THE EFFECTS OF WORKING MEMORY CAPACITY ON COLLABORATIVE INHIBITION ACROSS CATEGORIZED AND UNRELATED LISTS

by

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DEDICATION

I am dedicating this thesis to my teacher and mentor, Dr. Michelle Meade, for her unwavering support and wisdom in making this thesis a reality. She has taught me the importance of research and what it is to be a researcher. Thank you for believing in me.

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ABSTRACT

The current study examined if working memory capacity (WMC) predicts collaborative inhibition and if this influence can be generalized across categorized and uncategorized lists. Across two experiments, participants' WMC was measured using the operation span, reading span, and symmetry span. They were then presented with the unrelated lists only (Experiment 1), or unrelated words lists and categorized word lists (Experiment 2). Participants were asked to recall the lists on their own or in collaboration with another participant (recall test 1). In addition, they were given a subsequent individual recall test (recall test 2), and an individual source monitoring recognition test. Results from both experiments showed collaborative inhibition in recall test 1 and post collaborative benefits in recall test 2. Importantly, the pattern of collaboration results did not vary across WMC. Higher WMC individuals and lower WMC individuals showed similar effects of collaboration across unrelated and categorized lists. These findings identify important parameters of if and when WMC influences collaborative memory. Moreover, future research can investigate if mechanisms such as attentional control, retrieval inhibition, and collaborative process variables related to collaborative inhibition play a role when WMC is at work.

CHAPTER ONE

THE EFFECTS OF WORKING MEMORY CAPACITY ON COLLABORATIVE INHIBITION ACROSS CATEGORIZED AND UNRELATED LISTS

Introduction

The main goal of this study is to extend the theoretical understanding of collaborative inhibition. Collaborative inhibition is the finding that individuals in collaborative groups show lower recall in comparison to the pooled recall of the same number of individuals in the individual condition (Basden, Basden, Bryner, & Thomas, 1997). Of interest to the current project is how working memory capacity (WMC) influences collaborative inhibition. WMC is an individual's ability to maintain attention in the face of the distraction (Hood, Whillock, Meade, & Hutchison, 2023). Throughout this paper, we aim to answer the questions: Do individual differences in WMC predict collaborative inhibition? And, if so, does this influence generalize across categorized and uncategorized lists? Given how powerful collaborative inhibition is, this study will help in further determining the factors underlying collaborative inhibition.

Collaborative Inhibition and Underlying Mechanisms

Collaborative inhibition is measured by comparing memory performance of individuals recalling together (collaborative group) to the pooled recall of the same number of individuals recalling alone (pooled group). The pooled group provides a baseline measure of how much individuals can recall on their own. If there is no influence of collaboration on individual memory, then collaborative groups and pooled groups should show equivalent memory performance because, in both cases, memory for the same number of people is being compared. However, much research has demonstrated collaborative inhibition, or the finding that individuals remembering in collaborative groups tend to recall less information than the combined recall of same number of individuals remembering alone (see Rajaram, 2018 for review).

A recent meta-analysis by Marion and Thorley (2016) demonstrated that collaborative inhibition is a robust effect. Further, group size, retrieval type, type of memory test, study materials, and the social relationships between group members moderate the collaborative inhibition effect. Specifically, collaborative inhibition is greater with larger collaborative groups because the more group members there are, the greater the risk of disruptions as the group collaborates. Collaborative inhibition is greater when group members take turns during collaboration, rather than remember together in a free-for-all discussion, again because turn taking is more disruptive to individuals' recall outputs. In terms of the type of memory test, they found a stronger effect on free recall tests compared to cued recall tests because cued recall offers retrieval support and organization. The study materials used have also shown to moderate the collaborative inhibition effect where uncategorized materials show greater effects vs. story-like materials, again because the story provides structure to aid organization and recall. Additionally, the social cohesion between collaborative group members determines the magnitude of collaborative inhibition, with the effects being greater for strangers vs. friends.

Finally, the meta-analyses revealed that there may be lasting effects of collaboration on subsequent individual memory performance. Prior collaboration aids later individual memory, most likely because participants are re-exposed to study materials during collaboration.

The present-day theory that best explains collaborative inhibition is the Retrieval Strategy Disruption theory proposed by Basden et al. (1997). This theory states that everyone has their own distinctive strategies of encoding and recalling materials. During an individual recall, this strategy could lead to the best performance, whereas recalling within a group could disrupt an individual's strategy of encoding and recalling materials, which leads to collaborative inhibition. Many studies support the idea that retrieval strategy disruption underlies collaborative inhibition (see Rajaram, 2018 for review). For example, Wright and Klumpp (2004) assigned participants to three conditions: nominal condition, collaborative see condition, collaborative not see condition. In the collaborative see condition, the pairs utilized a turn-taking procedure where one participant recalled an item that their partner could see. In the collaborative not see condition, pairs used the same turn taking procedure, but a barrier was placed in between the two participants to avoid seeing each other's answers. Interestingly, they found collaborative inhibition only in the collaborative see condition, demonstrating that the items recalled produced the collaborative disruption, not just the process of taking turns. These findings serve as evidence in support of the retrieval strategy disruption theory.

However, growing research suggests that collaborative inhibition is multiply determined and there are additional factors that could underlie and influence the effect (Hood et al., 2023). For example, Barber, Harris and Rajaram (2015) demonstrated that retrieval inhibition is an additional alternate factor of collaborative inhibition. Retrieval inhibition occurs when noncued words are inhibited as a result of the strengthening of cued words, rendering them inaccessible for retrieval. Because retrieval inhibition is relatively longer lasting than retrieval strategy disruption, the authors tested for any lasting impact of collaboration on subsequent individual recall and recognition tests. Across the two experiments, participants studied the lists by themselves and then completed an initial recall test alone or in collaboration with another participant. The subsequent recall and recognition tests were always completed individually. They found memory deficits that lingered from collaboration onto following individual recall and recognition tests supporting the conclusion that retrieval inhibition plays a role in collaborative inhibition.

Meade and Gigone (2011) demonstrated that collaborative process variables influence the magnitude of the collaborative inhibition effect. Collaborative process variables are known as the ways in which individuals communicate and exchange information, and the characteristics underlying collaboration in group settings (Meade, 2013; Whillock et al., 2020). This study relied on categorized lists. Importantly, for Experiment 1 they found greater collaborative inhibition for the unshared items compared to the shared items. Follow up analyses confirmed that shared items were more likely to be acknowledged, elaborated upon, and incorporated into the groups' recall. These findings suggest that collaborative process variables can influence the magnitude of collaborative inhibition (see too Meade, Nokes, & Morrow, 2009).

Given the increasing evidence that multiple factors underlie collaborative inhibition, there is great need to identify factors and processes that influence the effect. It is still unknown how the multiple processes interact with each other or if there are individual differences in how these processes are utilized. In the current study, we expand on this literature to examine working memory capacity as an individual difference factor that may influence collaborative inhibition.

Working Memory Capacity

According to Hood et al. (2023), WMC is comprised of attentional control (maintaining information when faced with distraction; Engle & Kane, 2004) and secondary memory processes (effectively retrieving information from long-term memory after it is no longer maintained in working memory; Unsworth & Engle, 2007). More specifically, attentional control is the capacity to organize thoughts and ideas to align with internal goals and to maintain information while blocking out any intrusive thoughts or external distractions. High WMC individuals perform comparatively better than low WMC individuals on various attentional control tasks (Hutchison, 2011; Conway et al., 2001; Kane et al., 2001; McVay & Kane, 2009; Redick, 2014). This is more likely to happen when low WMC individuals have difficulty in maintaining goal-relevant information and surrender to distractions present either internally or from their external environments (Engle & Kane, 2004). This is important for collaborative inhibition because when participants work together, they must be able to recall items relevant to the task at hand and must maintain information in the face of distraction, which may present itself as disruption from their partner.

Regarding secondary memory processes, retrieval from long term memory requires effective strategies and the ability to discriminate between studied items and novel items. Many previous studies have shown that high WMC individuals can better differentiate between studied and non-studied items, and this results in higher levels of accurate recall (e.g., Unsworth, Brewer, & Spillers, 2009; Unsworth, 2010, 2016; Unsworth & Engle, 2007) and lower levels of false recall (Unsworth, 2007; Rosen & Engle, 1997). This is applicable to collaborative inhibition as participants in the collaborative condition must distinguish between relevant and irrelevant items suggested by their partners when deciding which items were presented on during study.

Collaborative Inhibition and WMC

Hood et al. (2023) examined the relationship between working memory capacity and collaborative inhibition for categorized word lists. They presented three hypotheses to explain how WMC might influence collaborative inhibition: the attentional control hypothesis, the elaborative encoding hypothesis, and the additive hypothesis. The attentional control hypothesis states that recalling with a partner or in a group setting is potentially disruptive, and in order for task performance to be successful, an individual needs greater attentional control to stay focused on recalling their items in the face of distraction. Higher WMC participants are better able to control attention in the face of disruptions, so they should show less collaborative inhibition. Based on the retrieval strategy disruption theory, the elaborative encoding hypothesis states that individuals high in WMC would show greater levels of collaborative inhibition compared with low WMC individuals. The reasoning for this prediction is that high WMC individuals are generating elaborative encoding strategies during the study phase that would be more prone to disruptions when recalling with a partner. In contrast, the low WMC individuals would more likely rely more on a less effective strategy (such as rehearsal) and would be less disrupted by collaboration. Finally, the additive hypothesis predicts equal magnitudes of collaborative inhibition for both low WMC and high WMC individuals and states that there are two possible explanations for this. One explanation is that WMC is not related to the collaborative inhibition effect. The other explanation is that WMC differences in attentional control and elaborative encoding cancel each other out.

