proportions of correctly recalled items during final individual recall in the CI**I** condition (.46) with II**I** condition (.49) and that this difference was not significant, t (94) = 1.00, SE = .03. If anything, recall in the CI**I** condition was numerically lower than recall in the II**I** condition. This finding refutes the combined-strategy hypothesis and suggests that the group strategies (and re-exposure) that accrued during the initial group recall trial were not readily integrated with subsequent individual retrieval strategies in the CII condition.

The relative benefits of the individual retrieval strategy (securing individual organization *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) was also assessed by comparing the IC**I** condition (.52) with the CI**I** condition (.46) This comparison showed significantly superior final individual recall in the IC**I** condition compared to the CI**I** condition, t (94) = 2.34, SE = .02. This finding supports both the idea that securing one's own organization prior to group recall is beneficial for later individual memory and the idea that initial group recall can be harmful to retaining one's own individual organization. This is because in Recall 3, the recall in the IC**I** condition (.52) was numerically, though not statistically, higher than in the II**I** condition (.49) and because recall in the CI**I** condition (.46) was numerically, though not statistically, lower than the II**I** condition (.49). Taken together, these findings provide some evidence in favor of the individual-strategy hypothesis but no evidence in favor of the combined-strategy hypothesis.

The group-strategy hypothesis can be evaluated by comparing the proportions of correctly recalled items during final individual recall in the CC**I** condition (.55) with the II**I** condition (.49). A follow-up contrast revealed that final individual recall performance was indeed greater in the CC**I** condition than in the II**I** condition (.49), t (94) = 2.48, SE = .03. This finding supports the group-strategy hypothesis and suggests that repeated group recall trials are important for taking advantage of the re-exposure benefits that accrue from group recall during later individual recall.

The above analyses indicate that repeated group recall trials generate benefits on final individual recall that are greater than those associated with repeated individual recall 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 CC**I** versus the CI**I** conditions and the CC**I** versus the IC**I** conditions. The contrast between the CC**I** condition and the CI**I** condition was significant, t (94) = 3.87, SE = .02 and while a trend in this direction was also observed for the comparison between, the CC**I** condition and the IC**I** condition, this difference failed to reach significance, t (94) = 1.46, p = .15.

Taken together, these findings provide convincing support for the group-strategy hypothesis and 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.

Note that the analyses presented above do not consider whether a participant wrote the words down during prior group recall. Thus, it is possible that the re-exposure benefits of prior group recall observed in the CC**I** condition is different for the participants who wrote the words down compared to those participants that did not write the words down during prior group recall. To examine this possibility, final individual recall scores of scribers were contrasted with final individual recall scores of non-scribers. The results of this analysis suggest that the re-exposure benefits of prior group recall observed in the CCI condition are not different for scribers and non-scribers (F < 1). Similar analyses were performed to contrast final individual recall scored of scribers and non-scribers in the ICI and CII conditions, but yielded no significant differences either (Fs < 1).

Hypermnesia

As noted previously, benefits of prior individual retrieval on later individual 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, difference (or hypermnesia) scores were calculated 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, current design (see also Weldon and 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 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 (**II**I, I**II** and **II**I**).** 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).

The relative benefits of intervening trials was assessed (individual recall or collaborative recall during Recall 2) by comparing difference scores between Recall 1 and Recall 3 in the **III** condition with the **I**C**I** condition. Hypermnesia was significantly higher in the **I**C**I** (.15) compared to the **II**I (.09) condition, t (94) = 3.77, SE = .02. Higher levels of hypermnesia in the ICI condition compared to the III condition seems inconsistent with the lack of a difference in final individual recall 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 nonsignificant, albeit numerical, difference in individual recall during Recall 1 (.40 in **I**II condition and .37 in the **I**CI), t (94) = 1.33, SE = .02. This numerical difference in baseline or initial individual recall performance disguised the re-exposure benefits of prior group recall that were present in the ICI condition. This hypermnesia measure supports the individual-strategy hypothesis and suggests that intervening collaboration improves final individual recall when individual retrieval strategies have been secured through an initial individual recall trial.

In the previous section on *Final Individual Recall*, beneficial effects of repeated group recall were observed on final individual recall (the CCI condition). These benefits were also observed in the hypermnesia measure because the change in correct recall from Recall 1 to Recall 3 was -.08 in the **C**I**I** condition and -.01 in the **C**C**I** 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 **C**I**I** condition but final individual recall was similar to initial group recall in the **C**C**I** condition. These hypermnesia findings provide further support for the group-strategy hypothesis.

One particular contrast in the difference scores for Recall 1 to Recall 2 was also assessed – that between **CC**I and **II**I - although it was not of a priori interest. This contrast showed that groups exhibit more hypermnesia (.09 in the **CC**I condition) than did individuals (.04 in the **II**I condition), t (94) = 3.58, SE = .01. To our knowledge, this is the first direct empirical evidence for cross-cuing (i.e. that group recall facilitates additional recall) during group recall because groups benefited from repeated recall trials more than individuals recalling alone

(Finlay et al., 2000; Meudell, Hitch, & Boyle, 1995; Meudell, Hitch, & Kirby, 1992; Weldon & Bellinger, 1997). The notion of cross-cuing is different from the mechanism of re-exposure discussed previously 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 that it can also trigger recall of other items in response to having heard the mention of an item by another group member (the cross-cuing effect). Weldon & Bellinger (1997) failed to find this effect under similar conditions although hypermnesia effects in their study were smaller, making it difficult to detect possible differences.

In sum, these hypermnesia analyses support the group-strategy hypothesis – group responses strengthened by repeated retrieval can benefit later individual memory. In addition, these hypermnesia 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 trials.

We first examined the effects of intervening group recall on the changes in individual recall by comparing lost items (forgetting) on one hand and recovered items (reminiscence) on the other hand from Recall 1 to Recall 3 in the **I**C**I** condition compared to the **III** condition. This comparison is of interest because the intervening group recall trial in the **I**C**I** condition can improve final individual recall by providing re-exposure to additional items (leading to an increase in reminiscence). Items produced during the intervening group recall trial can also disappear in final individual recall for various reasons (this would be the case if individual contributions did not fare well during collaborative recall). These potential changes in the **I**C**I** conditions were compared to the baseline changes in the **III** condition where no group recall intervened. As suggested by the net increase in hypermnesia in the **I**C**I** condition over the **III** condition from Recall 1 to Recall 3, reminiscence was also significantly higher in the **I**C**I** 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 **I**C**I** condition (see also Finlay et al., 2000). There was also some forgetting in the **I**C**I** condition (.05) but, interestingly, this did not differ from the baseline rate of forgetting in the **I**I**I** condition (.04), t (94) = 1.27 SE = .01. Taken together, these two findings show that the disruptive effects of group recall does not lead to a change in final individual forgetting, and are consistent with the group-strategy hypothesis in that re-exposure during second group recall increased final individual recall in the ICI condition compared to the III condition. These findings also provide support for the individual-strategy hypothesis in that if individual recall organization 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 **I**I**I** condition.).

