Collaborative Inhibition Effect: The Role of Memory Task and Retrieval Method

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Consent to participate: Informed consent was obtained from all participants.

Abstract

It is well established that the recall of collaborative groups is lower than the pooled recall of an equal number of lone individuals – the collaborative inhibition effect (Weldon & Bellinger, 1997). This is arguably the case because group members have conflicting retrieval strategies that disrupt each other's recall - the retrieval strategies disruption hypothesis (Basden et al., 1997). In two experiments, we further examined this hypothesis by testing whether the memory task (free recall vs. serial recall) and the recall method (turn-taking vs. unconstraint) moderate collaborative inhibition. Experiment 1 compared the performance of collaborative and nominal groups in a free recall and a serial recall task. Results revealed collaborative inhibition in free recall, but this effect was reduced in serial recall. In Experiment 2, collaborative and nominal performance was compared in the same tasks with collaborative but also nominal groups, using the turn-taking method. The collaborative inhibition effect was still observed in free recall, although to a lesser extent when participants in nominal groups used the turn-taking method. In the serial recall task, the collaborative inhibition effect was eliminated. Taken together, these results further support retrieval strategies disruption as an explanation for the collaborative inhibition effect.

Keywords: collaborative inhibition; retrieval strategies; free recall; serial recall; turn-taking method

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Introduction

Remembering information or events is often a cooperative and social activity (e.g., Garcia-Marques et al., 2012; Hinsz et al., 1997; Larson & Christensen, 1993; Maswood & Rajaram, 2019; Rajaram & Pereira-Pasarin, 2010). This view of memory as a social activity is reflected in the growing interest in collaborative memory research, particularly over the last three decades (see Marion & Thorley, 2016; Rajaram & Maswood, 2017; Rajaram & Pereira-Pasarin, 2010, for reviews).

Collaborative memory can be defined as a process involving two or more people collaborating to remember previously experienced information (Meade et al., 2009). The experimental examination of collaborative memory typically includes a learning phase presenting the stimuli (e.g., words) and a subsequent collaborative or individual recall task. In individual recall conditions, participants freely recall as much information as possible from the learning phase. In collaborative recall conditions, participants recall this information collaboratively, typically using one of two methods: free-for-all or turn-taking. In the free-for-all method, the group is instructed to remember as much information as possible, in any order, without time limitations or any other constraints to complete the recall task (e.g., Barber et al., 2014; Barber & Rajaram, 2011; Blumen et al., 2014; Maki et al., 2008; Weldon & Bellinger, 1997). All group members should contribute to recall, and any disagreements should be addressed through group discussion. In the turn-taking method, each group member has a few seconds to recall a given item. After a participant recalls an item or is unable to recall an item during their turn, the turn is immediately assigned to another group member, and so on until, after a few attempts, none of the participants can recall any stimulus (e.g., Basden et al., 1997; Thorley & Dewhurst, 2007; Wright & Klumpp, 2004). The usual constraints imposed in this task are that participants should not repeat items already recalled by other group members and that members should not talk among themselves. The recall performance of the collaborative groups is then compared with the recall of nominal groups, that is, the pooled recall of an equal number of lone individuals. Surprisingly, collaborative memory studies present somewhat paradoxical results: while collaborative groups recall more information than a single individual (Weldon & Bellinger, 1997; Yuker, 1955), they recall less than nominal groups. In other words, collaboration brings immediate costs to memory performance, an effect known as collaborative inhibition (Weldon & Bellinger, 1997).

The collaborative inhibition effect is very robust and has been replicated in several studies using different stimuli, including word pairs (Finlay et al., 2000), lists of associated words (Thorley & Dewhurst,

2007), stories (Takahashi & Saito, 2004), categorized lists (Basden et al., 2000; Rossi-Arnaud et al., 2017), unrelated words (Andersson et al., 2006; Blumen & Rajaram, 2008), videos (Saraiva et al., 2021), behavioral information (Garcia-Marques et al., 2012; Garrido et al., 2012a, 2012b), among others.