Hood et al. (2023) investigated these hypotheses by asking participants to complete working memory tasks (automated operation span, reading span, and the symmetry span). Then, participants were presented with categorized word lists and asked to remember them alone or in collaboration with another participant (individuals in the collaborative condition work together and individuals in the individual condition work by themselves). All participants then completed a second individual recall task. Hood et al. (2023) found that individuals lower in WMC presented greater collaborative inhibition and no post collaborative benefits, whereas individuals higher in WMC showed no collaborative inhibition and post collaborative benefits. This pattern supports the attentional control hypothesis and demonstrates that WMC does influence collaborative inhibition.

In a related study, Barber and Rajaram (2011) examined working memory and collaborative inhibition with a slightly different method. They used executive depletion such that participants were asked to complete a depleting executive control task in advance to the part-set cued task or collaborative retrieval task. Conversely, participants in the control condition performed a similar task that was not depleting of their attention. They then examined collaborative inhibition and post collaborative benefits for categorized lists. Their working memory measure did not allow them to determine the role of working memory on collaborative inhibition, but they did find working memory related differences on subsequent individual recall. That is, those participants with higher working memory scores derived greater post collaborative benefits on subsequent tests. This finding is consistent with Hood et al. (2023), and further supports the idea that working memory is related to collaborative inhibition.

Importantly, however, both Hood et al. (2023) and Barber and Rajaram (2011) relied on categorized lists. Categorized lists consist of exemplars that are related to the categorized list name. The categorized lists also included critical lures, or items that were strongly related to the list, but not presented. The main purpose of critical lures in categorized lists is that they serve as a measure of false recall. In contrast, an unrelated list is a list of items that may have little-to-no relation to each other. Further, there are no commonly shared critical lures for unrelated lists. Rather, false memory is measured by the number of extra list intrusions that are idiosyncratic to each individual.

Categorized Word Lists Influence Collaborative Inhibition and WMC

Categorized word lists are known to reduce collaborative inhibition (Basden et al., 1997). Multiple studies demonstrate that categorized word lists produce collaborative inhibition (e.g. Rajaram, Maswood, & Periera-Pasarin, 2020; Meade & Roediger, 2009; Whillock et al., 2020; Hood et al., 2023). However, the magnitude of collaborative inhibition may be influenced by the use of categories primarily because categories provide organization. That is, categorized word lists provide a structure and organization for recall, and so participants may be less likely to use their own idiosyncratic retrieval strategies when categorized structures are provided (Rajaram, Maswood, & Periera-Pasarin, 2020; see too Rajaram, 2018). Collaborative inhibition should be smaller for categorized lists because the more similar the strategies group members use, the less likely it is for disruptions to occur. In connection to the current study, providing structure and strategies may reduce any differences between high WMC individuals and low WMC individuals on collaborative tests because they are both more likely to use the provided categorical strategies rather than create their own strategies.

Further, the magnitude of collaborative inhibition is influenced by switching back and forth between categories, but the evidence is mixed on how category switching influences the magnitude of the effect. Basden et al. (1997) had nominal and collaborative groups recall categorized word lists on an unstructured recall test where participants could freely recall exemplars from any category in any order. They found that collaborative groups demonstrated more category switching than did the nominal groups, presumably because collaborative group participants were abandoning their own strategies to associate with the new category. In contrast, Hyman, Cardwell & Roy (2013) found that collaborative groups sampled from fewer categories, and that the limited exploration across categories contributed to the reduced recall in collaborative groups. Together, these findings demonstrate that category switching may influence collaborative inhibition.

Categorized word lists are also known to reduce differences in WMC (Unsworth, Spillers, & Brewer, 2012). Unsworth and Brewer (2012) examined differences between high and low WMC individuals and how categorization affects long term memory recall in two experiments. They had participants initially work through the operation, reading and symmetry span and then perform category cued recall and free recall tests. Findings from the two experiments showed that long-term memory recall for high and low WMC individuals varied due to differences in accessibility of retrieval cues and items on the lists. That is, on the free recall test, low WMC individuals had worse memory because they used less effective strategies to access cues and they had a hard time differentiating studied items. However, when they were provided with category cues, the cues narrowed down the possible studied items and eliminated memory differences between low WMC and high WMC groups.

Given that categorized word lists are known to reduce collaborative inhibition and working memory differences, it is necessary to study if working memory capacity predicts collaborative inhibition for uncategorized word lists. Specifically, the categorized word lists used in previous research provided all participants with a categorized organizational structure that they could use as a strategy. Although the high WMC individuals likely spontaneously used strategies for recall, the low WMC individuals likely got a boost from the categories. Of interest to the current experiment is how WMC influences collaboration in the absence of category cues. We hypothesize that when participants are given an uncategorized list, high WMC individuals will continue using their strategies, and have room to develop more complex strategies. The more elaborative strategies are more susceptible to disruptions, whereas the low WMC individuals would not have elaborative strategies to disrupt and thus show fewer disruptions. This should result in greater collaborative inhibition and smaller post collaborative benefits for higher WMC individuals. These hypotheses align with the elaborative encoding hypothesis outlined by Hood et al. (2023). Moreover, Experiment 1 included a final individual source monitoring test. Hood et al. (2023) speculated a better source monitoring ability might explain why higher WMC individuals show less disruption during collaboration and greater post collaborative benefits.

CHAPTER 2

EXPERIMENT 1

Experiment 1 examined the relationship between collaborative inhibition and working memory capacity for an unrelated (uncategorized) word list. Of interest is how WMC influences the magnitude of collaborative inhibition on recall test 1 and post collaborative benefits on the subsequent individual recall and recognition tests.

Methods

Participants

Sample size was determined by first computing a power analysis in G*Power. Using .56 as the effect size of the collaborative inhibition effect (Marion & Thorley, 2016), 36 participants are required to achieve a power of .90. Because collaborative inhibition requires 2 participants for a single data point, this means 72 participants are required. However, this was underpowered to detect individual differences in WMC. For example, Hood et al. (2023) reported a sample size of 120. When computing the power analysis for Experiment 1, in order to achieve a power of 90% we were required to have 99 participants in each group, which would total to 198 participants. Experiment 1 reported a sample size of 210. This included any additional (extra data) we collected to replace any exclusions. Students participated in the study as part of partial course credit for Introduction to Psychology 100 course and extra credit for higher-level psychology courses.

A total of 223 students were recruited from the Montana State University SONA subject pool. Of these participants, 13 were excluded for the following reasons: 6 were excluded because either WMC task data was missing or recall and recognition data was missing, 6 were excluded because they knew each other, and there was one participant that was accidentally left out. Decisions to remove participants were based entirely on notes from the subject log. All excluded participants were removed before we entered data or analyzed the data. Excluded participants were replaced with additional participants. The final sample size is 210.

Design

This experiment consisted of a 2 - Factor mixed design with collaboration as a between-subjects factor and WMC as a continuous variable. The dependent variables are correct and incorrect recall on recall test 1 and 2. Additionally, correct and incorrect recognition on the source monitoring test will also serve as dependent variables.

Working Memory Capacity Span Tasks

The operation span, reading span and the symmetry span served as measures of working memory capacity. Individually speaking, all three of these span tasks include task-specific variance due to different abilities that are not of interest. The operation span tests participants math ability, the reading span tests for verbal ability, and the symmetry span focuses on visuospatial ability. Including all three tasks is necessary in order to pull out common variance across the tasks to measure the underlying construct of WMC. Further, the current experiment used shortened, complex versions of each task. Foster et al. (2015) demonstrated that these complex span tasks can be shortened without losing their reliability when measuring WMC abilities. The shortened version of the complex span tasks includes one block containing randomized set of trials.

Automated Operation Span. The Automated Operation Span task was the first working memory task participants engaged in. The participants were instructed to memorize a string of letters while performing simple true or false math problems. That is, they were presented with a single letter (e.g., A, then asked to respond if (1 x 1) – 1 = 0 is true or false. They were then presented with another letter and another math problem. After 3-7 letter-math trials, they were asked to recall the letters. This test was self-paced, and participants approximately took around 15 minutes to complete the task.

Reading Span. The Reading Span task is complementary to the Operation Span task; however, instead of completing math problems participants were asked to verify the accuracy (sensical) of sentences (e.g., Jane went out to brunch and met her mother). They completed 1 block of trials in a self-paced manner and participants took approximately 15 minutes to complete the task.

Symmetry Span. The Symmetry Span task is similar to the first two tasks, except that participants are instructed to remember the location of grids in a 4 x 4 grid while verifying whether an image is vertically symmetrical. They completed 1 block of trials and participants took around 15 minutes to complete the task.

Collaborative Inhibition Tasks

The collaborative inhibition tasks consisted of a 60-item unrelated list. These unrelated items were matched to the categorized lists from Hood et al (2023) on length, subtitle frequency, and concreteness using the English Lexicon Project (Balota et al., 2007). Additionally, the participants were given a filler task consisting of mathematical problems. A source monitoring recognition test was also included. This test was comprised of 30 studied items (words that were presented in the list) and 30 filler items (words that were not presented anywhere in the experiment).

Post-experimental Questionnaires

The post recall questionnaires from Hood et al. (2023) were incorporated into the current study. These questionnaires consist of a demographics questionnaire, strategy questionnaire, and a metamemory questionnaire. The demographics questionnaire collects data about the participants' date of birth, age, education levels, native language, ethnicity, and race. The strategy questionnaire asks participants extensive questions about the strategies they may have used when recalling during the recall tests. The metamemory questionnaire requires participants to rate questions on a scale of 1 to 5 (1 being not very confident and 5 being very confident) their confidence levels about their own memory, their partner’s memory if they had to collaborate with someone else, recall ability, and the accuracy of their memory and recall abilities, as well as their partner’s.

