Divided Attention and Repetition at Encoding: The Role of Individual Subjective Organization in Group Recall

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Abstract of the Dissertation

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Collaborative inhibition refers to the phenomenon whereby a group performs worse than the same number of individuals who work alone and pool their nonredundant responses (i.e., nominal group). Two experiments explored the effects of weakened or strengthened individual memory on the magnitude of collaborative inhibition. Participants studied categorized words lists and performed a recall memory test in groups of three (collaborative condition) or individually (nominal condition). In Experiment 1, divided attention and collaborative inhibition effects were replicated and individual organization was significantly better in the full attention condition than in the divided attention condition. Weakened individual memory influenced group recall as collaborative inhibition attenuated from the full attention condition to the divided attention condition. In Experiment 2, repetition and collaborative inhibition effects were replicated and individual organization was significantly better in the repeated condition compared to the single presentation condition. Strengthened individual memory modified group recall as collaborative inhibition was present in the single presentation condition, but its effect was marginal in the repeated condition. These experiments are the first show that manipulations that produce opposite effects on individual conceptual processing and level of recall modify the negative effects of collaboration on group recall.

To my father

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And to my husband, my best friend and soul mate, Eric Pasarin, whose love I could not live without – Thank you, thank you, and thank you.

Introduction

The retrieval of the past in the context of social activities is a likely scenario in individuals' daily lives. For example, when family members get together for a family function they may engage in discussions of a family trip they took or a movie the family watched together. In doing so, these individuals attempt to retrieve information while exposed to the recall product of others who are contributing to the discussion. Extant research in the collaborative memory literature indicates that exposure to the recall product of group members during collaborative discussions inhibits overall group recall. This counterintuitive phenomenon named collaborative inhibition refers to the finding that a collaborative group performs worse than the same number of individuals who work alone and pool their nonredundant responses (i.e., a nominal group) (B. H. Basden, Basden, Bryner, & Thomas, 1997; Weldon & Bellinger, 1997).

Recently, a few studies that manipulated retrieval conditions suggest that although the negative effects of collaboration on group memory are robust, these effects are not ubiquitous. These studies reported that collaboration can benefit group memory performance in a recognition memory task (Clark, Hori, Putnam, & Martin, 2000), when group members perform the memory test after a one week delay (Takahashi & Saito, 2004), or when repeated study and retrieval sessions are used (B. H. Basden, Basden, & Henry, 2000). These studies primarily focused on retrieval manipulations and do not inform us of the effects of conceptual processing carried out by individuals at *encoding* on later group recall. This dissertation aimed to fill this gap in the literature. Conceptual processing often takes place at study (Rundus, 1971). It is important to understand how study conditions that increase or decrease conceptual processing can influence memory performance when individuals attempt to retrieve the past in social contexts.

The two experiments in the current study systematically explored two encoding manipulations that have the potential to protect group memory performance from collaborative inhibition. The goal of this study was to explore the effects of weakened or strengthened individual memory on the magnitude of collaborative inhibition. This study investigated how these opposite effects on individual encoding influenced group memory performance. Individual memory is weakened by divided attention and presumably strengthened by repetition at study. Experiment 1 investigated the effects of divided attention at study on group recall. This experiment explored whether divided attention modifies the negative effects of collaboration on group memory. Experiment 2 investigated the effects of repetition at study on group recall. This experiment assessed whether the magnitude of collaborative inhibition differs as a function of repetition.

Collaborative Inhibition

A brief overview of the collaborative memory paradigm is useful here to elaborate on the general procedures of collaborative memory studies. Participants in a standard collaborative memory study engage in an individual study session followed by a brief retention interval. The test phase consists of an individual memory test or a collaborative memory test in groups of two, three or more members. The memory output for the collaborative condition provides a measure of collaborative memory. The memory output for the individual condition provides a baseline measure of individual memory, as well as a measure of nominal group recall. A nominal group (i.e., a group in name only) is obtained by pooling the nonredundant responses of individuals who do not collaborate at test. For example, if participant 1 recalls three items (e.g., *stove, elevator,* and *river*), participant 2 recalls three items (e.g., *trophy, river,* and *school*), and participant 3 recalls four items (e.g., *stove, elevator, ostrich,* and *chisel*), the nonredundant output for this nominal group consists of seven items (e.g., *stove, elevator, river, trophy, school, ostrich,* and *chisel*). A nominal group allows experimenters to compare the memory performance of participants who collaborate at test with participants who do not collaborate at test (B. H. Basden et al., 1997; Weldon & Bellinger, 1997).

Group recall has been investigated using two types of collaboration procedures: a) a turn-taking procedure and b) a free-for-all procedure. In a turn-taking procedure, participants are instructed to take turns and to provide only one response on their turn (B. H. Basden et al., 1997; B. H. Basden et al., 2000; B. H. Basden, Basden, Thomas, & Souphasith, 1998; B. H. Basden, Reysen, & Basden, 2002; Wright & Klumpp, 2004). In a free-for-all procedure, participants in the collaborative condition are given a single blank sheet of paper and are instructed to provide as many responses as they can. One person in the group serves as the scribe and participants are not given instructions on how to develop a group recall strategy (Finlay, Hitch, & Meudell, 2000, Experiment 2 and 3; Johansson, Andersson, & Rönnberg, 2000,2005; Takahashi & Saito, 2004; Weldon & Bellinger, 1997; Weldon, Blair, & Huebsch, 2000; Yaron-Antar & Nachson, 2006). Both procedures yield similar results: Collaborative groups recall fewer items than nominal groups.

A vast body of research in the collaborative memory literature indicates that nominal groups outperform collaborative groups across a variety of study materials. Examples of stimuli used in these studies include: unrelated word lists (Andersson, Hitch, & Meudell, 2006; Andersson & Rönnberg, 1997; Leman & Oldham, 2005; Meudell, Hitch, & Kirby, 1992; Weldon & Bellinger, 1997, Experiment 1; Weldon et al., 2000; Wright & Klumpp, 2004), story recall (Takahashi & Saito, 2004; Weldon & Bellinger, 1997, Experiment 2), categorized lists (B. H. Basden et al., 1997; B. H. Basden et al., 2000; B. H. Basden et al., 1998; Meudell, Hitch, & Boyle, 1995), word pairs (Finlay et al., 2000, Experiment 2 and 3), associatively related items (B. H. Basden et al., 1998; B. H. Basden et al., 2002), semantic versus episodic tasks (Andersson & Rönnberg, 1996), and emotionally laden events (Yaron-Antar & Nachson, 2006). Interestingly, collaborative inhibition was also observed in a study that aimed to reduce social loafing by manipulating motivational factors. For example, motivation was manipulated by providing monetary compensation, increasing personal accountability by writing the person's name next to their responses, increasing group cohesion by asking group members to discuss their similarities and differences, and reducing gender differences by testing only women (Weldon et al., 2000). Altogether, despite differences in collaboration procedures and study materials these studies show that collaborative inhibition is a pervasive phenomenon.

Basden and colleagues have argued that the same cognitive mechanisms that produce part-list cuing inhibition are responsible for collaborative inhibition. In part-list cuing studies, participants are given either a part-list cued recall test or a free recall test (D. R. Basden & Basden, 1995; D. R. Basden, Basden, & Galloway, 1977; D. R. Basden & Draper, 1973; Bäuml & Aslan, 2006). In a part-list cued recall test, participants are given a test booklet that already contains, for example, 6 of the 12 studied items per word list, and are instructed to recall the *remaining* 6 studied items for each study list. In a free recall test, participants are given a blank sheet of paper and asked to recall as many items as they can from the study phase of the experiment. Results indicate that participants in the free recall test condition outperform participants in the part-list cued recall test condition in the recall of the *remaining* 6 studied items of each study list. This phenomenon is referred to as part-list cuing inhibition. Individuals' retrieval strategies are presumed less effective when part-list cues are present compared to when part-list cues are absent. The rationale for this phenomenon is that part-list cues introduce a retrieval order that is inconsistent with the idiosyncratic organization participants developed at encoding. When part-list cues are removed from the procedure participants are able to return to their original retrieval strategies established at encoding. Similar effects of part-list cuing inhibition have been reported for categorized word lists (D. R. Basden & Basden, 1995; D. R. Basden et al., 1977; D. R. Basden & Draper, 1973) and unrelated words lists (Bäuml & Aslan, 2006).

Consistent with the implications of part-list cues, Basden and colleagues proposed the retrieval strategy disruption hypothesis of collaborative inhibition. The cognitive mechanism assumed to accompany the negative effects of collaboration on group memory suggests that exposure to the recall product of group members during collaboration introduces a retrieval order that is inconsistent with the idiosyncratic sequence individuals might otherwise use. Consequently, participants in the collaborative condition perform worse than participants in the nominal condition. In contrast, participants in nominal groups are not exposed to the recall product of others during retrieval and therefore do not experience retrieval strategy disruption (B. H. Basden et al., 1997; B. H. Basden et al., 2000; B. H. Basden et al., 1998; B. H. Basden et al., 2002; Finlay et al., 2000; Weldon & Bellinger, 1997; Wright & Klumpp, 2004).