The retrieval strategies disruption hypothesis proposed by Basden et al. (1997) to explain collaborative inhibition has received the most empirical support (see Marion & Thorley, 2016, for a review). According to this account, individuals have their own strategies to encode and retrieve information, which they use during recall to retrieve as much information as possible. During collaborative recall, the exposure to the other group members' recall outputs disrupts the individuals' recall because the recall strategy suggested by the recall outputs of other group members interferes with their own retrieval strategies. This often results in a lower performance of the collaborative group compared to the performance of the nominal group.

The current studies constitute a further attempt to test the disruption of retrieval strategies hypothesis as an explanation for the collaborative inhibition effect. We did so by manipulating the retrieval task (free recall vs. serial recall) and the recall method (unconstrained vs. turn-taking).

In Experiment 1, the disruption of retrieval strategies hypothesis was further tested by comparing nominal and collaborative performance in a serial and a typical free recall task. Serial recall tasks encourage encoding and recall strategies based on the presentation order of the stimuli (e.g., Drewnowski & Murdock, 1980). Therefore, individual retrieval strategies are more likely to be disrupted in free recall tasks than in tasks in which the order of information to be retrieved is imposed (for a review, see Marion & Thorley, 2016). In collaborative serial recall conditions, all group members are more likely to share similar encoding and retrieval strategies; thus, recall disruption is less likely. Under these conditions, collaborative inhibition should be reduced or not even observed. Previous studies comparing the performance of collaborative and nominal groups in tasks that impose constraints on the organization of the information (e.g., serial recall and Method of Loci; Saraiva et al., 2016) did not observe collaborative inhibition in these conditions. This argument is further supported by other studies showing that endowing participants in a collaborative recall group with the same strategy of encoding and retrieval might reduce the collaborative inhibition effect (e.g., Barber et al., 2012; Finlay et al., 2000; Garcia-Marques et al., 2012; Harris et al., 2013). Notably, in tasks presenting constraints to retrieval (e.g., recognition, cued recall, serial recall), the imposed strategy may be inconsistent with participants' individual retrieval strategies in both collaborative and nominal groups. This inconsistency is likely to impair the performance of both groups and thus reduce or even eliminate the collaborative inhibition effect (e.g., Barber et al., 2010; Finlay et al., 2000; Thorley & Dewhurst, 2007, but see Andersson, 2001; Andersson &

Rönnberg, 1996; Kelley et al., 2014; for different results). Serial recall constitutes such a task likely to constrain the recall strategies in both collaborative and nominal conditions. In sum, both arguments converge in that serial recall should reduce or eliminate collaborative inhibition. This should be the case either because a similar recall strategy across collaborative group members minimizes the disruption of retrieval strategies or because, in serial recall, participants in both nominal and collaborative recall conditions are forced to abandon their idiosyncratic strategies. However, while in the former case, collaborative inhibition reduction will result from enhanced performance in collaborative groups, in the latter, it will derive from an evenly low recall performance in both groups.

Additionally, an important variable that might influence the collaborative inhibition effect is the collaborative recall method. While both collaborative recall methods (free-for-all and turn-taking) are reliable in leading to collaborative inhibition (Wright & Klumpp, 2004), the magnitude of the effect is larger when the turn-taking method is used (see Marion & Thorley, 2016 for a review). This is arguably the case because while in the free-for-all method, participants can recall several items at once, thus benefiting, to a certain extent, from their individual strategies, in the turn-taking method, the individual strategies are disrupted by each consecutive recall output provided by another group member (Marion & Thorley, 2016). Moreover, according to the production blocking hypothesis (Diehl & Stroebe, 1987), the time participants must wait between turns to express their ideas can impair performance as group members are more likely to forget the information they intended to verbalize. Although the production blocking account was initially advanced in the context of brainstorming research (e.g., Diehl & Stroebe, 1987), it has also been extended to collaborative inhibition studies, albeit with mixed results. For instance, Andersson et al. (2006) concluded that both the disruption of the retrieval strategies and production blocking might contribute to explaining collaborative inhibition, whereas Wright and Klumpp (2004) found otherwise. In their study, participants were divided into three conditions: see condition (i.e., participants took turns recalling the items and were able to see each other's recall outputs); not see condition (i.e., participants took turns during recall but did not see each other's recall outputs); and nominal condition. The results revealed that the performance in the see condition was significantly lower than in the other two conditions, replicating the collaborative inhibition effect. These results suggest that collaborative inhibition results from the product of recall, not the process of recall (i.e., taking turns). Still, the recall was lower in the not see condition than in the nominal condition, although the difference was not significant.