Procedure

Participants began the experiment by completing three working memory capacity tasks: automated operation span, reading span, symmetry span. After completing the working memory tasks, subjects were presented with 60 unrelated words on a computer screen in a random order. Each word was presented for two seconds with one second interstimulus interval (ISI). Participants were instructed to pay attention to the words because they would be tested on their memory for the words. Participants were then given a math filler task and asked to complete as many problems as possible in two minutes. Recall test 1 took place soon after and subjects were asked to recall words they were reasonably sure were on the computer screen and the experimenter wrote down the words recalled. Participants were given eight minutes to do this. Participants were randomly assigned to complete recall test 1 on their own (pooled group) or in collaboration with another participant (collaborative group). Participants in the collaborative group were given "free for all" instructions so that they collaborated freely with each other.

Immediately after, all participants completed recall test 2 individually. Participants were again given eight minutes to recall the word list. This time they wrote the words down. They were instructed not to guess and to write down the words they were reasonably sure they remembered from the study list.

Later, all participants completed a source monitoring recognition test individually. Participants in the collaborative condition were given a source monitoring test in which they had to indicate where in the experiment the item was presented and who (if anyone) recalled the word (if the participant themselves or if their partner recalled it), or if the item was not presented anywhere in the experiment. The source monitoring test for participants in the individual condition was the same except that it did not include the option to report one's partner recalled the word. Their test consisted of having to indicate where in the experiment the item was presented, if they themselves recalled an item, or if the item was not presented anywhere in the experiment. All participants had as much time as they needed to complete this task. Finally, subjects were asked to fill out a demographics questionnaire, along with a strategy and metamemory questionnaire.

Results

Collaborative Inhibition and Post Collaborative Benefits

Table 1 shows the mean proportion recalled on recall test 1 and recall test 2 as a function of collaboration. We conducted an independent samples t-test to examine collaborative inhibition in recall test 1 across the collaborative and nominal conditions. This t-test was significant, $t\ (102) = -2.08$, $p = .040$, indicating that there was significant collaborative inhibition detected on recall test 1. Additionally, a separate independent samples t-test was conducted to examine post-collaborative benefits on test 2. Recall test 2 was always completed individually, so this t-test compared recall performance across prior individual recall and prior collaborative recall. This t-test was significant, $t\ (208) = 1.97$, $p = .050$, indicating that there were significant post collaborative benefits on recall test 2.

Table 1. Mean Proportions (SD) of Correct Recall as a Function of Retrieval Condition (Collaborative and Nominal for Recall Test 1 and Prior Collaborative and Prior Nominal for Recall Test 2).

Retrieval Condition	Recall Test 1	Recall Test 2
Nominal	.30 (.10)	.17 (.10)
Collaborative	.26 (.10)	.20 (.10)

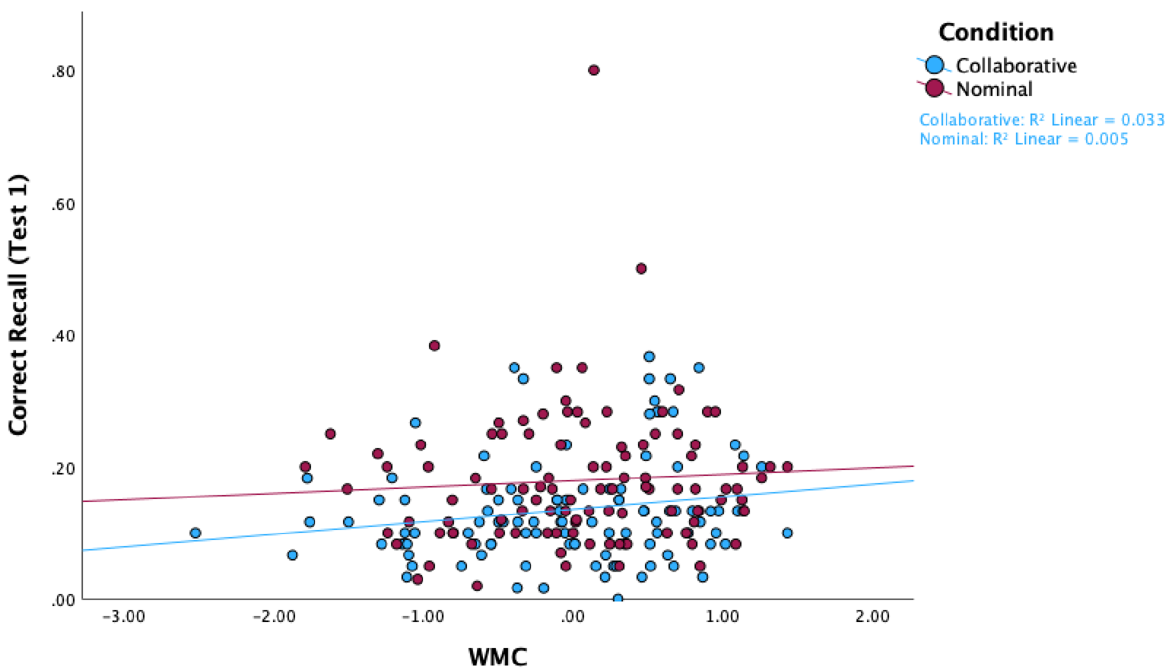
WMC as a Predictor of Collaborative Memory

Regression analyses were conducted to examine the influence of WMC on collaborative and individual memory performance on recall tests 1 and 2, and the source monitoring recognition test. These regression results are shown in Figures A, B, C, D, E and F. When running the regression analyses, we used participants' individual recall scores on test 1 (instead of the pooled group recall scores and the collaborative group recall scores, which were reported for recall test 1 in Table 1). That is, for those in the individual condition, we used their individual (unpooled) recall, and for those in the collaborative groups, we separated out each individual's contribution to the collaborative group. This was necessary in order to match each participant's WMC composite score to their recall performance.

Recall Test 1

Correct Recall. Correct recall was measured as the proportion of studied items individuals recalled. For correct recall in recall test 1 (Fig, A), we found a main effect of retrieval condition (b = .022, SE = .006, $\beta = .229$, $p < .001$). This is consistent with collaborative inhibition and demonstrates that individuals working in collaborative groups recalled less than individuals working in nominal groups. There was no main effect of WMC (b = .015, SE = .008, $\beta = .116$, $p = .085$), and the interaction between retrieval condition and WMC was not significant (b = -.005, SE = .009, $\beta = -.037$, $p = .587$). These results suggest that collaborative inhibition was the same for higher and lower WMC individuals, which is consistent with the additive hypothesis.

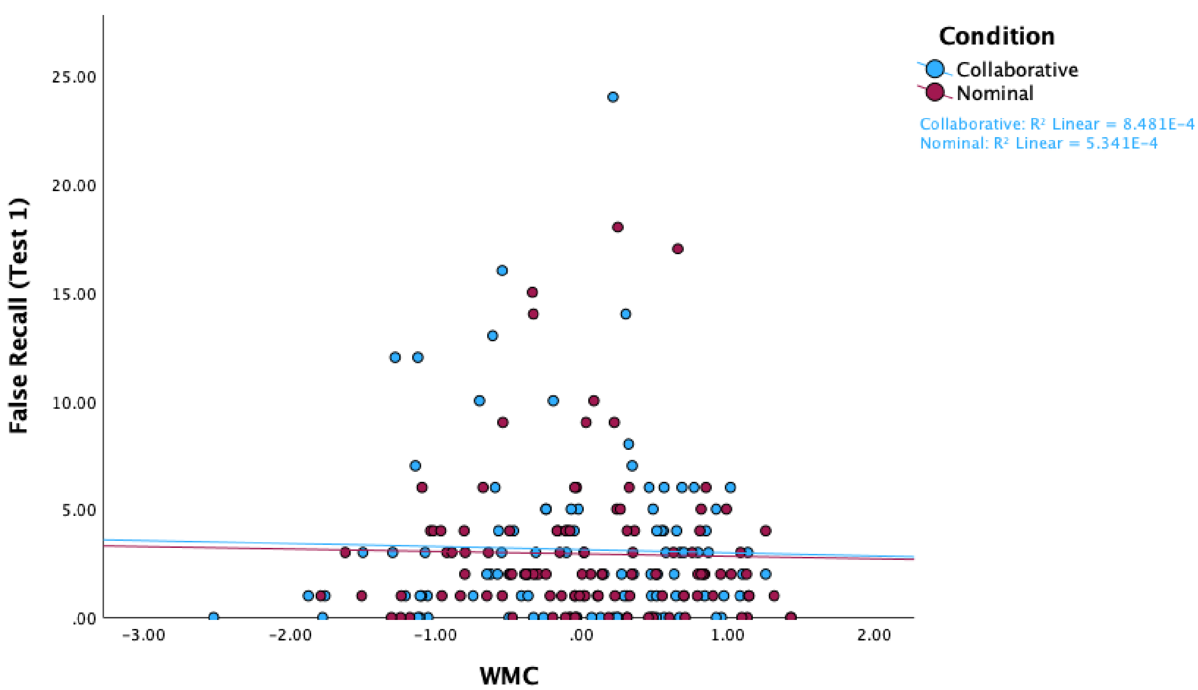
Figure A. Correct Recall on Test 1 as a function of WMC and Retrieval Condition



<u>False Recall.</u> False recall was measured as the number of extra list intrusions participants wrote on their recall tests. Extra list intrusions were items not presented on the study list. For false recall on recall test 1 (Fig. B), we found no main effect of retrieval condition (b = -.095, SE

= .252, β = -.026, p = .705) and no main effect of WMC (b = -.127, SE = .335, β = -.026, p = .704). There was a nonsignificant interaction between retrieval condition and WMC of false recall on recall test 1 (b = .016, SE = .337, β = .003, p = .961). This demonstrates that individuals in collaborative groups and nominal groups did not differ in the number of extralist intrusions they recorded, and this was true for higher and lower WMC individuals. Please note that the overall number of extralist intrusions was quite low (M = 3 words) and these effects should be interpreted with caution because of floor effects. Low levels of extra list intrusions are common for unrelated word lists because the lists were not designed to elicit false memory (cf., Roediger, 1996).