The effects of intervening group recall can also be assessed by comparing reminiscence and forgetting from Recall 1 to Recall 3 across the **C**I**I** condition and the **C**C**I** condition. This comparison sheds light on how reminiscence and forgetting contribute to the beneficial effects of repeated group retrievals on final individual recall discussed previously. From Recall 1 to Recall 3, reminiscence in the **C**C**I** condition (.10) was significantly higher than in the **C**I**I** condition (.06), t (94) = 2.94, SE = .01. This finding is consistent with the group-strategy hypothesis and suggests 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 **C**I**I** condition and .11 in the **C**C**I** 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

A paired frequency measure of subjective organization (Sternberg & Tulving, 1977) was used to assess the similarity of organization 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 organization has been used in prior collaborative memory studies (Finlay et al., 2000; Weldon & Bellinger, 1997). Although this measure yields a clearer picture

of organization when pictorial or more organized study material is used, rather than unrelated words, it is nevertheless useful for examining trends in the subjective organization across trials even with unrelated words (Weldon & Bellinger, 1997). It should be noted that unlike the other measures of organization such as the ARC scores (used on categorized lists) that can be used on recall responses *within* a recall trial (Roenker, Thompson, & Brown, 1971), the paired frequency measure – appropriate for assessing organization of unrelated information – requires comparisons *across* recall trials.

First, as expected, an increase in organization with repeated *individual* recall was observed 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 organization. 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 organized 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 organization.

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 while collaboration benefits final individual recall regardless of whether collaboration was preceded by individual or collaborative recall, the underlying processes differ. While collaboration benefits in the ICI condition are due to the integration of additional items provided by others to the individual retrieval organization established during Recall 1, collaboration benefits in the CCI condition are due to the stabilization of group retrieval strategies that occur during repeated group recall. However, 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.

II. Experiment 2

The key finding from Experiment 1 is that repeated group recall trials generate benefits on later individual recall that are greater than those acquired from repeated individual recall trials (CC**I** > II**I**). This finding was observed with the free recall task. The purpose of Experiment 2 was to examine the relationship between repeated group retrieval, and the type of memory task that is used to assess retention, by contrasting performance on free recall and recognition tasks. In a free recall task, participants are asked to recall as many items as they can in the absence of any cues. In a recognition task, participants are asked to decide if a particular item has been presented before or if it is new to them. It is important to note that the retrieval cues that are provided on an item-by-item basis during recognition are different from the part-list cues that are provided during free recall. The former reduces the need to rely on individual retrieval strategies while the latter interferes with the retrieval strategies required during free recall. In other words, contrasting performance on recall and recognition tasks does not bear any connection to the part-list cues discussed earlier in the context of collaborative inhibition. A comparison of these two tasks has educational implications as well because essay questions (requiring recall) and multiple-choice questions (requiring recognition) are two of the most common formats of testing in educational settings. To situate the rationale for Experiment 2, studies that examine the relationship between collaborative inhibition and different memory tasks will be reviewed next, followed by a discussion of studies that examine repeated individual retrieval with different memory tasks.

Collaborative Inhibition and Cued Retrieval

Research suggests that the negative effects of the retrieval disruption mechanism that is associated with group recall are reduced when cued retrieval takes place in a group setting (Clark et al., 2000; Finlay et al., 2000; Rajaram & Pereira-Pasarin, 2007; Weldon et al., 2000). The presence of cues is thought to reduce retrieval disruption because individual retrieval strategies are less critical for successful retrieval in cued tasks compared to uncued tasks. This argument is supported by the absence of collaborative inhibition when two individuals are asked to collaborate on a paired-associate cued recall task (Finlay et al., 2000). In a paired-associate cued recall task, participants first study paired associates (e.g. table-stool) and are then asked to recall the second half of each pair (e.g. stool) – given the first half of the pair (table) as a retrieval cue. The item-specific retrieval

cue provided by the first half of each pair is thought to reduce the importance of retrieval organization and make group retrieval less susceptible to disruption, thereby eliminating collaborative inhibition.

Another study suggests that repeated group encoding and repeated group retrieval can reduce the effects of the retrieval disruption mechanism when category-cued recall takes place in a group setting (B. H. Basden et al., 2000). In this study, three successive encoding-retrieval cycles (each cycle involved a study session followed by category cued recall) were completed individually or collaboratively prior to a final individual category-cued recall task. While collaborative inhibition was present during the first category-cued recall trial, collaborative inhibition was absent during the subsequent category-cued recall trials. These findings suggest that cued retrieval tasks are not necessarily impervious to retrieval disruption but that repeated group encoding and repeated group retrieval can protect against such retrieval disruption. However, because repeated group encoding and repeated group retrieval were used in this study, it remains unclear if collaborative inhibition disappeared because of repeated group encoding, repeated group recall or a combination of these factors. The presence of collaborative inhibition during the first collaborative category-cued recall trial is inconsistent with the Finlay et al. (2000) findings discussed earlier and the suggestion that collaborative inhibition is unlikely in the presence of item-specific retrieval cues. However, these findings can be reconciled by considering the unusual procedure employed during collaborative category-cued recall in the Basden et al. study (2000). A typical category-cued recall task involves providing a participant with one category at a time and then asking them to recall exemplars from that category before moving on to a different category. Basden and colleagues, however, provided all category names on top of each recall sheet and then asked participants to recall as many exemplars as they could remember from all of these categories. This modified version of category-cued recall, like free recall, may involve the use of individual retrieval strategies to a greater extent than a typical category-cued recall task because participants are free to organize their own output.

Additional studies are required to determine whether collaborative inhibition is present or absent when cued retrieval takes place in a group setting. However, considering that collaborative inhibition was absent during paired-associate cued recall in one study (Finlay et al., 2000) and during category-cued recall following one or two encoding-retrieval sessions in another study (Basden et al., 2000), it seem reasonable to conclude that the effects of retrieval disruption may be reduced when cued compared to uncued retrieval takes place in a group setting. If retrieval disruption is reduced when cued retrieval (compared to uncued retrieval) takes place in a group setting, benefits of repeated group retrieval on later individual retrieval may be easier to detect following cued retrieval

compared to uncued retrieval. However, it is also possible that the presence of item-specific retrieval cues reduces, or eliminates, the need for the development of stable group retrieval strategies. If this is the case, repeated group retrieval may not enhance the benefits of prior group retrieval on later individual retrieval to the same extent when cued task are used compared to when uncued tasks are used. In other words, if repeated group retrieval trials benefits later individual retrieval because repeated retrieval promotes the stabilization of group retrieval strategies, benefits on later individual retrieval may not be observed following cued group retrieval. In Experiment 2, these possibilities were examined by contrasting performance on an uncued task (free recall) with a cued task retrieval task (recognition).