Collaborative inhibition studies using the turn-taking method typically compare the performance of collaborative groups recalling in turns with the performance of nominal groups in an unrestricted free recall

task. Therefore, it seems plausible to argue that the difference between nominal and collaborative group recall may be due, at least in part, to the constraints imposed by the turn-taking method on collaborative groups. Experiment 2 further examines the influence of the turn-taking constraint on the recall task by comparing collaborative but also nominal groups, recalling with the turn-taking method much in line with the procedure reported by Wright and Klumpp (2004). However, the present study differs from that of Wright and Klumpp (2004) in the stimuli used (unrelated words vs. associated words), sample size, method of stimuli presentation (computerized vs. paper and pencil), and the turn-taking procedure (responding aloud vs. written response). In Experiment 2, we expected the turn-taking method to decrease recall in nominal groups, thus reducing the collaborative inhibition effect. Nevertheless, the disruption of retrieval strategies experienced during collaborative recall may still be enough to produce a lower recall performance than in nominal groups, even when the constraints of the turn-taking method are also imposed on these latter groups.

Moreover, in both experiments, we introduced a within-subject design. Although manipulating collaborative versus nominal recall within participants is not the standard in the collaborative memory literature, this design allows a more powerful comparison between the actual collaborative performance and the potential performance (nominal recall) of the same groups (see Barnier et al., 2018; Ekeocha & Brennan, 2008; Harris et al., 2011; Hinds & Payne, 2016; Saraiva et al., 2016; for a similar procedure).

Experiment 1

This experiment compares nominal and collaborative recall, using a serial and a free-recall memory task to further test the disruption of retrieval strategies hypothesis as an explanation for the collaborative inhibition effect. In a free recall task, the collaborative inhibition effect is expected because participants' retrieval strategies are likely to be disrupted by other group members' recall outputs. However, when asked to engage in a serial recall task, group members are more likely to use the same retrieval strategy, namely, to recall the information in the same order as it was presented. Using a similar recall strategy is expected to raise the collaborative group's recall performance to the level of the nominal group, reducing or eliminating collaborative inhibition. Alternatively, the collaborative inhibition effect might be reduced because serial recall disrupts participants' retrieval strategies in both collaborative and nominal conditions. If this is the case, collaborative inhibition is no longer expected at the cost of an evenly low recall performance in both groups.

Method

Participants

A sample of 74 groups was determined by *a priori* power analysis (G*Power) using as reference a medium to large effect size (η_p^2 = .10; effect size specification as in Cohen, 1988) and a power 1-β = 0.80 to detect the interaction between Group (nominal vs. collaborative; within-participants) and Memory Task (free vs. serial; between participants). Additionally, this sample size is sufficient to detect the collaborative inhibition effect using the mean effect size obtained for this effect reported in a recent meta-analysis (*d* = -0.78; and a power 1-β = 0.80, *N* = 44; Marion & Thorley, 2016). The final sample of the current study included 152 participants (128F, M_{age} =20.62; *SD* = 6.26) who were randomly assigned to one of the following recall tasks: free recall (N = 38 dyads) and serial recall (N = 38 dyads)[1]. All participants volunteered for the experiment.

Stimuli and design

Based on the number of stimuli used in previous studies (e.g., Abel & Bäuml, 2017; Saraiva et al., 2016), two lists of 30 unrelated words each (set A and set B) controlled for frequency (M_A = 5.81; M_B = 5.79; $t(29)$ = .02, p = .99), imagery (M_A = 5.94; M_B = 5.85; $t(29)$ = .89, p = .38), and concreteness (M_A = 6.17; M_B = 6.13; $t(29)$ = .22, p = .83) were selected from Marques (2005) (see Appendix). The order of the list presentation (A and B) was counterbalanced.

The group variable (nominal vs. collaborative) was manipulated within participants. Participants performed the recall task individually (nominal) and collaboratively in a counterbalanced order. The memory task was manipulated between participants, that is, half of the dyads performed a free recall task, and the other half performed a serial recall task. The dependent variable was the proportion between the number of correctly recalled words and the total number of words presented.