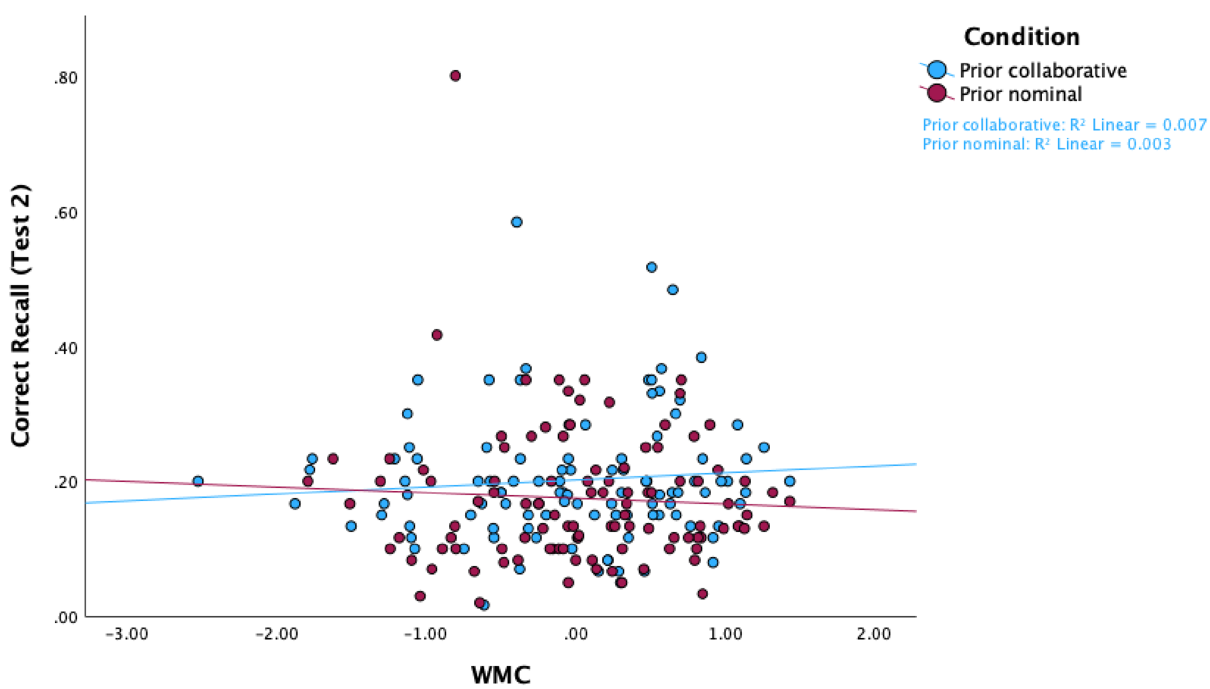
Figure B. False Recall at Test 1 as a function of WMC and Retrieval Condition



Recall Test 2

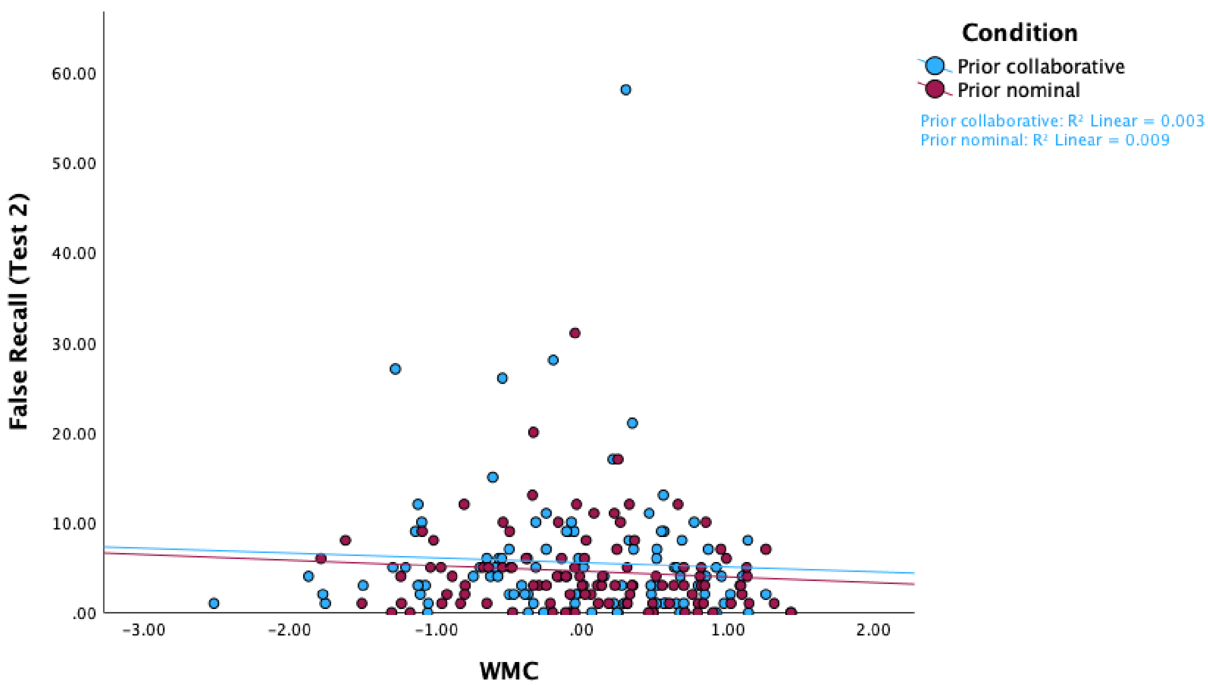
Correct Recall. Recall test 2 was always completed individually, and here we are interested in the lasting effect of prior collaboration on subsequent individual recall. For correct recall on recall test 2 (Fig. C), we found a main effect of retrieval condition (b = -.014, SE = .007, β = -.136, p = .049) and no main effect of WMC (b = .002, SE = .009, β = .014, p = .842). There was a nonsignificant interaction between retrieval condition and WMC for correct recall on recall test 2 (b = -.009, SE = .009, β = -.070, p = .309). This suggests that the retrieval condition does affect performance on recall test 2 demonstrating the presence of post-collaborative benefits. Importantly, the magnitude of these post collaborative benefits was equivalent for higher WMC individuals and lower WMC individuals.

Figure C. Correct Recall at Test 2 as a function of WMC and Prior Retrieval Condition



False Recall. For false recall on recall test 2 (Fig. D), we found no main effect of retrieval condition (b = -.490, SE = .433, β = -.078. p = .259) and no main effect of WMC (b = -.567, SE = .577, β = -.068, p = .326). There was a nonsignificant interaction between retrieval condition and WMC on false recall on recall test 2 (b = -.049, SE = .580, β = -.006, p = .933). This suggests that neither retrieval condition nor WMC had an effect on false recall on test 2. All participants recalled very few extralist intrusions and again, this is expected given the structure of the unrelated lists; cf. Roediger, 1996.

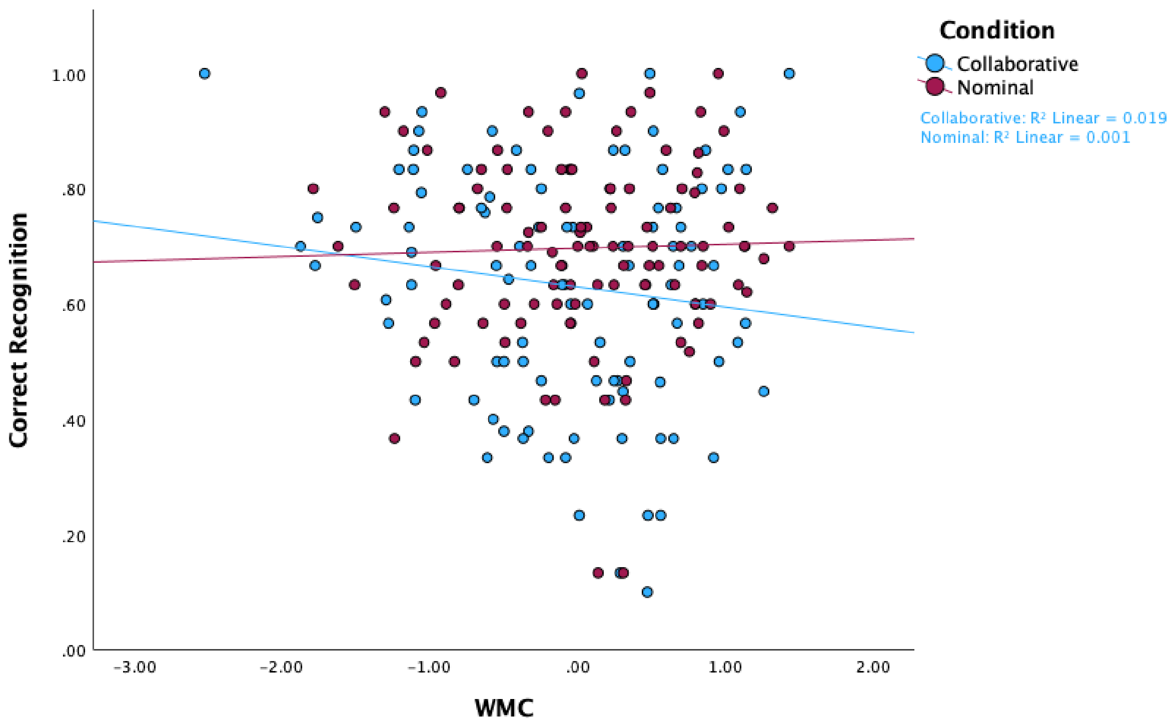
Figure D. False Recall at Test 2 as a function of WMC and Prior Retrieval Condition