In summary, collaborative inhibition is observed when group members recall fewer responses than the same number of individuals who work alone and pool their nonredundant responses (i.e., nominal group). Collaborative inhibition is a robust phenomenon and its effects have been reported across a variety of collaboration procedures and study materials. The cognitive mechanism responsible for collaborative inhibition shares similar features with the cognitive mechanism that modulates part-list cuing inhibition. In other words, during collaborative recall exposure to the recall product of group members introduces a retrieval sequence that is inconsistent with the order that individuals established at encoding. Therefore, nominal groups who are not exposed to the recall product of group members outperform collaborative groups. It remains an open question whether conditions that increase or decrease individual subjective organization at encoding can modify the effects of collaborative inhibition.

Benefits of Collaboration on Group Memory

Support for the retrieval disruption hypothesis of collaborative inhibition also comes from studies where collaborative inhibition disappeared when the test conditions did not demand the use of individual retrieval strategies. One study examined the effects of collaboration on group recall for word pairs in dyads (Finlay et al., 2000). Participants encoded word pairs and performed a free recall test or a cued recall test where one item in each word pair served as the retrieval cue. Although collaborative inhibition was present in the free recall test, it disappeared in the cued recall memory test. The presence of retrieval cues in the cued recall test reduced the need to rely on individual organization at test. Consequently, collaborative dyads experienced less disruption of their individual retrieval strategies when exposed to the recall product of group members during collaboration.

A second study that manipulated retrieval tasks that reduced the demand on individual retrieval strategies showed that collaborative inhibition disappeared in a recognition memory test (Clark et al., 2000). Participants studied lists of unrelated words and performed a group recognition memory test in triads, followed by an individual recognition memory test. The responses of the individual recognition memory test were calculated in terms of performance by the group's best member, the average of responses and the responses obtained by vote counting (i.e., two out of three votes wins). Results indicated group recognition memory performance was better than the comparison to the group's best member, the average of the responses and the responses obtained by vote counting. The experimenters suggested that collaborative inhibition is specific to free recall tests where group performance is influenced by the recall product of group members. When memory tasks, such as recognition, provide retrieval cues at test participants do not have to rely on their idiosyncratic organization.

Collaborative inhibition also dissipates under conditions that presumably weaken individual retrieval strategies. Based on the findings that delay (and retroactive interference ensued by delay) reduces part-list cuing inhibition (Raaijmakers & Phaf, 1999), a recent study explored the effects of delay on collaborative inhibition (Takahashi & Saito, 2004). The experimenters reasoned that delay would reduce the strength of individual retrieval strategies. Therefore, participants would benefit from exposure to the recall product of group members during collaboration. In Experiment 1, participants read a story and performed an immediate free recall memory test individually or in dyads. Collaborative inhibition was observed in the immediate condition. In Experiment 2, a different group of participants read the same story and performed the recall memory test after one week. As predicted, memory performance declined over delay. Even though collaboration did not facilitate new veridical memories, participants in the collaborative condition forgot fewer items than participants in the nominal condition. After a one week delay, participants were not able to effectively use their idiosyncratic retrieval strategies established at encoding. Consequently, exposure to the recall product of others during collaboration improved group memory performance in delayed testing. These findings provide a new insight into the nature of the collaborative inhibition phenomenon. Collaboration exerts a negative effect on group free recall in immediate testing conditions when individual retrieval structure is strong. However, collaboration helps group memory as individual episodic memory decreases and memory performance weakens over time.

In summary, collaborative inhibition disappeared when retrieval conditions did not demand the use of individual organization. This finding was observed in a collaborative cued recall test and recognition memory test. Collaborative inhibition also dissipated when individual memory performance decreased after delay and participants were able to benefit from the recall product of group members. These findings support the retrieval disruption hypothesis of collaborative inhibition and shed light on the cognitive mechanisms at retrieval that modulate collaborative inhibition. The experiments discussed in this dissertation investigated the nature of collaborative inhibition when conceptual processing – and consequently the level of memory performance - is modified at *encoding*. The next section describes study conditions that have been shown to reduce individual memory and conceptual processing at encoding.

Divided Attention and Individual Memory

The study phase methodology in instantiating full attention versus divided attention conditions consists of two tasks that are performed simultaneously. These tasks are typically referred to as primary and secondary tasks. For example, participants may be asked to read a list of words presented on a computer screen. In addition, participants may be instructed to listen to a series of tones presented on a tape recorder and to make a check mark on a sheet of paper for every high, medium or low tone they hear. In this example, the primary task is the word reading task and the secondary task is the tone monitoring task.

An extensive body of research shows that divided attention at encoding reduces subsequent individual memory for studied words relative to full attention in free recall (Baddeley, Lewis, Eldridge, & Thomson, 1984; Craik, Govoni, Naveh-Benjamin, & Anderson, 1996; Craik & Kester, 2000; Craik & McDowd, 1987; Eysenck & Eysenck, 1979), cued recall (Craik & Kester, 2000; Craik & McDowd, 1987,1998; Naveh-Benjamin, Craik, Guez, & Kreuger, 2005) and recognition (Craik & Kester, 2000; Craik & McDowd, 1987,1998). Performance on the secondary task is also impaired when attention is divided at encoding. Studies that manipulated whether the emphasis at encoding was on the word reading task or on the secondary task indicated a systematic trade-off in performance between both tasks. Emphasis on the word reading task improves later memory performance, but reduces performance on the secondary task. Similarly, emphasis on the secondary task improves performance on the secondary task, but reduces performance in the later memory task (Craik et al., 1996; Naveh-Benjamin et al., 2005). A recent study by Craik and Kester (2000) manipulated whether participants studied categorized word lists under full attention and divided attention conditions. The experimenters investigated whether divided attention at study would reduce memory performance and the likelihood that individuals would organize the retrieved items into categories. Results indicated that divided attention at study decreased memory performance and organization for categorized lists compared to full attention conditions (Craik & Kester, 2000). Altogether, these findings suggest that encoding involves consciously controlled processes that consume attentional resources and divided attention disrupts individual strategic encoding.

The disruptive effects of divided attention on individual memory are predicted by the evidence that divided attention at encoding disrupts conceptual processing of information (Geraci & Rajaram, 2002; Mulligan, 1998; Mulligan & Hartman, 1996). For example, experimenters manipulated the presentation of categorized word lists in full attention or divided attention conditions (Mulligan, 1998; Mulligan & Hartman, 1996). A digit monitoring task was used in the divided attention condition as participants were instructed to listen to a series of digits and to indicate each time they heard three odd digits in a row. At test, participants performed an explicit memory task (i.e., category cued recall or word-fragment cued recall) or an implicit memory task (i.e., word-fragment completion or category exemplar production). In an explicit memory task participants are instructed to think back to the study phase of the experiment and are required to retrieve as many items as they can remember. An implicit memory task is an indirect measure of memory performance. For example, participants may be asked to complete a word fragment (*e l_ _ h _ n _* for *elephant*) as quickly as possible with the first word that comes to mind. The difference in accuracy for completing word fragments for studied items and nonstudied items is referred to as priming. Evidence for implicit memory comes from more accuracy for studied items compared to nonstudied items and a lack of conscious awareness by participants that studied items were actually presented at encoding.

In both category cued recall and category exemplar production participants are presented with a category name at test and are required to provide as many exemplars to that category as possible. The difference between these two tasks concerns whether participants receive explicit memory or implicit memory instructions at test. In a category cued recall task, participants are given explicit memory instructions to think back to the study phase of the experiment to recall items that were presented at study. In a category exemplar production task participants are given implicit memory instructions to provide exemplars that come to mind for each category. No aspect of the study phase is mentioned in the implicit memory instructions for this task. The category exemplar production task relies on conceptual processing because there is no perceptual overlap between items presented across study and test. Therefore, participants need to rely on the meaning of studied items to complete the task.

Category cued recall, word-fragment cued recall and category exemplar production are primarily supported by conceptually driven processes, whereas implicit word-fragment completion is primarily supported by data driven processes (Roediger & McDermott, 1993; Roediger, Weldon, & Challis, 1989). Results indicate divided attention impairs memory performance in conceptually driven tasks (category cued recall, word-fragment cued recall and category exemplar production), but does not affect memory performance in data driven tasks (implicit word-fragment completion).

Together, these findings from explicit and implicit memory tests are consistent with those described earlier in showing that divided attention at study disrupts individual organization of information (Craik & Kester, 2000). Therefore, Experiment 1 focused on the effects of divided attention on conceptual processing in individuals and on the influence of collaboration on group recall.