Procedure

All procedures were conducted following the ethical guidelines of the host institution. The experiment was programmed in SuperLab 5.0 (Cedrus Corporation, San Pedro, CA). Participants sat on separate desks facing a 17" monitor connected to a computer that allowed for the simultaneous presentation of the stimuli to both members of the dyad. The initial instructions to the participants were as follows: "*We will present a set of words to which you should pay as much attention as possible because you will be asked to remember them later*". After this instruction, the words appeared one by one at the center of the screen in the same order for each dyad, during 5000 ms. Each word was preceded by a fixation cross ("+") presented for 500 ms to direct

[1] Despite that the collaborative inhibition effect increases as the group size increases (e.g., triads, tetrads), meta-analytic studies (e.g., Marion & Thorley, 2016) have already confirmed that collaborative inhibition was reliably observed in groups of two individuals.

participants' attention to the center of the screen where the words would appear. In the serial recall condition, each word was preceded by a number (between 1 and 30), and participants were told they would have to recall the items later in the same order in which they were presented. After a 2-minute distracting task, half of the dyads performed a free recall task, and the remaining dyads performed a serial recall task (between participants). In the free recall task, participants were instructed to recall as many words as possible without any particular order and write them down on a blank sheet. In the serial recall task, participants were instructed to recall as many words as possible in the same order they were studied and write them down on a blank sheet with entries numbered from 1 to 30.

In both serial and free recall conditions, participants recalled individually and collaboratively (counterbalanced within participants). Participants in nominal groups performed the recall task individually and in silence. Participants in collaborative groups recalled the items using the turn-taking method. The first participant to recall was selected randomly by the researcher. Each participant had 10 seconds to recall aloud one word, and both group members should write it down. Once a participant recalled a word, the turn was immediately given to the other group member even if the 10 seconds had not elapsed. When a participant was unable to recall a word within the time limit, the turn was given to the other participant. The task ended when, after three consecutive turns, none of the participants could recall any word. Participants were also instructed to recall aloud, not repeat words that were already recalled, write only one word per turn, and not talk to each other. Instructions were orally given by the researcher (the same researcher collected all the data). Immediately after completing the recall task (average 5 minutes), a new list of words was presented, followed by the distracting task and a new recall task (individual or collaborative, counterbalanced). The duration of the experiment was about 25 min.

Results[2]

As in standard collaborative memory studies, we compared the recall in collaborative and nominal conditions. Collaborative recall corresponds to the total number of unique words recalled by the two participants from the same collaborative dyad. Nominal recall corresponds to the sum of the non-redundant words recalled individually by the two participants of the same dyad. The proportion of correct recall[3] was calculated based on each set's total number of presented words (N = 30).

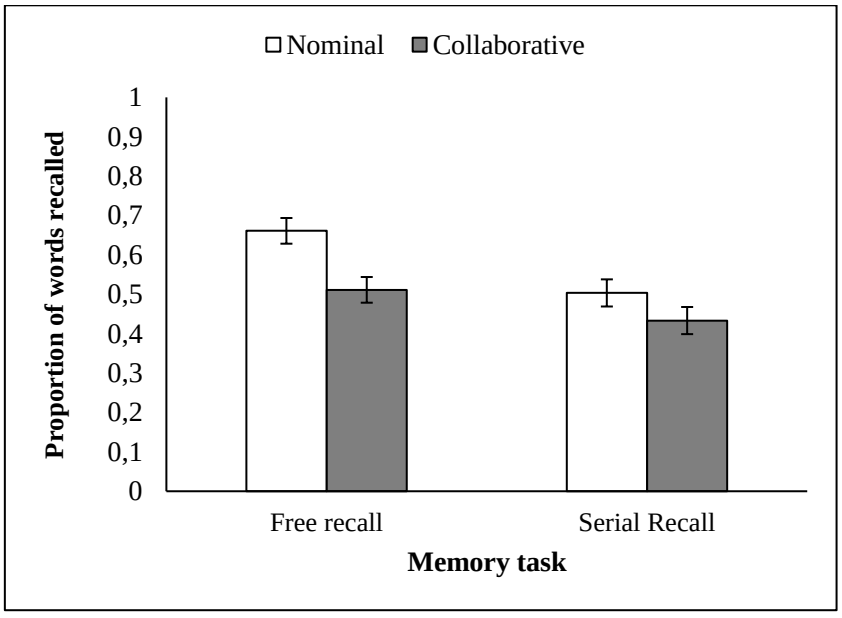
[2] The databases and the syntaxes for both experiments are available at OSF (https://osf.io/e95pd/?view_only=701e843751324d9c9b589fd3b407fbda)