Recognition

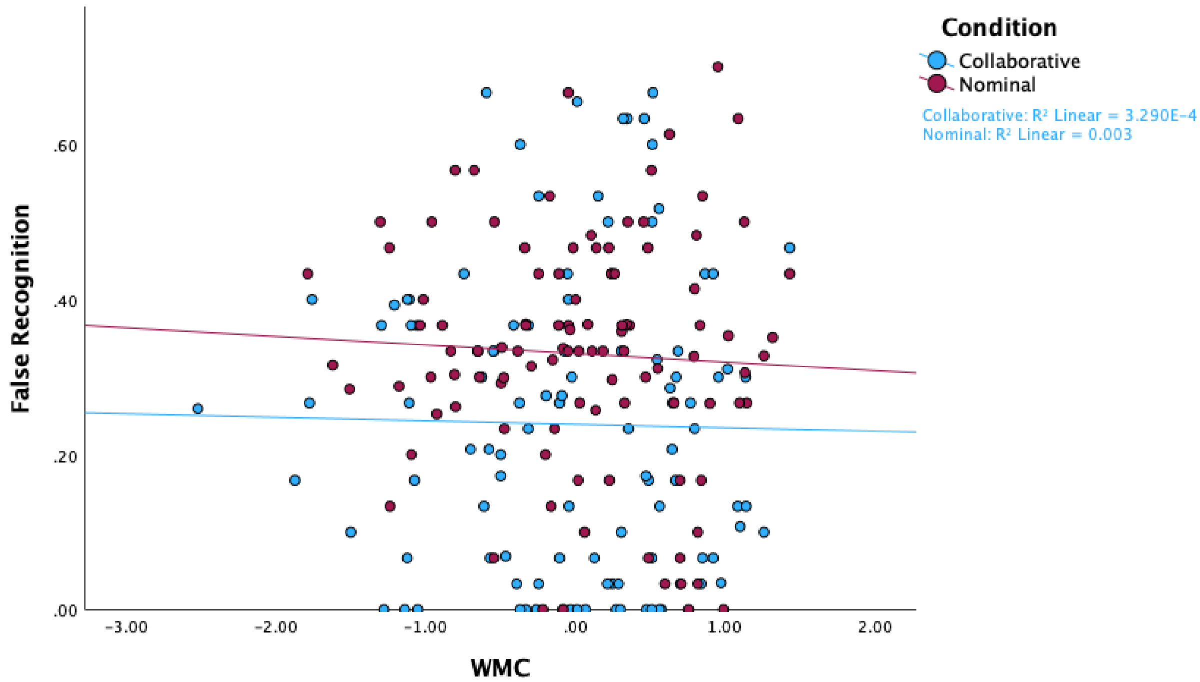
Correct Recognition. Correct recognition was defined as proportion of times participants attributed the source of the item as having been presented in the study list (sum of “list” responses plus "list and self" responses on the source test for individuals, and the sum of "list" responses plus "list and self" responses plus "list and other" responses on the source test for collaborators). For correct recognition on the recognition test (Fig. E), we found a main effect of retrieval condition (b = .033, SE = .013, β = .182, p = .008) and no main effect of WMC (b = -.016, SE = .017, β = -.064, p = .347). There was a nonsignificant interaction between retrieval condition and WMC on correct recognition on the recognition test (b = .021, SE = .017, β = .086, p = .209). This means that post collaborative benefits persisted on the final source test, and the magnitude of post collaborative benefits did not differ for higher WMC individuals and lower WMC individuals.

Figure E. Correct Recognition on Source Monitoring Test as a function of WMC and Prior Retrieval Condition



False Recognition. False recognition was defined as proportion of times participants attributed filler items as having been presented in the study list (sum of "list" responses plus "list and self" responses on the source test for individuals, and the sum of "list" responses plus "list and self" responses plus "list and other" responses on the source test for collaborators). For false recognition on the recognition test (Fig. F), we found a main effect of retrieval condition (b = .046, SE = .012, $\beta = .255$, $p < .001$) and no main effect of WMC (b = -.007, SE = .016, $\beta = -.031$, $p = .642$). There was a nonsignificant interaction between retrieval condition and WMC of false recognition on the recognition test (b = -.003, SE = .016, $\beta = -.014$, $p = .838$). These data show that evidence of error correction (cf. Ross et al., 2008): prior collaboration resulted in relatively fewer errors on the final recognition test. Importantly, the magnitude of error correction did not vary across higher WMC individuals and lower WMC individuals.

Figure F. False Recognition on Source Monitoring Test as a function of WMC and Prior Retrieval Condition



<u>Discussion</u>

To summarize our results, we found collaborative inhibition for correct recall on recall test 1 and post collaborative benefits for recall test 2 and recognition. We did not find an interaction between retrieval condition and working memory capacity on recall tests 1, 2, or the source monitoring on the recognition test. Further, we found no effects of WMC or collaboration on false recall, but we did find post collaborative benefits on false recognition (most likely we found effects on recognition and not recall because of the floor effect for false recall). The pattern of our results is supportive of the additive hypothesis demonstrating that collaborative inhibition and post collaborative benefits were the same for high and low WMC individuals.

In the current experiment, we found significant collaborative inhibition effects on recall test 1. Individuals collaborating with other participants recalled fewer items than participants who recalled on their own. This is consistent with previous literature demonstrating that collaborative inhibition is robust and generalizes across a range of study materials including unrelated word lists (e.g., Marion & Thorley, 2016; Weldon & Bellinger, 1997). Our findings of post collaborative benefits are also consistent with previous literature, as many studies show prior collaboration leads to better individual memory on subsequent tests (e.g. Blumen & Stern, 2010; Marion & Thorley, 2016; although see Wei et al. (under revision) for discussion).

Regarding WMC, the current study found no effects of WMC on recall or recognition. This is inconsistent with past research demonstrating that higher WMC individuals generally perform better than lower WMC individuals on memory tests (e.g., Unsworth, Brewer, & Spillers, 2009; Unsworth, 2010, 2016; Unsworth & Engle, 2007) and this is specifically true for unrelated items (Unsworth & Brewer, 2012). One possible explanation for the null effects of WMC might be that the study list was too long. Individual recall was at a reasonable level, and we did observe significant effects of collaboration. However, the somewhat low recall levels may have depressed memory recall for both higher and lower WMC individuals such that the higher WMC individuals did not have room to show their advantages. In Experiment 2, we shortened the study list to allow higher WMC individuals greater flexibility to showcase their elaborative strategies.

Most importantly, we found no evidence that WMC influences collaborative memory. The magnitude of collaborative inhibition and post collaborative benefits was the same for higher and lower WMC individuals, which is consistent with the additive hypothesis. Our findings are inconsistent with the findings of Hood et al. (2023) and Barber and Rajaram (2011). They both used categorized lists and found less collaborative inhibition for higher WMC individuals (Hood et al., 2023) and greater post collaborative benefits for higher WMC individuals (Barber & Rajaram, 2011; Hood et al., 2023). This may suggest that there is a different explanation for collaborative inhibition across categorized and uncategorized lists. Specifically, for categorized word lists, participants across the conditions got an organization; all participants were provided with categorized structure that they could use as a strategy. This was especially beneficial for the lower WMC individuals. In contrast, for the unrelated lists, participants needed to create their own strategies. Importantly, however, these comparisons are made across experiments. In addition to the list structure, many other factors can vary across experiments (e.g. participant sample, experimental contexts, etc.). In Experiment 2, we compare the effects of WMC on categorized and unrelated lists within a single experiment so we can more directly compare findings.

CHAPTER 3

EXPERIMENT 2

The goal of the current experiment is to examine categorized and uncategorized word lists as a within-subjects factor in a single experiment. Consistent with previous research, for categorized lists, we predict to find a lower collaborative inhibition effect for individuals higher in working memory capacity and greater post collaborative benefits. Furthermore, for unrelated lists, we predict to find greater collaborative inhibition for higher WMC individuals and smaller post collaborative benefits. These hypotheses align with the attentional control hypothesis and the elaborative encoding hypothesis stated by Hood et al. (2023).

Method

Participants

We computed a power analysis in G*Power using .56 as the effect size of the collaborative inhibition effect (Marion & Thorley, 2016), 36 participants are required to achieve a power of .90. Because collaborative inhibition requires 2 participants for a single data point, this means 72 participants are required. However, this was underpowered to detect individual differences in WMC. For example, Hood et al. (2023) reported a sample size of 120 and Experiment 1 reported a sample size of 210. Therefore, we have planned to collect data from 210 participants including any additional (extra) data. Data collection is currently on-going. We have collected data from 146 participants and will include those participants in the analyses. Data collection will continue until we reach the full sample size of 210. Students will primarily participate in the study as part of partial course credit for Introduction to Psychology 100 course and extra credit for higher-level psychology courses.