Rationale for Experiment 1

Divided attention has been shown to impair conceptual processing and it is indeed the case that memory performance is better in full attention conditions than in divided attention conditions (Craik & Kester, 2000; Eysenck & Eysenck, 1979; Geraci & Rajaram, 2002; Mulligan, 1998; Mulligan & Hartman, 1996). Divided attention has also been shown to reduce individual organization compared with full attention conditions (Craik & Kester, 2000). Together, these findings converge on the prediction that reducing conceptual processing in individuals by dividing attention at study could reduce the negative effects of collaboration in group recall. This question is important to investigate because it has the potential to show whether collaboration can protect group recall when individual memory is weakened.

Participants studied categorized word lists individually under full attention and divided attention conditions. Divided attention has been manipulated successfully both as a between-subjects variable (Craik et al., 1996; Mulligan & Hartman, 1996; Naveh-Benjamin et al., 2005) and as a within-subjects variable (Craik & Kester, 2000; Geraci & Rajaram, 2002). In our study, we manipulated divided attention in a within-subjects design for the following reasons: a) the recall scores for the full attention and divided attention conditions are typically higher in a within-subjects design than a between-subjects design and b) a recent study that reported that divided attention reduced individual organization for categorized lists manipulated divided attention in a within-subjects design (Craik & Kester, 2000).

Predictions for Overall Recall

The secondary task in the divided attention condition consisted of a digit monitoring task. At test, participants performed a free recall test individually (i.e., nominal condition) or in groups of three (i.e., collaborative condition). As free recall memory tasks are mediated by conceptually driven processes, we expect to replicate the effect of divided attention at encoding. In other words, memory performance is expected to be better in the full attention condition than in the divided attention condition.

The prediction of a main effect of collaboration, or better memory performance for nominal groups than collaborative groups, is qualified by a possible interaction between collaboration and attention. We expect to replicate the collaborative inhibition effect in the full attention condition. In other words, we expect nominal groups to outperform collaborative groups.

There are three possible outcomes for the effects of collaboration on group recall in the divided attention condition. One possibility is that collaborative inhibition will attenuate when attention is divided at study. This pattern of results predicts an interaction between collaboration and attention, such that collaborative inhibition will be present in the full attention condition, but will attenuate in the divided attention condition. Support for this prediction comes from studies that observed reduced memory performance and organization for categorized lists in conceptually driven tasks when attention was divided at study (Craik & Kester, 2000; Mulligan & Hartman, 1996). As individual memory became weaker due to divided attention, participants would be left with fewer idiosyncratic retrieval strategies that could be disrupted during collaboration. As a result, participants in the collaborative condition could benefit from hearing the recall product of group members during collaboration. This outcome would provide the novel finding that despite the robustness of the negative effects of collaboration on group recall, collaborative inhibition attenuates when individual encoding is disrupted.

A second possibility of the effects of collaboration on group recall in the divided attention condition concerns a cross-over interaction between collaboration and attention. While we predict collaborative inhibition in the full attention condition, we predict that collaborative *facilitation* will be present in the divided attention condition. As indicated previously, divided attention at encoding reduces conceptual processing (Craik & Kester, 2000; Eysenck & Eysenck, 1979; Geraci & Rajaram, 2002; Mulligan, 1998; Mulligan & Hartman, 1996). Consequently, individuals' idiosyncratic retrieval strategies would be so poor in the divided attention condition that participants in the collaborative condition would benefit from exposure to the recall product of other group members during collaboration. Nominal groups would perform below the optimum level and collaborative groups would benefit from others' input and therefore outperform nominal groups. This pattern of results would suggest that when individual memory is weakened and individuals are unable to establish successful retrieval strategies, collaboration facilitates group recall.

As a third possibility of the effects of collaboration on group recall in the divided attention condition, we predict that collaborative inhibition will be present at both levels of attention. Although divided attention impairs conceptual processing (Craik & Kester, 2000; Eysenck & Eysenck, 1979; Geraci & Rajaram, 2002; Mulligan, 1998; Mulligan & Hartman, 1996) and organization (Craik & Kester, 2000), participants might nonetheless be left with sufficient retrieval strategies to experience disruption from exposure to the recall product of group members during collaboration. This outcome would provide the novel finding that collaborative inhibition is a robust effect and that it impairs group recall when attention is divided at study.

Turning to the predictions for organization, as noted earlier, organization in free recall of categorized lists was higher in the full attention condition than in the divided attention condition (Craik & Kester, 2000). Based on these findings, we predict a main effect of attention such that more organization will be observed in the full attention condition than in the divided attention condition.

Support for our prediction of a main effect of collaboration for organization comes from studies in collaborative memory that measured organization in categorized lists. These studies reported that collaboration disrupted individual retrieval strategies and that organization was higher for nominal groups than collaborative groups (B. H. Basden et al., 1997; B. H. Basden et al., 2000; B. H. Basden et al., 1998). Based on these findings, we predict that nominal groups in our study will also show higher levels of organization than collaborative groups. Although we expect to replicate this finding, there also exist critical differences between the parameters in our study and in the studies by B. H. Basden et al. that could likely influence our results for organization as a function of collaboration. We will provide more details about these parameters in the Results and Discussion section of Experiment 1.

Method

Participants

Ninety-six Stony Brook University undergraduates participated in this experiment in partial fulfillment of a course requirement or for monetary compensation of $5.00. Forty-eight participants were tested in the collaborative condition in groups of three and 48 participants were tested in the nominal condition individually, yielding 16 triads in each condition.

Materials

Ten categories with 12 target exemplars in each category were selected from a set of word norms (Battig & Montague, 1969). Twelve additional categories with one exemplar in each category served as buffers in the study lists: three categories for primacy buffers and three categories for recency buffers. Buffers are included at the beginning and at the end of study lists to eliminate the primacy effect (i.e., remembering the first few items on the list) and the recency effect (i.e., remembering that last few items on the list) observed in free recall. The target exemplars and buffer exemplars were equated on word length of five to nine letters ($F < 1$, $M = 6.77$) and low taxonomic frequency ($F < 1$, $M = 28.23$). A digit monitoring task was used to divide attention at study (Geraci & Rajaram, 2002; Mulligan & Hartman, 1996). At test, participants were given a blank sheet of paper to complete the free recall memory test.

Design

A 2 x 2 mixed factorial design was used in this study. Collaboration (collaborative versus nominal) was the between-subjects variable and attention (full attention versus divided attention) was the within-subjects variable. Two sets of categorized lists were created by dividing the ten target categorized lists into two groups of five target categorized lists. A similar procedure was used for the categorized lists used as buffers. The final two sets of items consisted of three primacy buffers, five target categorized lists and three recency buffers. With the exception of the buffer items, the target categorized lists were intermixed, such that no two items from the same category were presented consecutively. Attention was blocked at study and blocks were counterbalanced across participants for order and for item sets within the collaborative and nominal conditions. The counterbalancing of item sets and attention blocks resulted in four study lists per collaborative condition. Nominal groups were formed by randomly assigning individuals to the nominal condition as they arrived in the lab. These participants worked individually at study and at test. Collaborative groups were formed by randomly assigning three individuals to the collaborative condition as they arrived in the lab. These participants worked individually at study (while the other two group members were also present in the room) and recalled the studied items as a group.

Procedure

Each study item was presented for five seconds in lower case letters using Arial 60 point size font. An asterisk was used as a place holder during the interstimulus interval of one second. Participants in the collaborative and noncollaborative conditions encoded the items individually under full attention and divided attention instructions. In the full attention condition, participants were instructed to read each item silently and carefully and were informed of a possible memory test. In the divided attention condition, participants were given the same instructions as the full attention condition, but they encoded the categorized lists while simultaneously performing the digit monitoring task. Participants were encouraged to perform both tasks as accurately as possible. The digit monitoring task consisted of a random sequence of digits from 0 to 9 presented at a rate of 1.5 seconds on a compact disk player. The task was constructed according to the guidelines reported in previous divided attention studies (Geraci & Rajaram, 2002; Mulligan & Hartman, 1996). Participants were given a blank sheet of paper and required to make a check mark each time they heard a sequence of three odd digits in a row. There were a total of 47 target sequences of three odd digits randomly distributed throughout the 264 digits. The list was created such that no more than two even numbers were presented consecutively between the target sequences. The sequences of three odd digits were separated by at least one digit to four digits at the most. Participants practiced the digit monitoring task for 30 seconds before the study session began. As the attention manipulation was blocked, participants received a break of 30 seconds between the full attention and the divided attention study blocks.