[3] Typically, in serial recall tasks, the responses are scored as correct if entered in the proper position (see Thomas et al., 2003). However, to ensure that observed differences between the two memory tasks do not result from different scoring methods, we considered a recalled word as correct (if it has been presented on the list), irrespective of the position in which it was recalled.

Correct recall[4]

The recall of the words presented in the studied list was analyzed with a 2 (Group: nominal vs. collaborative) X 2 (Memory task: free recall vs. serial recall) mixed ANOVA and revealed a significant group main effect, $F(1, 74) = 44.13$, $p < .001$, $\eta_p^2 = .374$, 95% CI [.20, .51]. Recall in nominal groups was significantly higher ($M = .58$, $SD = .16$) than in collaborative groups ($M = .47$, $SD = .14$). This result replicates the collaborative inhibition effect. A significant main effect of memory task was also observed, $F(1, 74) = 19.06$, $p < .001$, $\eta_p^2 = .205$, 95% CI [.06, .35] revealing significantly higher performance in free recall ($M = .59$, $SD = .14$) than in serial recall ($M = .47$, $SD = .14$). The interaction between group and memory task was also significant, $F(1, 74) = 5.78$, $p = .02$, $\eta_p^2 = .072$, 95% CI [.00, .20] (see Figure 1).

Fig. 1 Proportion of words correctly recalled by the groups in both memory tasks (error bars indicate 95% confidence interval)



Planned contrasts testing our specific hypothesis revealed that free recall was significantly higher in nominal ($M = .66$, $SD = .15$) than in collaborative groups ($M = .51$, $SD = .12$), $F(1, 74) = 40.93$, $p < .001$, $\eta_p^2 = .356$, 95% CI [.19, .49]. In serial recall, the difference between nominal ($M = .50$, $SD = .13$) and collaborative groups ($M = .43$, $SD = .15$) albeit smaller, was also significant, $F(1, 74) = 8.98$, $p = .004$, $\eta_p^2 = .107$, 95% CI [.01, .25]. The observed change in the effect sizes (free: $dz = 1.066$; serial: $dz = .474$) confirms how much collaborative inhibition was reduced from free to serial recall. The performance in free recall was significantly

[4] Prior to all analyses reported, relevant assumptions were checked. Additional analysis of recall task order, stimulus list order, and the serial position curves for nominal and collaborative groups in both memory tasks can be found in SM. Relevant results are addressed in the discussion.

higher than in serial recall in both nominal, $F(1, 74) = 23.82$, $p < .001$, $\eta_p^2 = .244$, 95% CI [.09, .39], and collaborative conditions, $F(1, 74) = 6.33$, $p = .01$, $\eta_p^2 = .079$, 95% CI [.00, .21][5].

Errors

The number of errors (i.e., recalled words that were not in the stimulus list) and intrusions (i.e., recalled words that were presented in the previous list) was calculated for each group in each task (see SM for descriptive statistics). Overall, the number of errors was small (Min = 0, Max = 11; $M = 0.76$, $SD = 1.34$) of which only a few (Min = 0, Max = 3; $M = 0.18$, $SD = 0.51$) were intrusions from the previous list. Poisson regression revealed that group ($b = -.934$, $SE = .205$, $p < .001$) and memory task ($b = -.398$, $SE = .189$, $p = .04$) were significant predictors of the number of errors. The incidence rate ratio for errors in nominal groups was 39.3% higher than in collaborative groups and 67.1% higher in free than serial recall tasks. For the intrusions, memory task was not a significant predictor ($b = -.288$, $SE = .382$, $p = .45$), but the group was ($b = -1.299$, $SE = .461$, $p = .005$). The incidence rate ratio for intrusions in nominal groups was 27.3% higher than in collaborative groups.