The idea that benefits of prior group retrieval on subsequent individual retrieval may be easier to detect with cued tasks compared to uncued tasks is supported by the finding that paired-associate cued recall that takes place in a group setting increases final individual free recall, while collaborative free recall does not increase later individual free recall (Finlay et al., 2000). In this study, participants studied paired-associates and were then asked to complete a free recall or a paired-associate cued recall task alone or in a group setting, prior to a final individual recall task. Performance on the final individual free recall task was better when participants had collaborated during prior paired-associate cued recall compared to when participants worked alone during prior paired-associate cued recall. However, final individual free recall performance did not differ when free recall was completed in a group setting compared to when free recall was completed individually. Finlay and colleagues argued that benefits of prior group retrieval appeared after paired-associated cued recall because the presentation and retrieval of paired associates evoked a shared organization around the particular relationship that was emphasized by each paired association. Thus, collaboration benefits were observed on later individual free recall following paired-associated cued recall because the members of the group acquired similar retrieval strategies. This idea is consistent with the group-strategy hypothesis developed and tested in Experiment 1. However, note that the collaboration benefits observed in the Finlay et al. study may have been detected because the nature of the task encouraged the stabilization of group retrieval strategies. Such an outcome may not occur if a cued task does not require the development of group organization – as is the case during group recognition.

Only one study has explored the effects of prior group recognition on subsequent individual recognition, a task that does not require the development of group organization because the entire study item is recapitulated at test (Rajaram & Pereira-Pasarin, 2007). In this study, participants studied a list of words and pictures and later performed a recognition task individually or in groups of three. In the group condition, participants were asked to discuss whether an item was

studied or nonstudied and then provided an individual recognition response before the group proceeded to the next item. Results showed a net benefit of prior group discussion on the hits-false alarms and d' (memory sensitivity) measures of individual recognition performance even after a one week delay (when recognition decisions are more demanding and accuracy has declined). These results suggest that benefits of prior group recognition can be detected on later individual recognition. However, this study did not separate group recognition and individual recognition into separate retrieval sessions as in the present designs. Furthermore, this study does not address the issue of whether repeated group recognition benefits later individual recognition to a greater extent than repeated group recall, which was the focus of Experiment 2.

Repeated Retrieval and Cued Retrieval

As mentioned before, the testing effect or hypermnesia refers to the improvement in memory performance that accrues from repeated individual retrieval. The testing effect or hypermnesia has been found to be greater, or more consistent, for free recall compared to cued recall and recognition (Carpenter & DeLosh, 2006; Duchastel, 1981; Glover, 1989; Payne, Hembrooke, & Anastasi, 1993; Payne & Roediger, 1987). Hypermnesia may be greater during free recall because free recall involves more conceptual processing, or more effortful retrieval, than cued recall and recognition. Interestingly, prior individual recall has also been shown to benefit subsequent individual memory to a greater extent than prior cued recall and recognition, regardless of the task that is used during the final individual retrieval session (recall, cued recall or recognition; Glover, 1989). As noted by others, this finding is inconsistent with the transfer-appropriate processing principle (Roediger & Karpicke, 2006a). Instead, these findings call attention to the importance of the generative processes involved in free recall for improving subsequent memory performance on both cued and uncued retrieval tasks.

Considering that prior individual recall benefits later individual memory to a greater extent than prior individual recognition, it is possible that prior group recalls benefit subsequent individual memory to a greater extent than prior group recognition. The findings of Experiment 1 suggest that repeated group recalls benefit later individual recall because repeated group recall trials promote the solidification of group retrieval strategies. It is possible that repeated group recognition does not benefit subsequent individual memory to a greater extent than repeated group recall, because the presence of item-specific retrieval cues

reduces the importance of group retrieval strategies for successful retrieval and, consequently, does not support the solidification of group retrieval strategies. In a sense, repeated group recognition may be more similar to repeated group study than repeated group retrieval because the item to be retrieved is provided during the test phase and does not have to be generated. As noted in the Introduction to Experiment 1, repeated individual retrieval can be more beneficial to individual memory than repeated individual studying (Roediger & Karpicke, 2006c; Wheeler et al., 2003). Considering that the testing effect is greater after repeated individual recall regardless of the final individual test format, repeated group recalls may also be more effective regardless of whether final individual memory is assessed with free recall or recognition. Experiment 2 addressed these issues by examining the potential for a benefit of repeated group recall and repeated group recognition on subsequent individual recall and recognition

Rationale for Experiment 2

Examining the relationship between repeated group retrieval and the type of memory task that is used to assess retention (recall or recognition) is important from both educational and theoretical standpoints. Student performance is often measured with both uncued tasks such as free recall (essays) and cued tasks such as recognition (multiple-choice). At a theoretical level, repeated group recall and repeated group recognition are expected to exert different effect on subsequent individual memory because the mechanisms influencing group recall and group recognition vary. It is also possible that the effects of prior group retrieval history (group recognition and group recall) is a function of the type of final test that an individual receives – individual recall or individual recognition. The individual memory literature suggest that final individual recall or recognition benefits to a greater extent when prior individual retrieval consisted of recall rather than recognition (Carpenter & DeLosh, 2006; Duchastel, 1981; Glover, 1989). If this pattern carries over to a situation where prior individual retrieval involves group collaboration, one would expect repeated group recall to benefit later individual retrieval to a greater extent than repeated group recognition, regardless of the final individual memory test (recall or recognition). This is because the development of stable group retrieval strategies – as afforded by repeated group recall – are also important for observing benefits of prior group retrieval on later individual memory in the presence of item-specific cues. A final possibility is that prior group recognition is optimal for later individual recognition while prior group recall is optimal for later individual recall, consistent with the transfer-appropriate

processing principle (Morris et al., 1977; Roediger et al., 1989). A comparison of repeated group recall and repeated group recognition on subsequent individual recall and recognition allows a test of these contrasting predictions.

Design and Predictions

Experiment 2 examined the relationship between repeated group recall and repeated group recognition on subsequent individual recall and individual recognition. Each participant completed a CCI (collaborative-collaborative-individual) retrieval sequence in one of four retrieval task conditions. The final individual retrieval tasks – recall and recognition – are known to yield different levels of performance for reasons unrelated to prior group retrieval history. Therefore, comparisons across conditions require that final individual recognition performance and final individual recall performance are assessed in two separate experiments. Experiment 2a examined the relative benefits of repeated group recall and repeated group recognition on subsequent individual recall. Participants in this experiment completed two group recall trials or two group recognition trials followed by an individual recall trial - C*Recall*-C*Recall*-**I*Recall*** and C*Recognition*-C*Recognition*-**I*Recall*** conditions, respectively. Experiment 2b examined the relative benefits of repeated group recall and repeated group recognition on subsequent individual recognition. Participants in this experiment completed two group recognition trials or two group recall trials followed by an individual recognition trial - C*Recognition*-C*Recognition*-**I*Recognition*** and CRecall-C*Recall*-**I*Recognition*** conditions, respectively.