Following the presentation of the two word lists, participants engaged in a distractor task typically used in memory studies to fill the brief interval between study and test and to prevent idiosyncratic practice by participants. In the current study, participants wrote the names of Presidents of the United States for five minutes. After the distractor task, participants performed one of two free recall memory tests: in groups of three (i.e., collaborative condition) or individually (i.e., nominal condition). Participants in the collaborative condition were given one blank sheet of paper. A free-for-all collaborative memory procedure was used such that one person in the triad served as the scribe and participants were instructed to recall as many items as they can from both study lists. Participants were required to provide one final group answer and they were not instructed on how to resolve disagreements in the group. The groups' free recall tests were self-paced and lasted approximately 10 minutes. Participants in the nominal condition performed the recall memory test individually and were instructed to recall as many items as they could from both study lists. The duration of the free recall test for the nominal condition also lasted 10 minutes. The nominal group output was calculated by using the standard procedure in collaborative memory studies. Briefly, the nonredundant output of three participants who worked individually at test was pooled to form one nominal group score.

Organization in the collaborative and nominal conditions for both levels of attention was measured by calculating Adjusted Ratio of Clustering (ARC) scores. ARC scores have been used in both individual memory studies (Craik & Kester, 2000; Roenker, Thompson, & Brown, 1971) and collaborative memory studies (B. H. Basden et al., 1997; B. H. Basden et al., 2000; B. H. Basden et al., 1998) to measure the ratio of clustering, or the order in which participants recall items from categorized lists. The clustering ratio scores are calculated in the following way:

$$\text{ARC} = \frac{\text{observed number of clusters minus the expected number of clusters}}{\text{maximum number of clusters minus the expected number of clusters}}$$

The observed number of clusters refers to the number of times a category item follows an item from the same category. For example, if a collaborative group recalls eight items from three categories (e.g., a, a, b, a, b, c, c, c), the observed number of clusters from this group recall is 3. The maximum number of clusters is obtained by calculating the number of items recalled minus the number of categories represented in the recall product. The maximum number of clusters for this example is 5: eight items recalled minus three categories (a, b, and c).

The expected number of clusters refers to the number of category repetitions recalled greater than chance performance. The expected number of clusters is obtained by adding the total number of items recalled from a category and squaring this sum. This process is repeated for each category recalled and added together. The final sum is divided by the total number of items recalled. Lastly, this ratio is subtracted by one. In the current example, the sum of three (a + a + a) squared, plus two (b + b) squared, plus three (c + c + c) squared equals 22. Twenty-two divided by eight (total number of items recalled) equals 2.75. When one is subtracted from this quotient, the expected number of clusters is 1.75. To calculate the ARC score for this example, the three components computed here are inserted in the formula indicated above and the ARC score equals .39.

Adjusted ratio of clustering scores range from negative scores to positive one. Negative scores reflect below chance performance and a positive one score reflects perfect clustering. Based on discussions in an e-mail exchange with David Basden (March 23rd, 2007) regarding the treatment of negative ARC scores, in the present experiment negative ARC scores were replaced with zero as an indicator that no organization was evident in the recall product. The ARC scores for three individuals in the nominal group were calculated in the same way described above and were averaged to produce one final measure of organization.

Results and Discussion

For all the analyses reported in Experiment 1 and Experiment 2 the alpha level was set at .05, unless otherwise noted.

Overall Recall

A 2 x 2 mixed analysis of variance (ANOVA) for collaborative versus nominal conditions and full attention versus divided attention was conducted on the mean proportions of overall recall. A main effect of attention was observed such that recall was better in the full attention condition (*M* =.50) than in the divided attention condition (*M* =.11), $F(1,30) = 530.46$, *MSe* = .01. This finding replicates the ubiquitous effect of divided attention reported in the literature that divided attention at study disrupts memory performance in conceptually driven tasks (Craik & Kester, 2000; Eysenck & Eysenck, 1979; Geraci & Rajaram, 2002; Mulligan & Hartman, 1996). A significant effect of collaborative inhibition was observed such that memory performance was better in the nominal condition (*M* =.35) than in the collaborative condition (*M* =.27), $F(1, 30) = 10.38$, *MSe* = .01. Although the mean proportion recall for nominal and collaborative groups are lower than the proportions reported in the literature, we nevertheless replicated the negative effects of collaboration in group recall (B. H. Basden et al., 1997; B. H. Basden et al., 2000; B. H. Basden et al., 1998; Finlay et al., 2000; Weldon & Bellinger, 1997; Wright & Klumpp, 2004). As noted earlier, we manipulated attention at encoding as a within-subjects variable. Divided attention at study reduced memory performance in the divided attention condition compared to the full attention condition. The mean proportion recall for the nominal and collaborative groups obtained here were averaged across high levels of recall in the full attention condition and low levels of recall in the divided attention condition. Consequently, this procedure used to calculate recall across attention conditions resulted in lower levels of recall for the nominal and collaborative conditions. When the mean proportion recall for the nominal and collaborative groups are considered only for the full attention condition (reported next), the levels of performance in our experiment are comparable to the proportions reported in the literature.

Ours is the first study to our knowledge to assess the effects of collaboration on group recall when attention is divided at study. A significant interaction between collaboration and attention was observed such that the magnitude of the collaborative inhibition effect was different at each level of attention, $F(1, 30) = 4.07$, *MSe* = .01. Follow-up comparisons indicated that the collaborative inhibition effect was larger in the full attention condition (nominal recall *M* =.56; collaborative recall *M* =.44), *t*(30) = 3.11, *SE* =.04, and attenuated in the divided attention condition, (nominal recall *M* =.14; collaborative recall *M* =.09), *t*(30) = 2.21, *SE* =.02 (see Figure 1). As memory performance (Mulligan & Hartman, 1996) and individual organization (Craik & Kester, 2000) have been shown to be reduced under divided attention conditions, participants are left with some, but fewer, idiosyncratic retrieval strategies in the divided attention condition that could be disrupted during collaboration. Because more items were encoded in the full attention condition than in the divided attention condition, there is more room for disruption of individual retrieval strategies to occur during collaboration under full attention encoding. Therefore, a larger collaborative inhibition effect resulted in the full attention condition than in the divided attention condition. This novel finding suggests that the negative effects of collaboration on group recall are bigger when individual encoding is intact and attenuate when individual encoding is disrupted. These findings also suggest that subjective organization was likely lower in the divided attention condition and in turn led to lower collaborative inhibition. To examine this possibility we turned to the analyses of the ARC scores in the next section.

It is possible that the results for the divided attention are qualified by performance values that are rather low (14% for the nominal condition and 9% for the collaborative condition). Therefore, it is useful to note that while overall recall was low in the divided attention condition, (*M* =.11), it was nevertheless significantly above zero, *t*(32) = 9.56, *SE* = .02. Further, these values are comparable to the values reported in the literature when attention is divided using the digit monitoring task (Geraci & Rajaram, 2002; Mulligan & Hartman, 1996). Finally, recall levels in the divided attention condition for both the nominal (*M*=.14) and collaborative groups (*M* =.09) were also significantly different from zero, *t*(16) = 8.28, *SE* = .02, and *t*(16) = 5.86, *SE* = .02, respectively. Taken together, these findings suggest that despite low recall, the divided attention results are in line with the general literature. It would be useful in future studies to use alternative manipulations of divided attention that are less detrimental to episodic memory in order to extend the findings of this study under conditions of higher recall in the divided attention condition.

In regard to intrusions in recall, collaborative groups usually produce more intrusions than nominal groups (B. H. Basden et al., 1997; B. H. Basden et al., 1998). In contrast to these findings, our results indicated the novel finding that nominal groups (*M* =.05) reported significantly more intrusions than collaborative groups (*M* = .02), *t*(30) = 3.23, *SE* = .01 (see Table 2). In both experiments an intrusion was defined as an item that was not presented at study, but was recalled at test. Even though our results suggest a pattern reversed from the literature, the proportions of intrusions were low and there was no relation between the intrusions and studied material. In other words, the intrusions did not come from categories that were presented at study. Although the mechanism that is driving this pattern of results is unclear, one possibility is that collaborative groups are more successful at pruning intrusions than nominal groups. This interpretation is consistent with the published data from our laboratory on the effects of collaboration on individual memory where collaboration reduced false alarms in individual recognition memory (Rajaram & Pereira-Pasarin, 2007). Another possibility for the pattern of intrusions observed here is that since nominal groups recall more items than collaborative groups, unrelated intrusions might also be higher for nominal groups for the same reasons.

Adjusted Ratio of Clustering (ARC)

A 2 x 2 mixed ANOVA for collaboration and attention was conducted on the mean proportions of organization measured by ARC scores. A significant main effect of attention was observed such that organization was higher in the full attention condition (M =.34) than in the divided attention condition (M =.12), $F(1, 30) = 17.18$, $MSe = .05$ (see Table 1). This finding replicates the results reported in the literature that divided attention at encoding disrupts organization in conceptually driven tasks (Craik & Kester, 2000). Furthermore, this finding supports our results for overall recall, such that the magnitude of the collaborative inhibition effect was bigger in the full attention condition and attenuated in the divided attention condition. As information is more organized in the full attention condition than in the divided attention condition, participants in the collaborative condition experienced more disruption of individual retrieval strategies in the full attention condition than in the divided attention condition.