Design

The design for the Experiment consists of a 2 (Collaboration: individual or collaborative) x 2 (List Type: categorized or unrelated) mixed factorial design with WMC as a continuous variable. Collaboration was manipulated between participants and list type was manipulated within participants. The dependent variables are correct and incorrect recall on recall test 1 and 2 and correct and incorrect recognition on the source monitoring test.

Materials

The materials are the same materials used in Hood et al. (2023) and a shortened subset of the same materials used in Experiment 1. Specifically, we used the operation span, reading span and the symmetry span and the six categorized lists from Hood et al. (2023). Each category consisted of 17 items. The 5 most common exemplars from each category were intentionally left off of the list and designated as critical lures. Additionally, we included a 90-item source monitoring recognition test for the categorized lists utilized in Meade & Roediger (2006). For the unrelated list, we shortened the 60-item word list used in Experiment 1 to include 40 words. This change is to ensure the unrelated recall rates are not on the floor. We also included the same final questionnaires as Hood et al. (2023) and Experiment 1 consisting of the metamemory, strategy, and demographics questionnaires. The strategy questionnaire was modified to determine what strategies were used when recalling the categorized lists and the unrelated list separately.

Procedure

The procedure for Experiment 2 is similar to Experiment 1 and Hood et al. (2023), where participants began the experiment by the automated operation span, reading span, and symmetry span. After completing the working memory tasks, subjects completed two study-tests cycles: one for categorized lists and one for unrelated lists. The order in which participants were presented the categorized and unrelated list was counterbalanced. For the categorized word lists, the experimenter verbally labelled each category, and participants were then showed exemplars from each category in a blocked fashion. Each exemplar was presented for two seconds with a one second interstimulus interval (ISI). Participants then completed a math filler task in which they were instructed to complete as many problems as possible within two minutes. Then, the participants are instructed to recall the categorized word lists. Participants were given two minutes for each categorized list. During recall test 1, the subjects were asked to recall words they were reasonably sure were presented on the computer screen. Subjects either recall collaboratively with another participant or they recalled by themselves. Immediately after, all participants completed recall test 2 individually. Again, they were given two minutes to recall each list. Later, all participants were given a source monitoring test where they were required to indicate the specific source for each item. In the collaborative condition, they indicated where in the experiment the item was presented and who recalled the word (if the participant themselves or if their partner recalled it), and if the item was not presented anywhere in the experiment. In the individual condition, participants indicated where in the experiment the item was presented, if they themselves recalled an item, or if the item was not presented anywhere in the experiment. Participants had as much time as they needed to complete this task.

Next, the participants were presented with unrelated lists. Procedures for the unrelated lists were the same as the one followed for the categorized lists with the following exceptions: the experimenter did not provide verbal labels, and participants were asked to recall the entire list at once (rather than recall by category). On both recall tests, participants were given 6 minutes to recall as many unrelated words as possible. After completing both study-test cycles, participants completed the post experimental questionnaires.

Results

Data from 146 participants is presented as part of this thesis. Data analysis is currently ongoing and will continue until all data are collected. The current analyses are under powered and should be considered with caution.

Collaborative Inhibition and Post Collaborative Benefits

Table 2 shows the mean proportion recalled on recall tests 1 and 2 as a function of retrieval condition (collaborative vs. nominal) and list type (categorized vs. unrelated). Independent samples t-tests were conducted on recall test 1 to determine if collaborative inhibition was detected across the two retrieval conditions. As the current experiment included the list type (categorized vs. unrelated), we computed separate t-tests for the categorized lists and the unrelated list on recall test 1. For categorized lists, this test was significant, $t\ (58.08) = -5.844$, $p < .001$, demonstrating that there was significant collaborative inhibition present on recall test 1. For the unrelated list, the test was marginally significant, t (71) = -1.969, p = .053, demonstrating that there was significant collaborative inhibition present on recall test 1.

Additionally, independent samples t-tests were also computed on recall test 2 to determine if post-collaborative benefits were detected across the retrieval conditions. For the categorized lists, this test was significant, t (144) = 3.12, p = .002, indicating that there were significant post-collaborative benefits detected on recall test 2. For the unrelated list, this test was significant, t (144) = 3.23, p = .002, demonstrating that there were significant post-collaborative benefits present on recall test 2.

Table 2. Mean Proportions (SD) of Correct Recall as a Function of Retrieval Condition (Collaborative and Nominal for Recall Test 1 and Prior Collaborative and Prior Nominal for Recall Test 2) and List Type (Categorized and Unrelated).

Retrieval Condition X List Type	Recall Test 1	Recall Test 2
Nominal - Categorized	.76 (.18)	.40 (.13)
Collaborative - Categorized	.55 (.11)	.47 (.11)
Nominal - Unrelated	.37 (.11)	.18 (.09)
Collaborative - Unrelated	.31 (.12)	.24 (.11)

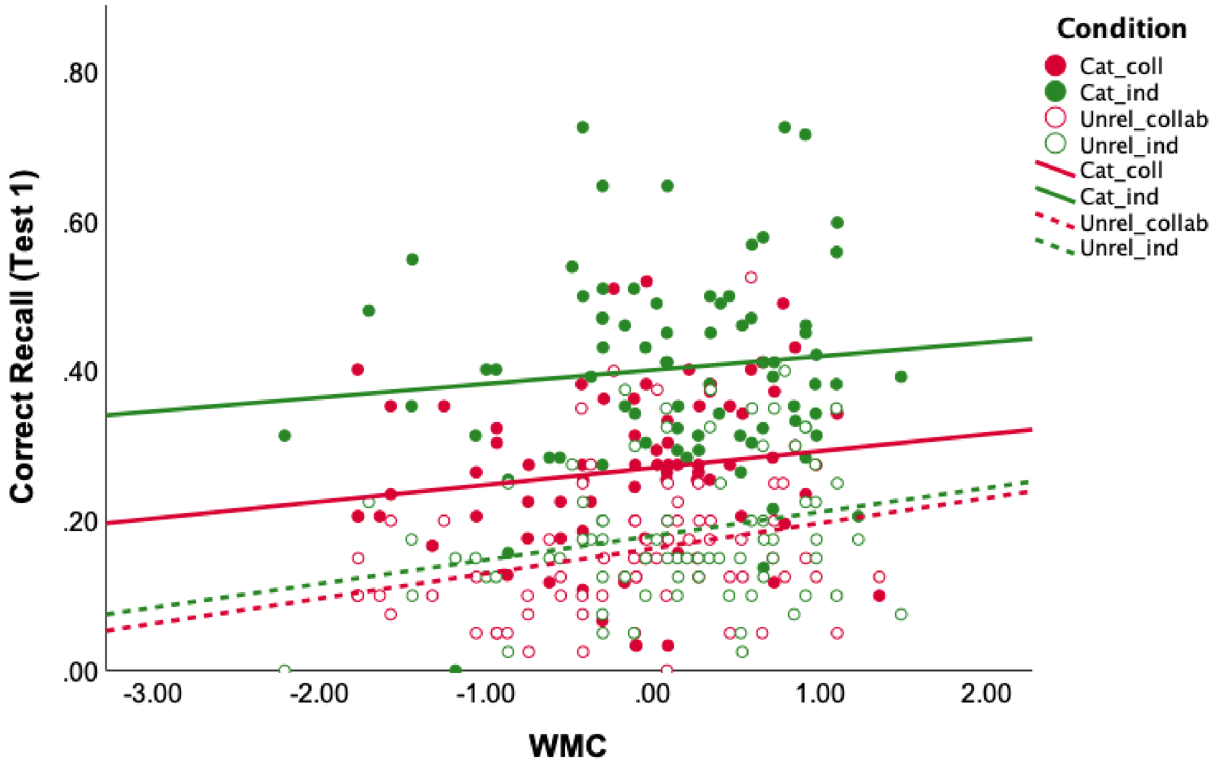
Working Memory as a Predictor of Collaborative Memory

We conducted linear mixed effects (LME) modeling to test for the three-way interaction between WMC x Retrieval condition (Collaborative vs. Nominal) x List type (Categorized vs. Unrelated) for correct and false recall on recall tests 1 and 2. Note that the recognition data is not reported in the thesis because data analysis is on-going. Note also that, as in Experiment 1, individual recall 1 scores were used in the LME analyses, rather than the combined recall of pooled groups and collaborative groups as reported for recall test 1 in Table 2. Individual recall scores are necessary to understand how each individual's recall is influenced by their WMC.

Recall Test 1

Correct Recall. Correct recall data are presented in Figure G. There was a significant main effect of condition (β = -.08, SE = .02, t = -5.16, p < .001), a significant main effect of list type (β = .16, SE = 6.83e-03, t = 23.80, p < .001), and a significant main effect of WMC (β = .03, SE = .02, t = 2.11, p = .035). These main effects were qualified by significant interactions between condition and list type (β = -.04, SE = 6.83e-03, t = -6.03, p < .001), and list type and WMC (β = -.01, SE = 6.83e-03, t = -1.97, p = .049). These interactions demonstrate that collaborative inhibition was relatively larger for the categorized word lists, and that WMC was relatively more predictive of recall on the uncategorized lists. The interaction between condition and WMC was nonsignificant (β = .02, SE = .02, t = 1.09, p = .275). Importantly, the three-way interaction between condition, list type and WMC was nonsignificant (β = .01, SE = 6.83e-03, t = 1.63, p = .102). This means that collaborative inhibition was the same for higher and lower WMC individuals and this applies for the categorized lists and the unrelated list. These data are consistent with the results of Experiment 1 and they support the additive hypothesis. Furthermore, these results do not replicate Hood et al. (2023) findings that supported the attentional control hypothesis.