Experiment 2a: Predictions

The possible outcomes and explanations associated with each outcome are summarized in Table 3. One possibility is that the solidification of group retrieval strategies that occurs during repeated group recall trials benefits later individual recall to a greater extent than the reduction of retrieval disruption that is afforded by the presence of item-specific retrieval cues during repeated group recognition. If this is the case, final individual recall should be better following two group recall trials compared to two group recognition trials (C*Recall*-C*Recall*-**I*Recall*** > C*Recognition*-C*Recognition*-**I*Recall***). This finding would be consistent with the group-strategy hypothesis and the transfer-appropriate processing principle. Another possibility is that the reduction in retrieval disruption afforded by the presence of item-specific retrieval cues during repeated group recognition benefits

later individual recall performance to a greater extent than the solidification of group retrieval strategies that occur during repeated group recall. If this is the case, final individual recall performance should be better following two group recognition trials compared to two group recall trials (C*Recognition*-C*Recognition*-**I*Recall*** > C*Recall*-C*Recall*-**I*Recall***). This finding would be consistent with the retrieval disruption explanation of collaborative inhibition because this process essentially amounts to re-exposure benefits that are further filtered through group confirmation. A final possibility is that **t**he stabilization of group retrieval strategies during repeated group recall and the reduction in retrieval disruption afforded by the presence of item-specific retrieval cues during repeated group recognition generate comparable benefits on later individual recall - because both sets of processes outlined above operate together. If this is the case, final individual recall performance would be similar following two group recall trial and two group recognition trials (C*Recall*-C*Recall*-**I*Recall*** ~ C*Recognition*-C*Recognition*-**I*Recall***).This finding would be consistent with the group-strategy hypothesis and the idea that the presence of item-specific retrieval cues reduces retrieval disruption.

Experiment 2b: *Predictions*

The possible outcomes and explanations associated with each outcome are summarized in Table 4. One possibility is that the reduction of retrieval disruption that is afforded by the presence of item-specific retrieval cues during repeated group recognition benefits later individual recognition to a greater extent than the solidification of group retrieval strategies that occur during repeated group recall. If this is the case, final individual recognition should be better following two group recognition trials compared to two group recall trials (C*Recognition*-C*Recognition*-**I*Recognition*** **>** C*Recall*-C*Recall*-**I*Recognition***). This finding would be consistent with the transfer-appropriate processing principle and the idea that the presence of item-specific retrieval cues reduces retrieval disruption. Another possibility is that the solidification of group retrieval strategies benefits later individual recognition to a greater extent than the reduction of retrieval disruption. If this is the case, final individual recognition should be better following two group recall trials compared to two group recognition trials C*Recall*-C*Recall*-**I*Recognition*** > C*Recognition*-C*Recognition*-**I*Recognition***). This finding would be consistent with the group-strategy hypothesis. A final possibility is that the reduction in retrieval disruption that is afforded by the presence of item-specific retrieval cues and the stabilization of group retrieval strategies generates comparable benefits on later individual recognition. If this is the case, final individual recognition would be similar following two group recognition trials and two group recall trials (C*Recognition*-C*Recognition*-

I*Recognition* ~ C*Recall*-C*Recall*-**I*Recognition***). This finding would be consistent with the group-strategy hypothesis and the idea that retrieval disruption is reduced in the presence of item-specific retrieval cues.

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 (C*Recall*-C*Recall*-**I*Recall***, C*Recognition*-C*recognition*-**I*Recall***, C*Recognition*- C*recognition*-**I*Recognition*** and C*Recall*-C*Recall*-**I*Recognition***) was a between-subject factor. A total of 16 three-person groups were randomly assigned to each retrieval sequence condition (i.e. 48 participants in each retrieval sequence condition) as they arrived in the lab.

Materials

Study items were composed of 166 common words from the same database that was used in Experiment 1(Clark et al., 2000; Paivio et al., 1968). There were a total of 160 targets, 3 primacy buffers and 3 recency buffers. As in Experiment 1, study items were concrete (M = 6.76) nouns with high imageability (M = 6.42). A different presentation order and a different set of nonstudied items were created for each recognition trial in the repeated recognition conditions (i.e. the C*Recognition*- C*recognition*-**I*Recall*** and C*Recognition*- C*recognition*-**I*Recognition*** conditions). To this end, target items were divided into 4 sets of 40 items each. These four sets were then counterbalanced across studied and nonstudied conditions. The four sets did not differ in terms of concreteness, imageability or mean frequency (ts < 1.98). A total of four study lists and 12 recognition booklets were created from the four sets for counterbalancing purposes. A different presentation order and a different set of nonstudied items for each recognition trial is the standard procedure used in the testing effect literature (Carpenter & DeLosh, 2006; Duchastel, 1981; Glover, 1989). However, it is possible that using a different presentation order and a different set of nonstudied

items during each recognition trial disturbs retrieval organization and could have influenced the different pattern of results associated with repeated individual recall compared to repeated individual recognition (Carpenter & DeLosh, 2006; Duchastel, 1981; Glover, 1989). On the other hand, using a different presentation order and a different set of nonstudied items in each recognition trial also increases the likelihood of observing an increase across retrieval trials because it will decrease false alarms. By contrast, using the same presentation order and the same set of nonstudied items would increase false alarms and reduce the possibility of observing an increase in recognition performance across retrieval trials. Furthermore, order effects are more likely to influence recall rather than recognition performance. Thus, recognition performance is less likely to suffer from using a different presentation order than from an increase in false alarms. For all these reasons, the selected test list construction creates stringent conditions for comparing the effects of repeated group recall and repeated group recognition on subsequent individual recall and individual recognition. As in Experiment 1, study items were presented with an LCD projector.

For exploratory purposes only, we also included a post-experiment questionnaire (see Appendix 1). The first six questions in this post-experiment questionnaire queried participants about their perceived group cohesion during group retrieval. These questions were adopted from a previous investigation of the relationship between social loafing and collaborative inhibition (Weldon et al., 2000). Questions 7 through 11 were included to obtain assessments of each participant's own contributions to the group product, the other group members' contributions to the group product, as well as whether a group leader was perceived to emerge during group collaboration.

Procedure

The study phase, distracter phase and retrieval phase was identical to Experiment 1 with the following exceptions. First, presentation time was reduced from 6 seconds to 1 second and a 2 second ISI. Second, a 1 hour delay was introduced after completion of the study phase and distracter phase, and before the beginning of the retrieval phase. These adjustments to the procedure were made to reduce ceiling effects in group recognition performance and at the same time avoid floor effects in group recall performance. Third, participants were asked to collaboratively and individually recall studied words and/or recognize them among nonstudied words for seven minutes. As in Experiment 1, all participants were encouraged to contribute as much as they could. Finally, participants completed the post-experiment questionnaire at the end of the retrieval phase. The total time for the entire procedure was approximately two hours (including the 1-hour delay).

Experiment 2a: Results and Discussion

The proportions of correct recall, hits, false alarms and corrected recognition (hits-false alarms and memory sensitivity (d')) at each retrieval trial in each retrieval sequence condition of Experiment 2a are summarized in the upper panel of Table 5. Two-tailed significance tests with an alpha level of .05 were used for all comparisons, unless noted otherwise. First, the final individual recall analyses will be discussed in the context of the predictions summarized in Table 3. Then, the exploratory analyses of the post-experiment questionnaire will be presented.