Turning to the ARC measures across collaborative and nominal conditions, we found that despite the presence of a significant collaborative inhibition effect in overall recall, the level of organization, as measured with ARC scores, was equivalent for nominal groups (M =.23) and collaborative groups (M =.24), $F(1, 30) < 1$. Furthermore, the interaction between collaboration and attention was not significant, $F(1, 30) < 1$ (see Table 1). Organization is reported to be typically higher in nominal groups than collaborative groups (B. H. Basden et al., 1997; B. H. Basden et al., 2000; B. H. Basden et al., 1998). As indicated earlier, there are several differences between the parameters in our study and the studies by B. H. Basden et al. that might account for the discrepancy in our findings. First, we manipulated attention at encoding whereas participants in the B.H. Basden et al. studies encoded items only under full attention conditions.

Furthermore, we manipulated attention as a within-subjects variable in order to maximize the impact of this variable on memory. As such, the recall protocol of each participant in the collaborative and nominal conditions in our experiment included items from both full attention and divided attention encoding conditions. We observed that participants in our study were equally likely to switch between recalling items from the full attention condition and the divided attention condition, thereby disrupting organization at recall equally across collaborative and nominal conditions. Second, we used a free-for-all procedure during recall whereas B. H. Basden et al. used a turn-taking procedure. It is possible that a turn-taking procedure disrupts organization more because each participant can recall only one item on their turn, thereby lowering the ARC measure. In contrast, in a free-for-all procedure, a single group member can recall several items consecutively, thereby reducing retrieval disruption during group recall. Third, we used a retention interval of five minutes to reduce recency effects, whereas B. H. Basden et al. used a retention interval of only 30 seconds. It is possible that organization (and recall to a lesser extent) reduces quickly with delay. Fourth, in the B. H. Basden et al. (2000) and B. H. Basden et al. (1998) studies, study items were blocked by category at presentation. In addition, a category cued recall test was used such that, participants were given the names of each category and were required to recall as many exemplars as possible. In contrast, study items in our experiment were intermixed, such that no two items from the same category were presented consecutively. Further, participants in the nominal and collaborative conditions performed a free recall test. The use of category blocking at study and category cued recall at test are conditions more likely to induce organization during encoding and retrieval, respectively, compared to the conditions in our study.

In summary, as noted earlier, the critical prediction of higher level of organization in the full attention condition compared to the divided attention condition was borne out in our results. The parameters described here provide several reasons for equal levels of organization between nominal and collaborative conditions in Experiment 1. Future studies should explore the validity of these parameters and thereby, shed more light on the role of individual organization in group recall, and on the cognitive mechanisms associated with collaborative inhibition.

Unadjusted Ratio of Clustering

As indicated earlier, ARC scores vary from an upper bound of positive one to negative values. We analyzed the ARC using the conventional procedure of setting the negative scores to zero, as well as by retaining all the positive and negative values as calculated (i.e., unadjusted ratio of clustering). The findings for clustering scores show that the general conclusions are supported with both the adjusted and unadjusted analyses. As with the results of the adjusted ARC score analyses described above, a main effect of attention was significant in the unadjusted ARC scores as well, such that organization was higher for the full attention condition (*M* = .29) than the divided attention condition (*M* = -.19), $F(1, 30) = 16.78$, *MSe* = . 23. Although the difference in organization between the nominal condition (*M* = .06) and the collaborative condition (*M* =.03) was numerically in the right direction, the main effect of collaboration was not statistically significant, $F(1, 30) < 1$. In the divided attention condition, unadjusted ratio of clustering scores were numerically lower for the collaborative group (*M* = -.29) than for the nominal group (*M* = -.11), $t(30) < 1$, SE = . 24. This finding is in the right direction in showing that organization was lower in the collaborative condition than in the nominal condition although the difference was not statistically significant. Similarly, the full attention condition also did not reveal a difference in clustering between the nominal (*M* =.23) and the collaborative (*M* = .35) conditions, $t(30) = 1.11$, $SE = .10$. The interaction between collaboration and attention was also not significant, $F(1, 30) = 1.55$, *MSe* = . 23. Altogether, these results support our findings for overall recall that more organization (i.e., full attention encoding) leads to more collaborative inhibition and less organization (i.e., divided attention encoding) yields less collaborative inhibition. As we discussed earlier, the lack of a difference in ARC scores between collaborative and nominal groups may be attributed to several design features in our experiment that diverged from previous studies.

Experiment 2

Repetition and Individual Memory

A plethora of studies in the memory literature indicate that repetition improves retrieval compared to conditions where information is presented only once (Crowder, 1976; Glenberg, 1979; Greene, 1989). Spaced repetition is particularly effective in improving conceptual processing of study material (Challis, 1993). Spaced repetition involves repeating study items that are separated by two or more intervening items. Spaced repetition is more effective than massed repetition (i.e., presentation occurs in immediate successions) in improving memory performance, a finding known as the spacing effect. The spacing effect is a robust memory phenomenon and it has been observed in explicit memory tests (e.g., free recall, cued recall and recognition) (Braun & Rubin, 1998; Crowder, 1976; Glenberg, 1979; Greene, 1989; Toppino & Bloom, 2002; Toppino, Hara, & Hackman, 2002) and conceptual implicit memory tests (e.g., the general knowledge test) (Challis & Sidhu, 1993). Despite our understanding of the effects of spaced repetition on individual memory, the influence of spaced repetition on collaborative recall has not been explored. It is important to investigate this question because spaced repetition increases recall which in turn can protect individual memory from collaborative inhibition.

Given the vast body of research confirming the benefits of spaced repetition over massed repetition on conceptual processing, Experiment 2 examined the effects of spaced repetition compared to single presentation on collaborative recall. The prediction that spaced repetition would improve individual memory is supported by a study that examined the effects of rehearsal in free recall (Rundus, 1971). Overt rehearsal of study items was measured in a series of experiments. Spaced repetition led to more rehearsal after the second presentation than massed repetition and single presentation (Experiment 3). This study also showed that when subjects studied categorized lists, clustering occurred both during rehearsal and later recall (Experiment 4). Together, these findings suggest that spaced repetition of category exemplars in study lists should increase organization during later recall.

Evidence that spaced repetition promotes rehearsal and conceptual processing is consistent with our expectation that spaced repetition is likely to increase individual memory compared to a single presentation. Experiment 2 created these study conditions because this experiment tested the hypothesis that increased conceptual processing (through spaced repetition) could protect individual memory from the negative effects of collaboration.

Rationale for Experiment 2

In the first experiment we examined the effects of collaboration on group recall when individual memory was weakened by divided attention. In Experiment 2 we investigated a complementary research question by exploring study conditions that strengthen individual memory. Together, we sought to gain a better understanding of the effects of collaboration on group recall as conceptual processing varied on a continuum from poorer to richer encoding conditions.

As indicated earlier, despite the robustness of the collaborative inhibition effect, a few studies have shown that this effect can dissipate under certain retrieval conditions. Existing evidence suggests that the negative effects of collaboration on group recall dissipate when repetition occurs both at study and at test (B. H. Basden et al., 2000, Experiment 2). Basden and colleagues reasoned that group memory can benefit from additional exposure to study materials. Participants viewed a categorized word list and performed an individual recall or a group recall memory test. After the first study-recall cycle, participants repeated the same procedure to a total of three consecutive study-recall cycles. Collaborative inhibition was reported in the first study-recall cycle, but disappeared in the second and third study-recall cycles. The benefits of re-exposure were assumed to be accompanied by increased organization of information at encoding, although measures of organization were not separately reported for performance after each study-recall cycle. Nonetheless, if additional study exposures (via repetition) strengthened mnemonic encoding, then participants were less likely to experience retrieval strategy disruption during collaboration. These findings suggest that the magnitude of the negative effects of collaboration on group recall can be reduced if group members are given additional opportunities to encode information.

The findings reported by B.H. Basden et al. are interesting and important for identifying conditions that can counteract collaborative inhibition. However, the manipulation of repeated encoding in the B. H. Basden et al. study was interwoven with repeated testing, making it difficult to isolate the independent effects of study repetition on individual memory and collaborative inhibition. In Experiment 2, we isolated the study repetition variable and investigated whether this variable by itself can protect group memory from collaborative inhibition. This experiment tested the hypothesis that study repetition strengthens conceptual processing in individuals. If repetition is a process that allows individuals to rehearse information, it is expected that repetition would improve individual retrieval strategies. Further, it is expected that stronger individual memory would be less vulnerable to disruption from exposure to the recall product of group members. Therefore, the magnitude of collaborative inhibition could decrease in the repeated condition compared to the single presentation condition.