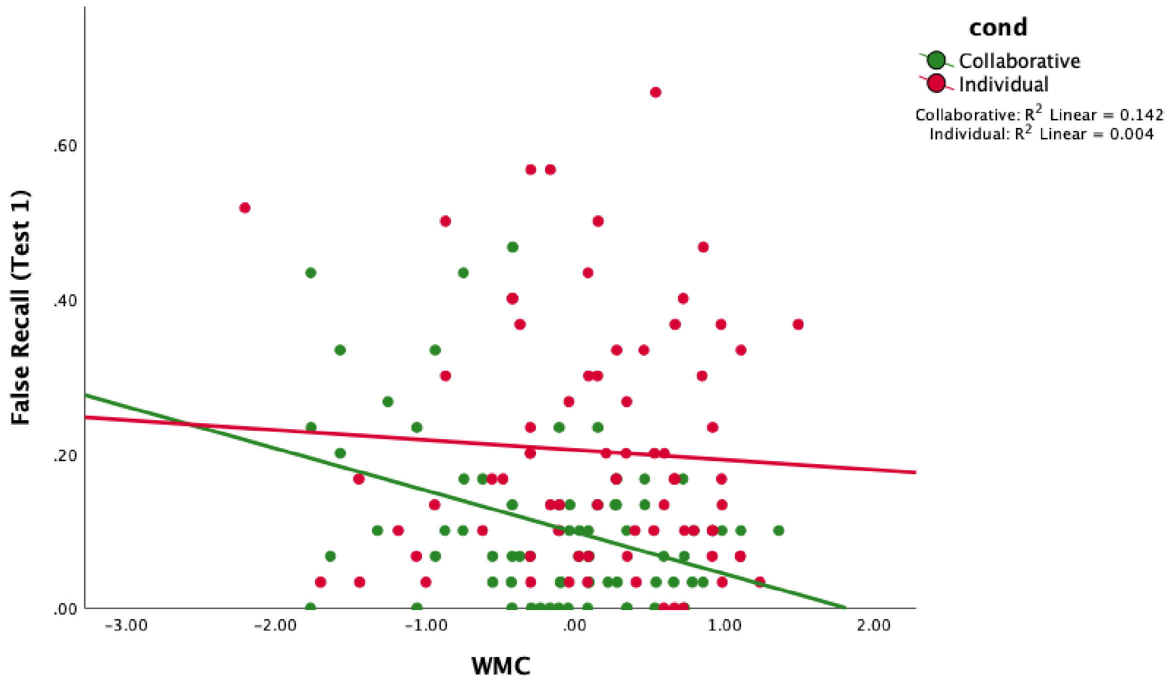
Figure G. Correct Recall at Test 1 as a function of WMC, List Type, and Retrieval Condition



<u>False Recall.</u> False recall in Experiment 2 only includes the analyses of categorized lists as these lists consist of lures that act as a measure of false recall (extra list intrusions are not reported because like Experiment 1, and consistent with past research (e.g., Roediger, 1996), there were very few extra list intrusions recalled and any interpretations are confounded by floor effects). False recall on the categorized lists was measured as the proportion of non-presented critical lures participants recalled (see Figure H). There was a significant main effect of condition (β = -.15, SE = .03, t = -4.72, p < .001) and a significant main effect of WMC (β = -.07, SE = .03, t = -2.22, p = .027). There was a nonsignificant interaction between retrieval condition and WMC (β = -.04, SE = .03, t = -1.38, p = .167). This suggests that collaborative groups demonstrated reduced false recall in the collaborative groups, and higher WMC

individuals reported lower levels of false recall than lower WMC individuals. Importantly, the magnitude of false recall did not vary across WMC.

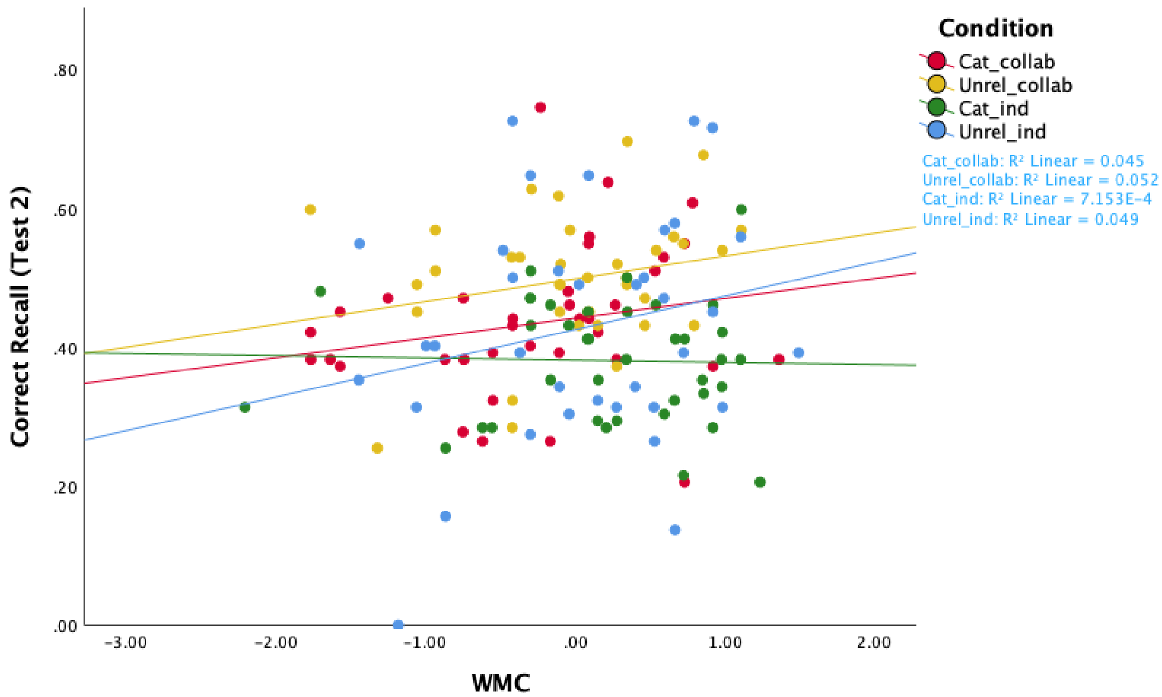
Figure H. False Recall at Test 1 as a function of WMC and Retrieval Condition



Recall Test 2

Correct Recall. Correct recall data for recall test 2 are presented in Figure I. There was a significant main effect of condition (β = .07, SE = .02, t = 4.12, p < .001), a significant main effect of list type (β = .21, SE = 6.77e-03, t = 30.92, p < .001), and a significant main effect of WMC (β = .04, SE = .02, t = 2.62, p = .009). None of the interactions were significant. There was a nonsignificant interaction between condition and list type (β = 3.18e-03, SE = 6.77e-03, t = .47, p = .638). There was a nonsignificant interaction between condition and WMC (β = .01, SE = .02, t = .60, p = .548). There was a nonsignificant interaction between list type and WMC (β = -3.60e-03, SE = 6.77e-03, t = -.53, p = .595). There was a nonsignificant three-way interaction between condition, list type and WMC (β = 6.01e-03, SE = 6.77e-03, t = .89, p = .375). This suggests that recall was higher for categorized word lists than unrelated word lists, recall was higher following collaboration than following individual recall, and recall was higher for higher WMC individuals than low WMC individuals.

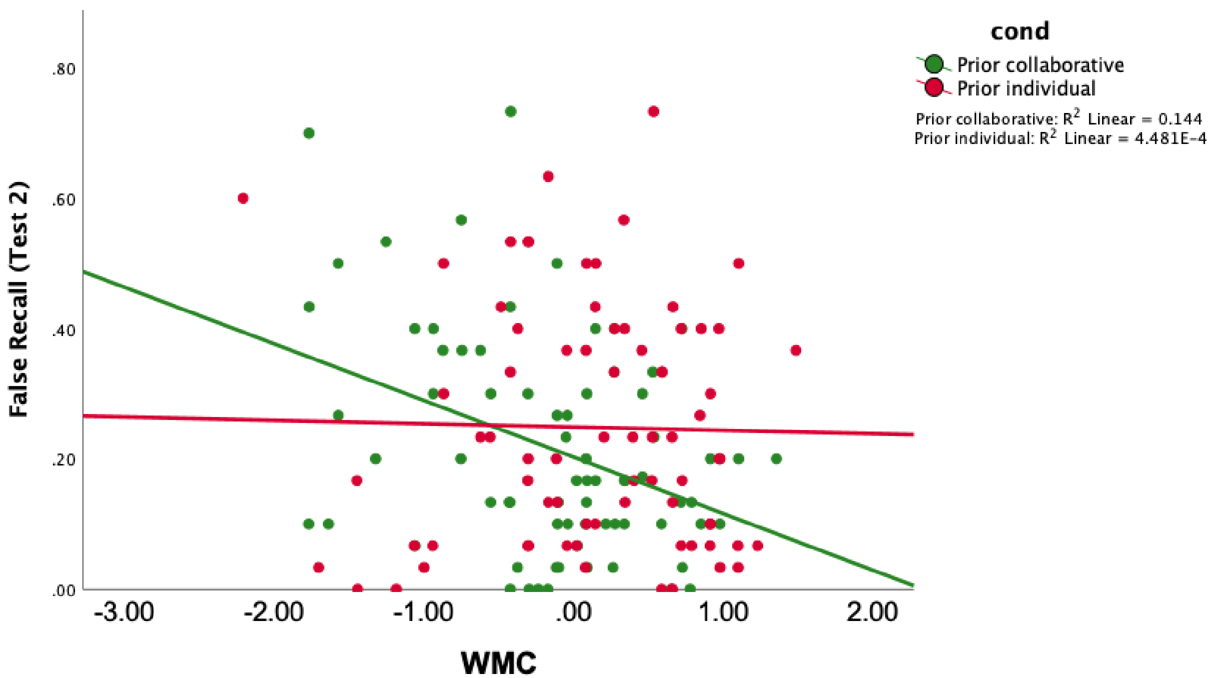
Figure I. Correct Recall at Test 2 as a function of WMC, List Type, and Prior Retrieval Condition