Overall, the main findings of Experiment 1 replicate the collaborative inhibition effect in both memory tasks. However, the effect size of collaborative inhibition was smaller in the serial recall task (vs. free recall). These results further showed that serial recall hindered the performance in nominal and collaborative conditions, suggesting that participants in both groups were forced to abandon their idiosyncratic retrieval strategies.

Experiment 2

In the classic collaborative memory paradigm, collaborative groups' recall performance with the turn-taking method is directly compared with nominal groups' performance in unconstrained free recall tasks (as in Experiment 1). Thus, in addition to the disruption of retrieval strategies derived from the exposure to the recall outputs of the other group members, the recall process (i.e., turn-taking) might prevent group members from readily using their retrieval strategies and potentially impair their performance.

The goal of Experiment 2 was to further examine the contribution of other group members' recall outputs and the process of recalling in turn, in reducing collaborative recall. Therefore, to enable the critical comparison between collaborative and nominal groups, the turn-taking method was used in collaborative but also in nominal groups (lone individuals recalling in turns; for a similar procedure, see Wright & Klumpp, 2004; not see condition). In contrast to Wright and Klumpp (2004), we expected that turn-taking would significantly

[5] Considering the recall task order, we found that in the free recall task, the nominal performance did not vary with task order, but the collaborative recall was higher when it was the second task than the first. In the serial recall task, nominal group performance was higher when it was the second recall task (vs. first) and the collaborative performance did not vary with task order (see SM for more details).

decrease the amount of information typically recalled in standard nominal group conditions because the recall constraints imposed by this method might prevent participants from readily using their retrieval strategies or, at least, make them more likely to forget the information they intended to recall (Diehl & Stroebe, 1987). However, the disruption of retrieval strategies in collaborative groups might still be enough to render their recall performance lower than nominal groups (even when these take turns), and the collaborative inhibition effect could still be observed.

Method

Participants

The sample size was determined based on the same parameters as in Experiment 1. One-hundred and fifty-two participants (133F, M_{age} = 21.16; *SD* = 4.41) were recruited as in Experiment 1 and divided into dyads that were randomly assigned to one of the following recall tasks: free recall (N = 38 dyads) and serial recall (N = 38 dyads).

Stimuli, design, and procedure

The stimuli, design, and procedure were similar to that described in Experiment 1. However, the recall task in both nominal and collaborative groups followed the turn-taking method. In the individual recall task, participants in nominal groups were asked to write down as many words as they could remember. To implement the turn-taking method in similar conditions to collaborative recall, participants were told that they would have to write down the words in turn. One participant was randomly chosen to start the task and given 10 seconds to individually recall one word. Once the participant wrote down the word, the turn was given to the other participant, and so on, even if the 10 seconds had not elapsed. A beep signaled the turn change. When a participant could not recall a word within 10 seconds, the turn was given to the other participant. The task ended when none of the participants could recall any word after three consecutive turns. Importantly, participants could not see the words recalled by the other participant (see Wright & Klumpp, 2004, not see condition). The collaborative recall task was the same as in Experiment 1.

Results

Correct recall[6]

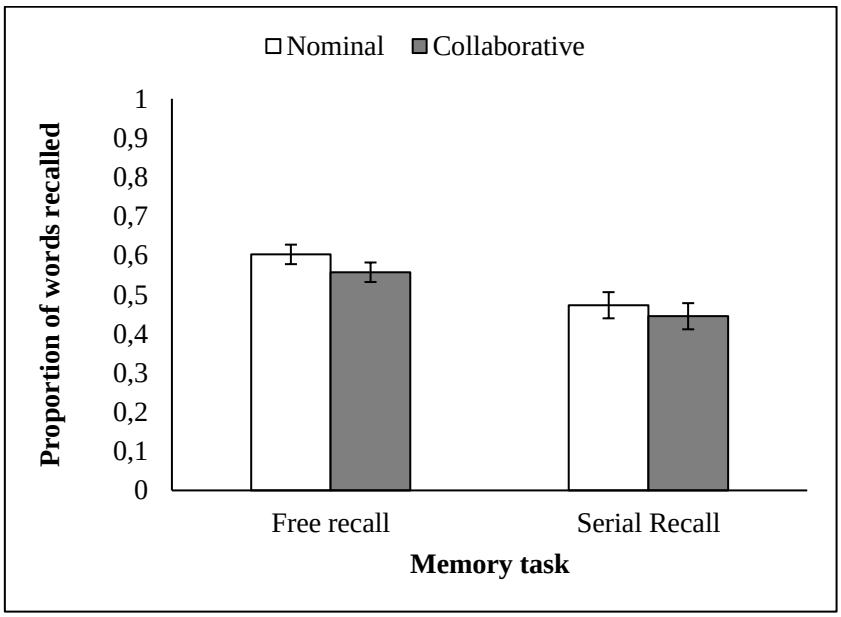
Similar to Experiment 1, in the serial recall task, all the recalled words were considered correct (as long as they were part of the presented word list), regardless of the order in which they were recalled.