Final Individual Recall

Final individual recall performance after two group recall trials (C*Recall*-C*Recall*-**I*Recall***) was .33 and final individual recall after two group recognition trials (C*Recognition*- C*recognition*-**I*Recall***) was .34. These final individual recall proportions were not significantly different from each other, t (94) = .66, SE = .02. This finding suggests that the type of memory test (recall or recognition) that is used during repeated group retrieval does not influence later individual recall. Thus, the reduction of retrieval disruption that is afforded by the presence of item-specific cues during repeated group recognition does not generate benefits beyond those generated by the solidification of group retrieval strategies during repeated group recall – this is quite a fascinating finding considering that prior group recognition was very close to ceiling (hits-false alarms =.93) during the second group recognition trial but somehow did not carry over to later individual recall. This finding is consistent with the group-strategy hypothesis and the idea that retrieval disruption is reduced in the presence of item-specific retrieval cues. Note that although prior group recognition was quite high and prior group recall was quite low, hypermnesia from Recall 1 to Recall 2 was found to be significant in both conditions (**C*Recall*-C*Recall***-I*Recall* and **C*Recognition*- C*recognition***-I*Recall*). Group recall was .33 during Recall 1 (**C*Recall*-**C*Recall*-I*Recall*) and .35 during Recall 2 (C*Recall*-**C*Recall*-**I*Recall*) - this increase in group recall across recall trials was numerically small but statistically reliable, t (47) = 4.08, SE = .01. Similarly, group recognition increased from Retrieval 1 to Retrieval 2 in terms of hits-false alarms (.90 to .93) as well as d' (.3.57 to 3.84), t (47) = 3.93, SE =.06 and t (47) = 2.93, SE = .64, respectively.

As in Experiment 1, we examined the issue of whether final individual recall varied as a function of whether participants wrote the responses down during repeated group recall and repeated group recognition. To address this issue, a contrast between scribers and non-scriber were performed in the C*Recall*-C*Recall*-**I*Recall*** and the C*Recognition*- C*recognition*-**I*Recall*** condition. As in

Experiment 1, final individual recall did not differ as a function of whether participants wrote the responses down during repeated group recall or repeated group recognition ($F < 1$).

In sum, the final individual recall measure suggests that the type of memory test used during repeated group retrieval (recall or recognition) is not an important factor when the final individual memory test is recall - at least for the test delay used in this study. Thus, the stabilization of group retrieval strategies during repeated group recall and the presence of item-specific retrieval cues during repeated group recognition generate comparable benefits on later individual recall. This finding is consistent with the group-strategy hypothesis and the idea that retrieval disruption is reduced during repeated group recognition.

Post-Experiment Questionnaire

The post-experiment questionnaire was included for exploratory purposes only. Of particular interest was whether perceived group cohesion varied as a function of the retrieval sequence condition. The mean and correlations among group cohesions questions (Question 1-6, Appendix 1) are shown in Table 6. An exploratory factor analysis seemed appropriate because the correlation matrix included several moderate to high values and partial correlations (correlations between variables partialling out all other variables) were typically lower - as indicated by an adequate level of .76 on Kaiser's Measure of Sampling Adequacy. A principal component analysis was used to estimate the number of factors, then, a principal factor analysis was performed. One factor (Question 1: How cohesive do you think the group was?) was extracted based on both inspection of the scree plot and an eigenvalue greater than 1 (the Eigen values were 3.12, .98, .87, 46, .36 and .21). In the principal factor analysis, this factor accounted for 52 % of the total variance.

The first set of exploratory analyses addressed the issue of whether there were any general differences in perceived group cohesion between conditions. Average group cohesion in the C*Recall*-C*Recall*-**I*Recall*** condition was 5.58 and average cohesion in the C*Recognition*- C*recognition*-**I*Recall*** condition was 6.00. This difference was marginally significant, t (94) = 1.89, p = .06. This marginal finding suggests that perceived group cohesion may be lower following repeated group recall compared to repeated group recognition.

The second set of exploratory analyses addressed the issue of whether perceived group cohesion differed between the two conditions when participants reported that one or two members dominated the group (Question 8, Appendix 1). In the C*Recall*-C*Recall*-**I*Recall*** condition, group cohesion was 5.65 among the 17 participants who reported that one or two members dominated the group. In the C*Recognition*- C*recognition*-**I*Recall*** condition, group cohesion was 6.13 among

the 16 participants who reported that one or two members dominated the group. This difference was not significant, t (31) = 1.28, SE = .37. Group cohesion also did not differ between conditions for participants who reported that no person dominated the group. Specifically, group cohesion when no person dominated the group was 5.55 (N = 31) in the C*Recall*-C*Recall*-**I*Recall*** condition and 5.94 (N = 32) in the C*Recognition*- C*recognition*-**I*Recall*** condition, t (61) = 1.41, SE =.27.

The third set of exploratory analyses was conducted to explore whether group cohesion correlated with group memory performance. Group cohesion was significantly correlated with group recall performance (r = .32, p =.03) during the second group recall trial (i.e. in the C*Recall*-**C*Recall***-I*Recall* condition). No other correlations between perceived group cohesion and group memory performance were significant. When the data were broken down in terms of participants who reported that one or two members dominated the group and those that reported that no person dominated the group, no significant correlations between group cohesion and group memory performance were observed in ether conditions in either of the two groups (i.e. one or two persons dominated versus no person dominated the group).

The fourth set of exploratory analyses addressed the issue of whether perceived group cohesion correlated with later individual memory performance. Group cohesion was marginally correlated with final individual memory performance in the C*Recall*-C*Recall*-**I*Recall*** condition (r = .28, p = .06) and the *CRecognition*-C*Recognition*-**I*Recall*** condition. (r = .27, p = .07). However, when the data were broken down in terms of participants who reported that one or two persons dominated the group and those who reported that no person dominated the group, there were no significant correlations between perceived group cohesion and final individual recall in the C*Recall*-C*Recall*-**I*Recall*** condition. In the *CRecognition*-C*Recognition*-**C*Recall*** condition, no significant correlation between group cohesion and final individual recall was observed in participants that reported that one or two members dominated the group, however, a marginal correlation was observed in participants who reported that no person dominated the group (r = .33, p = .06).

Taken together, the trends observed in these exploratory analyses suggest that group cohesion may differ as a function of the type of memory task that is used to assess retention. However, it is possible that perceived group cohesion is related to recall but not recognition performance because the ranges of values for both group cohesion and recognition scores are restricted.

Experiment 2b: Results and Discussion

The proportions of correct recall, hits, false alarms and corrected recognition (hits-false alarms and memory sensitivity (d')) at each retrieval trial in each retrieval sequence condition are summarized in the lower panel of Table 5. Again, two-tailed significance tests with an alpha level of .05 were used for all comparisons, unless noted otherwise. As in Experiment 2a, the final individual recall analyses will be discussed prior to the exploratory analyses of the post-experiment questionnaire (see Table 4 for a summary of predictions).