<u>False Recall.</u> False recall for recall test 2 was again only measured for categorized word lists (see Figure J). There was no main effect of condition (β = -.05, SE = .03, t = -1.58, p = .113). There was a significant main effect of WMC (β = -.08, SE = .03, t = -2.36, p = .018). These effects were qualified by a significant interaction between condition and WMC (β = -.07, SE = .03, t = -2.13, p = .034). We ran Pearson's correlations to explain this interaction. These results show that in the collaborative condition, participants' WMC score and false recall scores were negatively correlated (r = -.379, p = .001). Furthermore, in the individual condition,

participants' WMC score and false recall scores were not correlated (*r* = -.021, *p* = .858). Thus, for lower WMC individuals, false recall from recall test 1 persisted over to false recall test 2. More generally, these results suggest that higher the participant's WMC score, the lower the false recall.

Figure J. False Recall at Test 2 as a function of WMC and Prior Retrieval Condition



<u>Discussion</u>

In summary, the results demonstrated that collaborative inhibition was present for correct recall in recall test 1 and post collaborative benefits for recall test 2. Further, we found higher WMC individuals had higher correct recall and lower false recall on both recall tests. Finally, recall was consistently higher for categorized lists than unrelated lists. Importantly, however, we did not find a three-way interaction between condition, list type and WMC on recall test 1 and 2.

For unrelated word lists, the current results replicate Experiment 1 and support the additive hypothesis. Also important is that, in contrast to the results of Experiment 1, we did obtain effects of WMC in the current experiment. This demonstrates that the null interactions between WMC and collaboration in Experiment 1 were not because we had a failed manipulation of WMC. In Experiment 2, when we did find effects of WMC, WMC still did not interact with collaboration. Thus, we have converging evidence in support of the additive hypothesis.

Interestingly, the results also show support for the additive hypothesis with the categorized lists. With the categorized lists in Hood et al. (2023), they found that the low WMC individuals showed greater collaborative inhibition and high WMC showed no collaborative inhibition. This makes sense because, with the categorized lists, the participants get an organization across the lists and importantly, the low WMC individuals get the boost they need from the list names (cf. Unsworth & Brewer, 2012). However, with the current results, we found evidence that the additive hypothesis explains the data for both unrelated and categorized lists.

GENERAL DISCUSSION

In the current study, we aimed to clarify the relationship between working memory capacity and collaborative inhibition. Across two experiments, we found evidence for collaborative inhibition and post collaborative benefits on unrelated lists (Experiment 1 and 2) and categorized lists (Experiment 2 only). Post collaborative benefits persisted on the source monitoring recognition test, resulting in greater correct recognition and lower false recognition (Experiment 1 only). Importantly, the magnitude of collaborative inhibition and post collaborative benefits were not influenced by WMC. Across both unrelated and categorized word lists, higher WMC individuals and lower WMC individuals showed similar effects of collaboration. These results are consistent with the additive hypothesis of WMC and collaborative inhibition.

Collaborative Inhibition and Post Collaborative Benefits

Across the two experiments, we found collaborative inhibition. These findings replicate past work (Hood et al., 2023; Marion & Thorley, 2016; Wright & Klumpp, 2004; Rajaram, Maswood, & Periera-Pasarin, 2020; Meade & Roediger, 2009; Whillock et al., 2020) and demonstrates the effect generalizes across categorized and unrelated lists. Interestingly, collaborative inhibition in Experiment 2 was marginal for the unrelated lists. Most likely this is because data collection is ongoing, and this analysis is currently underpowered. In Experiment 2, larger collaborative inhibition occurred for categorized lists. To our knowledge, this is the first experiment to directly compare collaborative inhibition for categorized and unrelated lists in a single experiment. Generally, this is consistent with prior research showing that collaborative inhibition is influenced by categorized materials (Basden et al, 1997; Hyman, et al., 2013)

Furthermore, we found significant post collaborative benefits. This suggests that prior collaboration aided individual memory on the subsequent recall test showing better correct recall and recognition after collaboration. This replicates past research and extends to both unrelated and categorized lists (Hood et al, 2023; Barber & Rajaram, 2011; Marion & Thorley, 2016; Blumen & Stern, 2010). We also found post collaborative benefits on false memory (Barber et al. 2015). In addition, we found reduced false recognition in Experiment 1 and reduced false recall in Experiment 2. This suggests that prior collaboration can benefit memory for categorized lists by minimizing false recall on subsequent tests, which is consistent with error correction (cf. Ross et al., 2008).

Working Memory Capacity

We found no effects of WMC on memory in Experiment 1. Moreover, higher and lower WMC individuals did not differ on recall 1, recall 2, or recognition. This means that collaborative inhibition and post collaborative benefits were the same for higher and lower WMC supportive of the additive hypothesis. It also means that post collaborative benefits persisted on the recognition test and the magnitude of post collaborative benefits were the same for higher and lower WMC individuals. Conversely, we did find an effect of WMC on memory in Experiment 2. Altogether, we found that higher WMC individuals had higher correct recall on test 1 and 2, and lower false recall on test 1 and 2. This suggests that higher the participant's WMC score, the greater the correct recall on recall tests 1 and 2 and lower rates of false recall on tests 1 and 2. One possible explanation for the discrepancy is the list length differences across experiments. In Experiment 1, participants were presented 60 items. In Experiment 2, participants were presented 40 items. We found higher recall with 40 items, which allowed more room for higher WMC individuals to demonstrate their differences on the tests.

Working Memory Capacity as a Predictor of Collaborative

Across both experiments, we found no interactions between WMC and collaborative inhibition. This was true for unrelated lists (Experiment 1 and Experiment 2) and for categorized lists (Experiment 2 only). Especially important is that even when we manipulated list structure within a single experiment, we still found no evidence that WMC is related to collaborative memory. These results are inconsistent with Hood et al., (2023) and Barber and Rajaram (2015). Hood et al., (2023) and Barber & Rajaram (2015) showed that higher WMC individuals demonstrated less inhibition and greater post collaborative benefits on categorized lists.

These results support the additive hypothesis. This hypothesis stated that high WMC and low WMC may present equal magnitudes of collaborative inhibition and explained that it could be that WMC has no effect on collaboration, or it could be that attentional control and elaborative encoding are cancelling each other out. These two competing explanations for the additive hypothesis make it difficult to interpret the data. However, given that previous research has found support for attentional control (Hood et al., 2023 & Barber & Rajaram., 2015), it is likely that attentional control has some impact on collaborative memory. Therefore, the most likely explanation of our results is that attentional control and elaborative encoding occur at the same time and produce a null effect.

Limitations

The current study does have limitations. One possible limitation is order effects. It is possible that, based on the type of list participants are presented with first, the strategy they utilize to recall that list stays the same even when retrieving items for the other type of list. If that is the case, there may not be differences between the higher and lower WMC individuals demonstrating why we see the additive hypothesis. Future research can further examine any carry over effects of strategies on different types of lists. Also, it is important to determine how order effects and carry over effects might differentially impact higher WMC individuals and lower WMC individuals.

Another potential limitation is fatigue effects. Given that the experiment is two hours long and participants are asked to engage in higher-level attention tasks and are presented with 142 words in total, it is likely that the participants are mentally fatigued towards the end of the experiment. This could be an underlying factor that is contributing towards suboptimal memory performance on the second type of list being presented. Also, it is possible that any effects of fatigue might differ across higher and lower WMC individuals. Future research can examine if differences in memory performance are observed when rest opportunities are presented during the experiment.

Finally, data collection is on-going and the analyses reported here are underpowered. We anticipate the results might change as we finalize data collection. In addition, there are several additional analyses we will complete in order to better understand our results. For example, we will include final recognition in Experiment 2. Also, in both experiments, we'll look at the partner's WMC in the collaborative condition. These will help provide a more thorough understanding of the data.

Conclusion

Collaboration is part of our everyday life and is widely applicable in many contexts. Given that collaboration is a ubiquitous activity, the results reported here have implication for a range of situations such as school-settings (e.g., students working together to recall class material), social settings (e.g., friends recollecting a past social outing), and workplaces (e.g., company members evaluating employees work performances). This present study will extend the theoretical understanding of collaborative inhibition and factors underlying it. Additionally, this will help us understand if working memory capacity generalizes across collaborative inhibition for both categorized and unrelated words. Future research can look at how working memory capacity relates to other mechanisms of collaborative inhibition such as attentional control (Hood et al., 2023), collaborative process variables (Whillock et al., 2020) and retrieval inhibition (Barber et al., 2015). Importantly, this study will extend the current research and bridge gaps in the memory and cognition literature.

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