Participants in Experiment 2 performed an individual encoding task under a single presentation condition and a repeated presentation condition. Items in the repeated presentation condition were presented three times with three or four intervening items between occurrences. Participants made pleasantness ratings on each item at study and performed a free recall test individually (i.e., nominal condition) or in groups of three (i.e., collaborative condition).

Predictions for Overall Recall

As free recall memory tasks are mediated by conceptual processes (Roediger & McDermott, 1993; Roediger et al., 1989), we expect to replicate the ubiquitous effect of repetition at encoding. In other words, we predict that memory performance will be better in the repeated presentation condition than in the single presentation condition (Crowder, 1976; Glenberg, 1979; Greene, 1989).

The prediction of a main effect of collaboration is modified by a possible interaction between collaboration and repetition. To reiterate, a main effect of collaboration refers to better memory performance in the nominal condition than in the collaborative condition. For the single presentation condition, we expect to replicate the collaborative inhibition effect. That is, we predict that participants in the nominal condition will outperform participants in the collaborative condition. There were three possible outcomes for the effects of collaboration on group recall in the repetition condition. One possibility is that collaborative inhibition will be present in the single presentation condition and attenuate in the repeated condition. Support for this prediction comes from a study that showed that spaced repetition promotes rehearsal and increases recall. This study also showed more clustering of categorized items during rehearsal and this clustering was evident in the recall output (Rundus, 1971). If repetition improves recall and rehearsal compared to single presentation, then individuals would have stronger retrieval strategies for repeated items. As individual retrieval strategies are made stronger and more organized, participants would experience less retrieval disruption during collaboration. Collaboration might disrupt only some of the retrieval strategies and leave other retrieval strategies intact. This pattern of results would provide the novel contribution that collaboration impairs group recall in a single presentation, but does less so when individual memory is strengthened.

A second possibility of the effects of collaboration on group recall in the repeated condition concerns a cross-over interaction between collaboration and repetition. While we predict that collaborative inhibition will be present in the single presentation condition, we expect that collaborative *facilitation* will be present in the repeated condition. As repetition promotes rehearsal and increases individual recall performance (Rundus, 1971), participants would experience less retrieval strategy disruption. We expect that with stronger individual retrieval strategies, participants in the collaborative condition would benefit from the recall product of group members. This pattern of results would suggest that collaboration impairs group recall in a single presentation, but facilitates group recall when individual memory is strengthened by repetition.

A third although unlikely possibility of the effects of collaboration on group recall in the repeated condition concerns the presence of collaborative inhibition at both levels of repetition. Repetition increases rehearsal that aid recall compared to a single presentation (Rundus, 1971). We expect that participants will experience strengthened individual retrieval strategies for repeated items than for items presented only once. If collaboration disrupts individual retrieval strategies and there are more retrieval strategies in the repeated condition, then we expect the magnitude of collaboration inhibition to be higher in the repeated condition relative to the single presentation condition. This pattern of results would suggest while repetition improves individual recall, it hinders group recall. Furthermore, these results would provide a novel context to study the effects of collaboration on group memory and replicate the robustness of the collaborative inhibition phenomenon.

Turning to the predictions for organization, an extant body of research indicates that repetition promotes conceptual processing of information (Challis, 1993) and rehearsal takes place during repetition (Rundus, 1971). Based on these findings, we predict a main effect of repetition, such that organization will be higher in the repeated condition than in the single presentation condition. As noted earlier, organization is typically higher for nominal groups than collaborative groups (B. H. Basden et al., 1997; B. H. Basden et al., 2000; B. H. Basden et al., 1998). For this reason, we predict a main effect of collaboration, such that organization will be higher for nominal groups than collaborative groups. However, differences between the parameters in our study and in the studies by B. H. Basden et al. discussed in Experiment 1 also apply to Experiment 2. Therefore, it is possible that our prediction of more organization for nominal groups than collaborative groups could be compromised.

Method

Participants

Ninety-six Stony Brook University undergraduates participated in this experiment in partial fulfillment of a course requirement. Forty-eight participants were tested in the collaborative condition in groups of three and 48 participants were tested in the nominal condition individually.

Materials

A total of 20 categories were selected from a set of categorized word norms (Battig & Montague, 1969). Eight critical categories with five exemplars in each category served as critical items. Eight categories with one exemplar in each category served as buffers in the study lists. Of these eight categories, four categories served as primacy buffers and four categories served as recency buffers in the study lists. Four additional categories with ten exemplars in each category served as filler items. The critical exemplars, buffer exemplars and filler exemplars were equated on word length of five to nine letters ($F < 1$, $M = 6.80$) and low taxonomic frequency ($F < 1$, $M = 26.22$). At test, participants were given a blank sheet of paper to complete the free recall memory test.

Design

A 2 x 2 mixed factorial design was used in this study. Collaboration (collaborative versus nominal) was the between-subjects variable and repetition (single presentation versus repeated) was the within-subjects variable. The eight critical categories were divided into two sets of four categories. One set of categories (i.e., 20 items) appeared in the single presentation condition and the other set of categories (i.e., 20 items) appeared in the repeated condition. The two sets of critical categories were counterbalanced for repetition across participants resulting in two study lists. A typical study list consisted of 128 slots: four slots for primacy buffers, 20 slots for critical items presented once, 60 slots for critical items presented three times, 40 slots for filler items presented once and four slots for recency buffers. With the exception of the buffer items, all items were randomized in the study lists so that no two items from the same category were presented consecutively. The lag (number of intervening items between two presentations of the same item) in the repeated condition consisted of three or four items.

Procedure

Each of the 128 study items was presented for five seconds in lower case letters using Arial 60 point size font. An asterisk was used as a place holder during the interstimulus interval of one second. Participants in the collaborative and nominal conditions were instructed to read each item silently and were informed of a possible memory test. Participants were also informed that some words would be repeated in the study list. Repeated items were presented three times with a lag of three or four intervening items between presentations.

A pleasantness task was used to encourage participants to encode the study items. Participants rated the pleasantness of each item on a scale of 1 to 5. A rating of 1 indicated the item was *very unpleasant* and a rating of 5 indicated the item was *very pleasant*. After the study phase, participants performed a distractor task in which they wrote down the names of Presidents of the United States for five minutes. The test phase followed the same procedure used in Experiment 1. Organization in the collaborative and nominal conditions at both levels of repetition was measured by calculating ARC scores.

Results and Discussion

Overall Recall

A 2 x 2 mixed ANOVA for collaboration and repetition was conducted on the mean proportions of overall recall. A significant main effect of repetition was observed such that recall was better in the repeated condition (M = .81) than in the single presentation condition (M = .56), $F(1, 30) = 98.05$, $MSe = .01$. This finding replicates the results reported in the literature that spaced repetition improves memory performance in conceptually driven tasks compared to conditions in which information is presented only once (Braun & Rubin, 1998; Challis, 1993; Crowder, 1976; Glenberg, 1979; Greene, 1989; Toppino & Bloom, 2002; Toppino et al., 2002). A main effect of collaboration was also observed such that recall was better in the nominal condition (M =.74) compared to the collaborative condition (M =.63), $F(1, 30) = 9.57$, $MSe = .02$. These results replicate the negative effects of collaboration on group recall reported in the collaborative memory literature (B. H. Basden et al., 1997; B. H. Basden et al., 2000; B. H. Basden et al., 1998; B. H. Basden et al., 2002; Finlay et al., 2000; Weldon & Bellinger, 1997; Wright & Klumpp, 2004).

Despite the robustness of the collaborative inhibition effect, the main effect of collaboration was qualified by a significant interaction between repetition and collaboration. The magnitude of collaborative inhibition differed at each level of repetition, $F(1, 30) = 4.93$, $MSe = .01$. The collaborative inhibition effect was significant in the single presentation condition (nominal recall M =.64; collaborative recall M =.48), $t(30) = 3.00$, $SE = .05$, but attenuated in the repeated presentation condition (nominal recall M =.83; collaborative recall M =.79), $t(30) = 1.78$, $SE = .03$, $p = .09$) (see Figure 2). These results support the hypothesis that repetition protects group recall against the disruption of individual retrieval strategies during collaboration. The mechanism assumed to accompany this pattern of results suggests that repetition at study promotes conceptual processing (Challis, 1993) and rehearsal takes place during repetition (Rundus, 1971). Repetition strengthens individual retrieval strategies thereby making individual organization and recall less vulnerable to disruption during collaboration. Even though collaboration may disrupt a few retrieval strategies, other strategies may remain intact. Thus, repetition at encoding has the potential to mitigate the negative effects of collaboration on group recall compared to the single presentation condition. These results provide the novel finding that collaboration impairs group recall when information is presented only once, but does so to a lesser extent when individual memory is strengthened by repetition at study. Further, these findings suggest that organization was higher in the repeated condition than in the single presentation condition. To investigate this possibility, we examined the analyses of ARC scores in the next section.