Final Individual Recognition

Corrected final individual recognition performance (hits-false alarms) was .88 after two group recognition trials (C*Recognition*-C*Recognition*-**I*Recognition*)** and .73 after two group recall trials (C*Recall*-C*Recall*-**I*Recognition***). This difference was statistically significant, t (94) = 5.24, SE = .03. The same pattern of results was observed in the d' measure – d' after two group recognition trials was 3.50 (C*Recognition*-C*Recognition*-**I*Recognition*)** and d' after two group recall trials was 2.44, t (94) = 6.79, SE = .16**.** These findings suggest that the type of memory task that is used to assess retention during repeated group retrieval (group recall or group recognition) is an important factor when the final individual task format is recognition. Thus, the reduction of retrieval disruption that is afforded by the presence of item-specific retrieval cues during repeated group recognition generate benefits on later individual recognition that are greater than those generated by the stabilization of group retrieval strategies during repeated group recall. This finding is consistent with the transfer-appropriate processing principle and the idea that the presence of item-specific retrieval cues reduces retrieval disruption.

As in Experiment 2a, hypermnesia (the net increase in memory performance) from Retrieval 1 to Retrieval 2 was significant in both conditions. Specifically, in the **C*Recognition*- C*recognition***-I*Recall* condition group recognition performance significantly increased in terms of hits-false alarms (.91 to .93) and d' (3.69 to 3.81), t (47) = 4.36, SE = .01 and t (47) = 2.48, SE = .05, respectively. Likewise, in the **C*Recall*-C*Recall***-I*Recognition* condition group recall performance was .35 during Recall 1 and .39 during Recall 2, t (47) = 7.74, SE = .01.

As a point of general interest, note that although group recall performance was numerically higher than in Experiment 2a a cross-experiment comparison suggest that group recall performance during Recall 1 (**C*Recall***-C*Recall*-I*Recall* vs. **C*Recall***-C*Recall*-I*Recognition*) was not different between experiments, t (94) = 1.78, SE = .02. Similarly, group recognition performance during Recall 1

(**C*Recognition*-**C*Recognition*-I*Recall* vs. **C*Recognition*-**C*Recognition*-I*Recognition*) was not different between experiments in terms of hits-false alarms or d' (*t*s < 1). Likewise, cross-experiment comparisons suggest that group recognition performance during second group recognition (C*Recognition*-**C*Recognition*-I*Recall* vs. C*Recognition*-**C*Recognition*-I*Recognition*), did not differ across experiments in terms of hits-false alarms or d' (*t*s < 1). However, group recall performance was greater during group Recall 2 (C*Recall*-**C*Recall*-I*Recall* versus C*Recall*-**C*Recall*-I*Recognition*) in Experiment 2b than in Experiment 2a, t (94) = 2.10, SE = .02

Again, we explored the issue of whether final individual recognition performance varied as a function of whether participants wrote the responses down during repeated group recall or repeated group recognition. As in Experiment 1 and Experiment 2a, final individual memory performance – in this case recognition performance (hits-false alarms and d') – did not differ as a function of whether participants wrote the responses down during repeated group recall or repeated group recognition (Fs < 1).

Hits and False Alarms

Examining group recognition performance (in the **C*Recognition*-**C*Recognition*-I*Recognition* condition) in terms of hits and false alarms separately, reveal a couple of things that the hits-minus-false alarms analyses did not detect. First, while false alarms decreased from Retrieval 1 to Retrieval 2 (.07 to .04), hits were similar during Retrieval 1 and Retrieval 2 (.98 and .97), t (47) = 5.03, SE = .01 and t (47) = .25, SE .01, respectively. These findings suggest that repeated group recognition is beneficial to final individual recognition because false alarms –or incorrect answer – are corrected by the other members of the group. Note that a similar pattern of results was observed in the **C*Recognition*-**C*Recognition*-I*Recall* condition of Experiment 2a (see Table 5). Second, while hits were only marginally different during final individual recognition (in the C*Recognition*-C*Recognition*-**I*Recognition*** versus the C*Recall*-C*Recall*-**I*Recognition*** condition), false alarms were greater following repeated group recall compared to repeated group recognition, t (94) = 1.93, SE = .02, p = .06 and t (94) = 6.46, SE = .02, respectively. These findings provide additional evidence for that repeated group recognition trial leads to a reduction in false alarms.

Post-Experiment Questionnaire

The correlations between group cohesion questions are shown in Table 7. As in Experiment 2a, an exploratory factor analysis seemed appropriate because the correlation matrix included several moderate to high values and partial

correlations were typically lower – as indicated by an adequate level of .82 on Kaiser's Measure of Sampling Adequacy. As in Experiment 2a an exploratory factor analysis was performance for questions related to group cohesion (Question 1-6). A principal component analysis was used to estimate the number of factors, then, a principal factory analysis was performed. Again, Question 1 was extracted based on both inspection of the scree plot and an eigenvalue greater than 1 (the eigenvalues were 3.31, .97, .58, .49, .37, .29). In the principal factor analysis, this question accounted for 55% of the total variance.

The first set of exploratory analyses addressed the issue of whether there were any general differences in perceived group cohesion between conditions. Average perceived group cohesion in the C*Recognition*- C*recognition*-**I*Recognition*** was 6.23 and average group cohesion in the C*Recall*-C*Recall*-**I*Recognition*** was 5.54 - this difference was significant, t (94) = 3.26, SE = .21. This finding is similar to the marginal effect observed in Experiment 2a, and suggests that group cohesion is lower following repeated group recall than following repeated group recognition, regardless of the final individual test format.

The second set of exploratory analyses which addressed the issue of whether group cohesion differed between the two conditions when participants reported that one or two members dominated the group yielded no significant differences. No significant differences in perceived group cohesion between the two conditions were observed in participants who reported that no person dominated the group either.

Again, the third set of exploratory analyses was conducted to explore whether group cohesion correlated with group performance. While group cohesion was not significantly correlated with group recognition performance during Retrieval 1 or Retrieval 2, group cohesion was significantly correlated with group recall performance during the first (**C*Recall***-C*Recall*-I*Recognition)* and second (C*Recall*-**C*Recall***-I*Recognition*) recall trial, r = .37, p = .01 and r = .47, p < .01, respectively. This finding provides converging evidence that group cohesion is a function of the type of memory task that is used during repeated group retrieval. Then again, it is possible that perceived group cohesion is related to recall but not recognition performance because the range of values for group cohesion and recognition are restricted. Again, these data were broken down in terms of participants that reported that one or two members dominated the group and those that reported that no person dominated the group but no significant correlations between group cohesion and group recognition performance was observed after this split either. However, group cohesion was correlated with group performance both when one or two members were reported to dominate the group (r = .46, p <.01) and when no person was reported to dominate the group (r = .54, p <.01). These findings suggest that group cohesion is correlated with

group recall performance regardless of whether a group leader was perceived to emerge during group collaboration.

Finally, the fourth set of exploratory analyses addressed the issue of whether group cohesion correlated with final individual recognition performance. However, no significant correlations were observed in any condition even when the data were broken down in terms of whether one or two persons were reported to dominate the group or when no person was reported to dominate the group.

Taken together, the exploratory analyses of Experiment 2b mimic the results of Experiment 2a. Specifically, while group cohesion appears to be greater during repeated group recognition compared to repeated group recall, it correlates with recall but not recognition. Then again, these findings are compromised by a restricted range of values in both group cohesion and recognition performance. Nevertheless, these exploratory analyses are informative in that they imply that effects of group collaboration on later individual memory are influenced by both cognitive and social factors such as group cohesion.

III. General Discussion

This dissertation was aimed at identifying conditions where benefits of re-exposure to study material during group collaboration can overcome the losses from retrieval disruption that accrue during group collaboration. The opposing effects of these mechanisms were tested with the goal of understanding how they carry over to, or enhance, later individual memory. Experiment 1 examined the effects of repeated group recall, repeated individual recall and combinations of group and individual recall on later individual recall performance. Experiment 2 examined the relative benefits of repeated group recall and repeated group recognition on later individual recall and recognition.

The key findings from Experiment 1 are that repeated group recalls (CC**I**), and individual recall prior to group recall (IC**I**) benefits later individual recall to a greater extent than repeated individual recall trials (II**I**). These findings support the group-strategy-hypothesis and the individual-hypothesis, respectively. The group-strategy hypothesis states that repeated group recall trials support the stabilization of group-retrieval strategies and allow individuals to use the additional items provided by the other members of the group during later individual recall. Evidence in favor of the group-strategy hypothesis were observed in the final individual recall measure (CC**I** > II**I** and CI**I**) and in the hypermnesia measure (because final individual recall was worse than initial group recall in the **C**I**I** condition but final individual recall was similar to initial group

recall in the **C**C**I** condition). The reminiscence and forgetting measures indicated a role for re-exposure (as indicated by greater reminiscence) and transfer of group responses to final individual recall (as indicated by lower forgetting) in mediating the benefits observed in the **C**C**I** condition. Finally, the trends observed in the paired frequency measure also support the group-strategy hypothesis because paired frequencies were numerically higher across Recall 1 and Recall 2 in the **CC**I condition compared to the **CI**I and **II**I conditions.

The individual-strategy hypothesis states that individual recall strategies must be secured before individual memory can benefit from prior group recall. Evidence in favor of the individual-strategy hypothesis was not observed in the final individual recall measure (probably because of numerically lower individual recall performance during Recall 1 in the ICI condition compared to the III condition) but appeared in the hypermnesia measure because the improvement in recall performance from Recall 1 to Recall 3 was significantly greater in the **I**C**I** condition compared to the **II**I condition. Greater reminiscence but similar forgetting from Recall 1 to Recall 3 in the **I**C**I** compared to the **II**I provides evidence in favor of re-exposure benefits rather than the recovery of individual retrieval strategies during final individual recall in the ICI condition.

Aside from the theoretical implications of the findings observed in Experiment 1, these findings also provide evidence-based recommendations for straightforward application to education. While group collaboration (or exam preparation in groups) prior to individual exam preparation may not enhance later individual exam performance, repeated group collaboration, or individual exam preparation prior to group collaboration may enhance later individual exam performance.

The key findings from Experiment 2 are that the type of memory test used during repeated group retrieval (recall or recognition) is an important factor when final individual memory is assessed with a recognition task but not when final individual memory is assessed with a recall task. In other words, the stabilization of group retrieval strategies during repeated group recall and the presence of item-specific retrieval cues during repeated group recognition generate comparable benefits on later individual recall (Experiment 2a: C*Recall*-C*Recall*-**I*Recall*** ~ C*Recognition*-C*Recognition*-**I*Recall***). This finding is consistent with the group-strategy hypothesis and the idea that retrieval disruption is reduced in the presence of item-specific retrieval cues. By contrast, the presence of item-specific retrieval cues during repeated group recognition generate greater benefits than the stabilization of group retrieval strategies during repeated group recall on later individual recognition (Experiment 2b: C*Recognition*- C*Recognition*-***IRecognition*** > C*Recall*-C*Recall*-**I*Recognition***). This finding is consistent with transfer-appropriate processing principle and the idea that retrieval disruption is reduced in the presence of item-specific retrieval cues. Most parsimoniously, the

transfer-appropriate processing principle can account for findings from both Experiments 2a and 2b because final individual memory performance benefited (or at least was comparable) when prior group collaboration involved the same task compared to when prior group collaboration involved a different task.

However, it is possible that a different pattern of results would appear if a delay was introduced between group retrieval trials and the final individual retrieval trial. This is because the item-specific retrieval cues provided during repeated group recognition can be considered additional study exposures. As mentioned previously, the testing effect literature suggest that while repeated individual *studying* leads to better individual recall after a short delay (5 minutes), repeated individual *recall* leads to better individual recall after 2-day and 1-week delays (Roediger & Karpicke, 2006b; Wheeler et al., 2003). If this pattern of results carries over to the effects of group retrieval on later individual retrieval, repeated group recall trials may prove to be more beneficial than repeated group recognition trials after a longer delay - providing further support for the group-strategy hypothesis and emphasizing the importance of generative processes for observing benefits of prior group collaboration on later individual memory at longer delays. Future research should be aimed at addressing this issue.

There are educational implications of the results observed in Experiment 2 as well. In particular, if students are preparing for a multiple-choice exam, exam preparation in groups should also involve multiple-choice questions. However, if students are preparing for an essay exam, exam preparation in groups can involve either multiple-choice or essay questions – the results of Experiment 2 suggest that they are equally effective.

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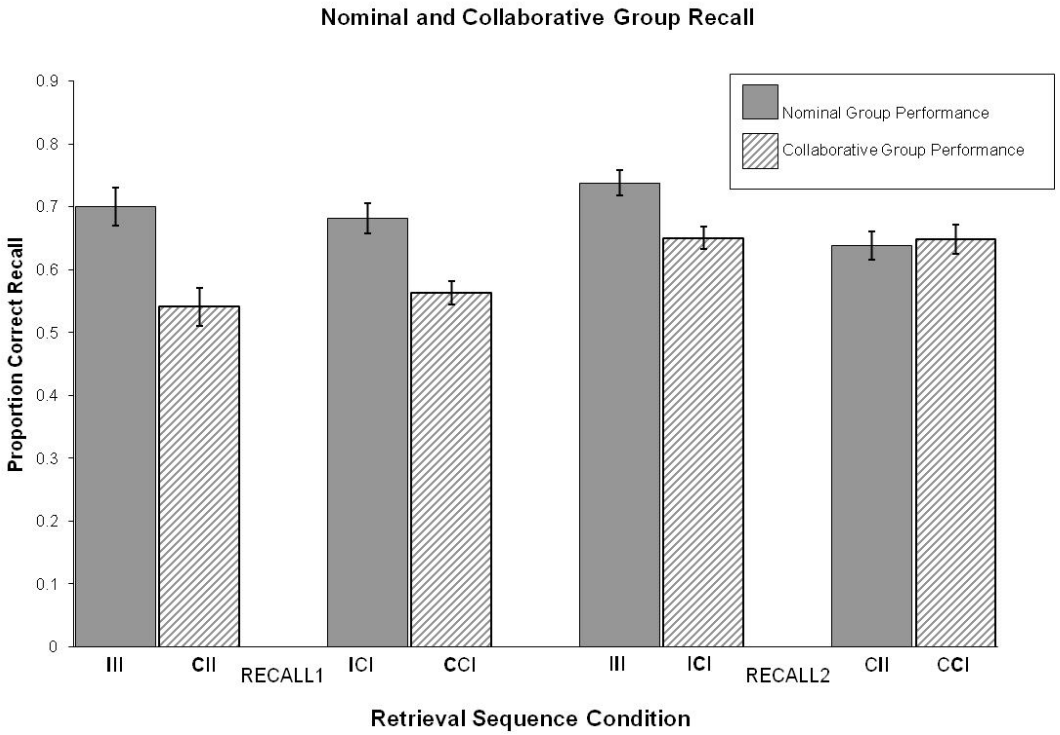