To our knowledge, this is the first study to manipulate the effects of repetition solely at study and collaboration on group recall. For this reason, there is no prior evidence on how repetition could influence the rate of intrusions in collaborative groups and nominal groups. Interestingly, we observed that collaborative groups (M =.01) reported significantly fewer intrusions than nominal groups (M=.05), $t(30) = 3.80$, $SE = .01$ (see Table 2). These results are in contrast to the findings reported for single presentation of categorized word lists which observed more intrusions for collaborative groups than for nominal groups (B. H. Basden et al., 1997; B. H. Basden et al., 1998). As in Experiment 1, our results show a pattern opposite to the findings reported in the literature. The proportions of intrusions were low and there was no relation between the intrusions and studied material. In other words, the intrusions did not come from categories that were presented at study. Nevertheless, it is important to note that under conditions that strengthen individual recall and organization, collaboration has the potential to suppress intrusions compared to nominal groups.

Adjusted Ratio of Clustering (ARC)

A 2 x 2 mixed ANOVA for collaboration and repetition was conducted on the mean proportions of organization measured by ARC scores. A significant main effect of repetition was observed such that organization was better in the repeated condition (M = .28) compared to the single presentation condition (M = .18), $F(1, 30) = 4.08$, $MSe = .04$ (see Table 1). These results replicate the findings reported in the literature that spaced repetition promotes conceptual processing (Challis, 1993) and improves rehearsal of information (Rundus, 1971).

Turning to the ARC measures across collaborative and nominal conditions, we found that despite the presence of a significant collaborative inhibition effect in overall recall, the level of organization was equivalent for collaborative groups (M =.24) and nominal groups (M =.22), $F(1, 30) < 1$ (see Table 1). Similarly, the interaction between collaboration and repetition was not significant, $F(1, 30) < 1.90$, $p > .05$. As indicated earlier, organization is typically higher in nominal groups than collaborative groups (B. H. Basden et al., 2000). However, Basden et al. did not isolate repetition at study as we did and did not require participants to make pleasantness judgments at study. Furthermore, the four differences in parameters between our study and the studies by B. H. Basden et al. listed in Experiment 1 could also have influenced the nature of organization at recall in Experiment 2.

An alternative explanation for the equivalent level of organization between the nominal and collaborative groups concerns the manipulation of repetition as a within-subjects variable. In the repeated condition, 20 critical items were presented three times, resulting in 60 presentations in this condition. In contrast, in the single presentation condition, 20 other critical items were presented only once. In order to equate the number of presentations (i.e., 60) at study between the repeated and the single presentation conditions, 40 filler items were included in the single presentation condition. Therefore, the recall product in the nominal and collaborative conditions consisted of repeated items, singly presented items and filler items. Interestingly, nominal groups (*M* =.52) recalled significantly more filler items than collaborative groups (*M* = .42), $t(30) = 2.28$, SE = .04. These findings suggest that the presence of more filler items during recall in the nominal condition in our study could have reduced the levels of organization in this condition typically observed in previous studies. Nevertheless, our results supported the critical prediction that organization was higher in the repeated condition compared to the single presentation condition.

Unadjusted Ratio of Clustering

As indicated earlier, ARC scores vary from an upper bound of positive one to negative values. We analyzed the ARC using the conventional procedure of setting the negative scores to zero, as well as by retaining all the positive and negative values as calculated (i.e., unadjusted ratio of clustering). As with the adjusted ARC analyses above, the values in the repeated condition (*M* = .13) and in the single presentation condition (*M* = .09) were numerically in the right direction although the main effect of repetition for the unadjusted clustering scores was not statistically significant, $F(1, 30) < 1$. A significant main effect of collaboration was observed, such that mean clustering scores for the nominal condition (*M* = .03) was significantly lower than the mean clustering scores for the collaborative condition (*M* =.19), $F(1, 30) = 4.87$, *MSe* = .09. This reversed effect might have come about because of the presence of more filler items during recall in the nominal condition (*M* =.52) than in the collaborative condition (*M* = .42) in our study. That is, the additional filler items could have reduced the level of organization in the nominal condition that is typically observed in previous studies. The data for the unadjusted ratio of clustering scores support this possibility. The interaction between repetition and collaboration was also not significant, (nominal repeated *M* =.03; nominal single, *M* = .03; collaborative repeated *M* =.23; collaborative single, *M*=.15), *F*(1, 30) < 1. Altogether, because collaborative inhibition was present for overall recall of filler items and single presentation items, these effects could have led to more negative unadjusted ratio of clustering scores for the nominal condition, thus reducing organization.

General Discussion

The goal of this study was to assess the effects of weakened versus strengthened individual memory on group memory. Collaborative inhibition refers to the finding that a group performs worse than the same number of individuals who work alone and pool their nonredundant responses (i.e., nominal group). We investigated whether conditions that affect individual memory at encoding could protect group recall from collaborative inhibition. The mechanism assumed to accompany the collaborative inhibition effect entails the disruption of individual retrieval strategies participants experience during group recall (B. H. Basden et al., 1997; B. H. Basden et al., 2000; B. H. Basden et al., 1998; B. H. Basden et al., 2002; Finlay et al., 2000; Wright & Klumpp, 2004). In other words, exposure to the recall product of group members during collaboration introduces a retrieval order that is inconsistent with the idiosyncratic organization individuals establish for encoding information. As a result, collaborative groups produce fewer items than nominal groups whose members work individually and have their nonredundant responses pooled.

The experiments discussed here tested the retrieval strategy disruption hypothesis of collaborative inhibition by investigating this hypothesis under study conditions that increased or decreased individual memory. Previous research has shown that divided attention and repetition at encoding have opposite effects on conceptual processing in individuals. Divided attention reduces individual conceptual processing (Craik & Kester, 2000; Eysenck & Eysenck, 1979; Geraci & Rajaram, 2002; Mulligan, 1998; Mulligan & Hartman, 1996) and repetition presumably increases conceptual processing (Challis, 1993; Rundus, 1971). The current study manipulated attention and repetition at encoding and measured the consequent changes in individual memory as well as the changes in collaborative inhibition. It is the first study to our knowledge to show that these variables influence the effects of collaboration in group recall.

In Experiment 1, poorer recall in the divided attention condition compared to the full attention condition was replicated. There was also a significant *decrease* in organization in the divided attention condition. A robust effect of collaborative inhibition was also observed indicating that recall was better in the nominal condition than in the collaborative condition. More importantly, weakened individual memory influenced the effects of collaboration on group recall; collaborative inhibition was present in the full attention condition, but it was attenuated in the divided attention condition.

Experiment 2 complemented the findings of Experiment 1 under study conditions that strengthened individual memory. In Experiment 2, recall was significantly better for the repeated study presentation condition compared to the single presentation condition. Further, subjective organization was *higher* in the repeated presentation condition than in the single presentation condition. A collaborative inhibition effect for overall recall was also replicated in this experiment. More importantly, the negative effects of collaboration on group recall varied as a function of repetition. Collaborative inhibition was present in the single presentation condition, but it was attenuated and marginal in the repeated condition.

Two important points regarding the results of Experiment 1 and 2 deserve further discussion here. In Experiment 1, the attenuation of collaborative inhibition in the divided attention condition was accompanied by a reduction in organization of individual retrieval strategies. Divided attention disrupted encoding as memory performance was worse in the divided attention condition. Importantly, divided attention also disrupted individual subjective organization as the level of organization was lower in the divided attention condition. Therefore, participants were left with lowered and reduced strategic organization for the items studied under divided attention. Collaboration had a negative impact on group recall in the full attention condition and the magnitude of collaborative inhibition decreased in the divided attention condition. Altogether, these results present a novel conclusion that when individual memory is intact, collaboration impairs group recall. However, when individual memory is impaired, collaborative inhibition attenuates.

In Experiment 2, the benefit of collaboration on group recall in the repeated condition was accompanied by an increase in individual subjective organization. Repetition promotes more elaboration and rehearsal in conceptually driven memory tasks (Challis, 1993; Rundus, 1971). Repetition at study increased overall recall and organization compared to the single presentation at study. Although some individual retrieval strategies were presumably disrupted during collaboration, other retrieval strategies remained intact as a result of repetition. These findings suggest that when individual memory is strengthened by study repetition, this mechanism can protect group recall from collaborative inhibition.