Figure 1 – Mean proportion of correct recall for nominal and collaborative groups.

Table 1 – Proportions of Correctly Recalled Items for Individuals, Collaborative Groups and Nominal Groups in Experiment 1.

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	-

Table 2 – Proportions of Hypermnesia, Reminiscence, and Forgetting across Recall Trials in Experiment 1.

Condition	Recall 1 to 2	Recall 2 to 3	Recall 1 to 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

Table 3 – Possible outcomes and explanations in Experiment 2a

Outcome	Explanation
C*Recall*-C*Recall*-**I*Recall*** **>** C*Recognition*-C*Recognition*-**I*Recall***	Stable group retrieval strategies benefit later individual memory when there is a match between prior and final test format – consistent with the *group-strategy hypothesis* and the *transfer-appropriate processing principle*.
C*Recognition*-C*Recognition*-**I*Recall*** > C*Recall*-C*Recall*-**I*Recall***	The presence of item-specific cues decreases retrieval disruption and input from others improve later individual recall, regardless of test format – consistent with the idea that *retrieval disruption* is reduced in the presence of item-specific retrieval cues.
C*Recall*-C*Recall*-**I*Recall*** **~** C*Recognition*-C*Recognition*-**I*Recall***	The stabilization of group retrieval strategies and the presence of item-specific cues generate comparable benefits on later individual recall – consistent with the *group-strategy hypothesis* and the idea that *retrieval disruption* is reduced in the presence of item-specific retrieval cues.

Table 4 – Possible outcomes and explanations in Experiment 2b

Outcome	Explanation
C*Recognition*-C*Recognition*-**I*Recognition*** **>** C*Recall*-C*Recall*-**I*Recognition***	Item-specific cues decrease retrieval disruption and input from others improve later individual memory when there is a match between prior and final test format - consistent with the *transfer-appropriate processing principle* and the idea that the presence of item-specific retrieval cues reduces retrieval disruption.
C*Recall*-C*Recall*-**I*Recognition*** > C*Recognition*-C*Recognition*-**I*Recognition***	Stable group-retrieval strategies benefit later individual memory, regardless of the final individual test format – consistent with the *group-strategy hypothesis*
C*Recognition*-C*Recognition*-**I*Recognition*** **~** C*Recall*-C*Recall*-**I*Recognition***	The presence of item-specific retrieval cues and the stabilization of group retrieval strategies generate comparable benefits on later individual recognition performance – consistent with the *group-strategy hypothesis* and the idea that the presence of item-specific cues reduce retrieval disruption.

Table 5 – Proportions of correct recall, hits, false alarms and corrected recognition (hits-false alarms and d') across retrieval trials in Experiment 2a 2b.

Experiment 2a			Proportion Correct Recall	
C*Recall*-C*Recall*-I*Recall*			.33	
C*Recall*-**C*Recall*-**I*Recall*			.33	
C*Recall*-C*Recall*-**I*Recall***			.33	
	Hits	FA	Hits-FA	d'
C*Recognition*-C*Recognition*-I*Recall*	.97	.07	.90	3.57
C*Recognition*-**C*Recognition*-**I*Recall*	.97	.03	.93	3.84
			Proportion Correct Recall	
C*Recognition*-C*Recognition*-**I*Recall***			.34	
Experiment 2b	Hits	FA	Hits-FA	d'
C*Recognition*-C*Recognition*-I*Recognition*	.98	.07	.91	3.69
C*Recognition*-**C*Recognition*-**I*Recognition*	.97	.04	.93	3.81
C*Recognition*-C*Recognition*-**I*Recognition***	.91	.04	.88	3.50
			Proportion Correct Recall	
C*Recall*-C*Recall*-I*Recognition*			.35	
C*Recall*-**C*Recall*-**I*Recognition*			.39	
	Hits	FA	Hits-FA	d'
C*Recall*-C*Recall*-**I*Recognition***	.88	.15	.73	2.44

Table 6 – Overall Means and Correlations among Post-Experiment Questions Related to Group Cohesion in Experiment 2a.

Question	1	2	3	4	5	6
Mean	5.79	6.08	5.65	5.80	4.48	5.55
1	-	.63**	.52*	.41**	.34**	.29**
2	-	-	.47**	.38**	.25*	.22*
3	-	-	-	.77**	.52**	.20*
4	-	-	-	-	.61**	.24*
5	-	-	-	-	-	.26*
6	-	-	-	-	-	-

* p <.05. ** p <.01.

Table 7 – Means and Correlations among Post-Experiment Questions Related to Group Cohesion in Experiment 2b.

Question	1	2	3	4	5	6
Mean	5.88	6.21	5.67	5.96	4.22	5.60
1	-	.53**	.47**	.35**	.22**	.49**
2	-	-	.59**	.41**	.27**	.45**
3	-	-	-	.66**	.52**	.52**
4	-	-	-	-	.57**	.50**
5	-	-	-	-	-	.28**
6	-	-	-	-	-	-

* p <.05. ** p <.01

Appendix 1

Post-Experiment Questionnaire

On a scale from 1 = "not at all" to 7 = "very much" answer questions 1-6.

1. How cohesive do you think the group was?

2. Do you think that your group worked well together on the task that you performed?

3. Would you want to remain a member of this group on future projects?

4. Overall, how much do you like the other members of your group?

5. How similar do you think you are to the other members of your group?

6. How motivated were you to do well on the memory test?

Answer questions 7-11 as instructed below
(i.e. yes or no, or rank as instructed, clarify your answers if you can)

7. Do you think that the other members of the group contributed as many words as they could remember?

8. Did you feel that one (or two) members dominated the group?

9. Can you provide an estimate of the number of words that each person in the group contributed?

10. Can you rank the other members of the group in terms of their contribution (1 = highest contributor, 2 = average contributor, 3 = least contributor)

11. Did you contribute as many words as you can remember?