As summarized above, the findings in the ARC scores (i.e., individual organization measure) were consistent with our predictions for the effects of divided attention (Experiment 1) and repetition (Experiment 2). We now turn to a discussion of how ARC scores compare across nominal and collaborative groups. Past research suggests that nominal groups typically produce higher ARC scores than collaborative groups (B. H. Basden et al., 1997; B. H. Basden et al., 2000; B. H. Basden et al., 1998). However, in both experiments reported here, organization measured by ARC scores for proportion recall was equivalent for nominal and collaborative groups. A possible explanation for this pattern of results concerns the manipulation of divided attention and repetition as within-subjects variables in Experiments 1 and 2, respectively. None of the previous studies that reported higher ARC scores for the nominal group included within-subjects manipulations at encoding. In a within-subjects manipulation, participants in both collaborative and nominal group switch from one condition to another during study and can also do so during recall, thereby leading to equivalent organization across nominal and collaborative groups. In other words, it is possible that organization may have been weakened equally in both collaborative and nominal groups as a result of switching across conditions. But, importantly, divided attention nonetheless affected organization more than full attention, and led to an attenuation of collaborative inhibition. Repetition on the other hand, increased organization compared to single presentation, thereby mitigating the collaborative inhibition effect.

A second possible explanation for no differences in organization between the nominal and collaborative conditions concerns the use of a turn-taking recall procedure in previous studies and a free-for-all recall procedure in our study. The turn-taking procedure requires each group member to provide only one item on their turn. In contrast, the free-for-all procedure does not impose any restrictions on the number of items each group member can contribute on their turn. This procedure enables group members to recall items in clusters because more items can be recalled sequentially by participants. It is possible that the turn-taking procedure further reduces organization in group recall because participants are restricted to providing only one item on their turn. In other words, organization in the turn-taking procedure depends on whether or not a group member provides an item from the same category as the previous group member.

A third possibility for the lack of differences in ARC scores for collaborative and nominal recall in our study concerns the manner in which items were presented at study. In the collaborative memory studies that reported ARC scores (B. H. Basden et al., 1997; B. H. Basden et al., 2000; B. H. Basden et al., 1998), items were blocked by category at study. Presenting items in a blocked fashion at study aids organization and retrieval. In our experiments, categorized items were intermixed at study. Therefore, individual retrieval strategies were less organized for both collaborative and nominal conditions. It is possible that the ARC measure is sensitive to the manner in which categorized items are presented at study and is not able to detect differences in organization between the collaborative and nominal conditions.

A forth possibility for the discrepancy in the organization measure of our study refers to the duration of the retention interval. We used a retention interval of five minutes to reduce rehearsal and recency effects. In contrast, B. H. Basden et al. used a retention interval of only thirty seconds. It is possible the shorter retention interval in their study enabled participants to maintain stronger and more organized retrieval strategies at recall. A shorter retention interval would be more efficient in increasing organization in nominal groups because individuals in this condition are not exposed to the recall product of group members.

Turning to Experiment 2, repetition and recall were manipulated differently in the Basden et al. (2000) study and in our study. Basden and colleagues manipulated repetition at study as well as at test as participants were given three cycles of study-recall sessions of the same study items. In our experiment, we isolated repetition only at encoding. All participants studied items once or three times and performed only one recall memory test. Although repetition increased organization, we included a pleasantness rating task at study. This task possibly facilitated organization for both collaborative and nominal groups at encoding as participants were required to process study items based on their semantic features. Further, as with Experiment 1, the repetition manipulation (single presentation and repeated presentation) was also instantiated in a within-subjects design. Thus, both nominal and collaborative groups produced items from two study conditions, leading to more switching back and forth across conditions than could occur in previous studies. As indicated earlier, filler items were used in the single presentation condition to equate the number of presentations across study conditions. Nominal groups recalled significantly more filler items than collaborative groups. It is possible that the presence of more filler items in nominal recall reduced the potential for more organized retrieval in this condition compared to collaborative groups. Nevertheless, the critical finding of greater organization for repeated than single presentation was observed in Experiment 2.

In order to gain a clearer understanding of the role of individual organization in group recall, future studies could investigate this research question by manipulating attention and repetition as between-subjects variables. This modification would reduce the likelihood of contamination in recall across study conditions (full versus divided attention and repeated versus single presentation). Further, an alternative divided attention task (i.e., tone monitoring) could be used to examine the role of individual organization in group recall under divided attention conditions that are not compromised by low levels of recall.

Altogether, the current study enables us to make inferences about the role of conceptual processing in group recall in daily scenarios. Individuals often attempt to retrieve the past in social situations. As such, it is possible that groups can experience less collaborative inhibition when individuals attempt to retrieve the past under conditions where their own individual memory is weak. Factors that can influence individual memory include the passage of time, the clarity of the events at encoding, and the level of attention with which participants encode the events. On the other hand, groups would also experience less collaborative inhibition when individuals attempt to retrieve the past under conditions where individual memory is strong. For example, students can benefit from class discussions if they study on their own before coming to class (Blumen & Rajaram, in press). In conclusion, this study showed that manipulations that influence conceptual processing at encoding affect the magnitude of collaborative inhibition. Despite the robustness of the collaborative inhibition effect, this effect attenuates when individual memory in weakened by divided attention or strengthened by repetition.

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Figure 1 - Mean proportion recall for the nominal and collaborative conditions as a function of attention.

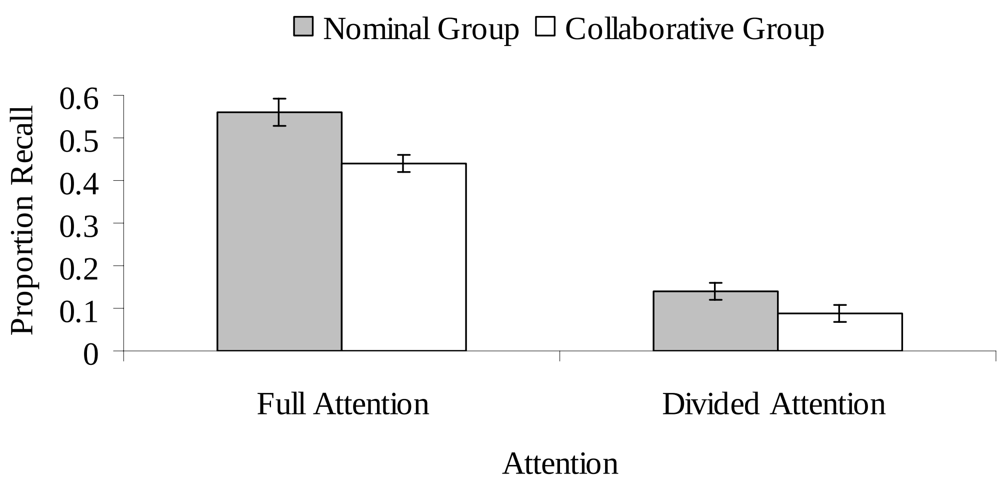

Figure 2 - Mean proportion recall for the nominal and collaborative conditions as a function of repetition.

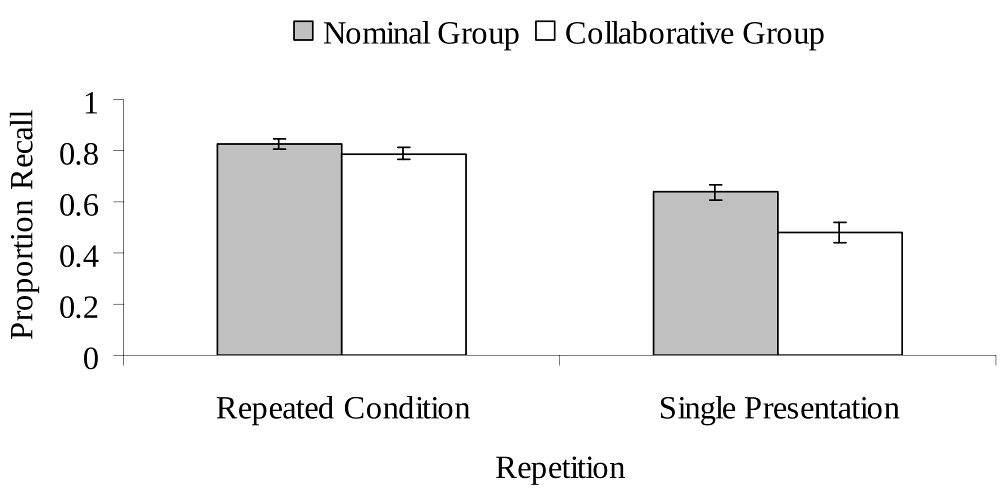

Table 1- Mean Adjusted Ratio of Clustering (ARC) scores for the nominal and collaborative conditions as a function of attention (Experiment 1) and repetition (Experiment 2).

	Condition			
	Full Attention	Divided Attention	Repeated Condition	Single Presentation
Nominal	.34 (.05)	.11 (.07)	.23 (.05)	.20 (.04)
Collaborative	.35 (.06)	.12 (.05)	.32 (.07)	.15 (.05)

Note: Standard errors are shown in parentheses.

Table 2- Mean proportion of intrusions for the nominal and collaborative conditions for Experiment 1 and Experiment 2.

	Experiment	
	Experiment 1	Experiment 2
Nominal	.05 (.01)	.05 (.01)
Collaborative	.02 (.003)	.01 (.01)

Note: Standard errors are shown in parentheses.