[6] Prior to all analyses reported, relevant assumptions were checked. Some additional analysis and the serial position curves for nominal and collaborative groups in both memory tasks can be found in SM.

The recall of the words presented in the studied list was analyzed with a 2 (Group: nominal vs. collaborative) X 2 (Memory task: serial recall vs. free recall) mixed ANOVA. The results revealed that the group main effect was significant, $F(1, 74) = 6.14$, $p = .02$, $\eta_p^2 = .077$, 95% CI [.00, .21], that is, nominal recall was higher ($M_{Nom} = .54$, $SD = .13$) than collaborative recall ($M_{Col} = .50$, $SD = .14$). The main effect of memory task was also significant, $F(1, 74) = 27.78$, $p < .001$, $\eta_p^2 = .273$, 95% CI [.11, .42], revealing that free recall was higher ($M = .58$, $SD = .12$) than serial recall ($M = .46$, $SD = .12$).

The interaction between memory task and group was not significant, $F(1,74) = 0.335$, $p = .56$, $\eta_p^2 = .005$, 95% CI [.00, .08]. To test our specific hypothesis, we computed planned contrasts that showed that free recall was significantly higher in nominal ($M = .60$, $SD = .12$) than in collaborative groups ($M = .56$, $SD = .11$), $F(1,74) = 4.67$, $p = .03$, $\eta_p^2 = .059$, 95% CI [.00, .18]. In serial recall the difference between nominal ($M = .47$, $SD = .11$) and collaborative groups ($M = .44$, $SD = .14$), was not significant[7], $F(1,74) = 1.80$, $p = .18$, $\eta_p^2 = .024$, 95% CI [.00, .13] (see Figure 2). Again, the observed change in the effect sizes (free: $dz = .415$; serial: $dz = .192$) confirms how much the collaborative inhibition was reduced from free to serial recall.[8]

Fig. 2 Proportion of words correctly recalled by the groups in both memory tasks (error bars indicate 95% confidence interval)



[7] Equivalence tests (TOST procedure; Lakens, 2017) using as bounds Cohen's medium effect size ($dz = .50$) indicated that the observed effect size in the serial recall ($dz = .192$) was significantly within the equivalent bounds, $t(37) = 1.89$, $p = .033$, suggesting that the absence of the collaborative inhibition effect in serial recall is reliable. The same procedure revealed that the presence of collaborative inhibition in the free recall is also reliable, $t(37) = 0.72$, $p = .238$.

[8] Considering the recall task order, we found that in the free recall task, the nominal performance did not vary with task order, but the collaborative recall was higher when it was the second task than the first. In the serial recall task, both nominal and collaborative group performance did not vary with task order (see SM for more details).

Errors

The number of errors was calculated as in Experiment 1 (see SM for descriptive statistics). Overall, there was a small number of errors (M = 0.76, SD = 1.24, Min = 0; Max = 7); of which only a few (M = 0.20, SD = 0.47, Min = 0; Max = 2) were intrusions from the previous list. Poisson regression revealed that memory task was not a significant predictor of the number of errors (b = .138, SE = .186, p = .458), but the group was (b = -1.344, SE = .229, p < .001). The incidence rate ratio for errors in nominal groups was 26.1% higher than for collaborative groups. Memory task (b = .194, SE = .360, p = .591) was not a significant predictor for intrusions, but the group was (b = -.742, SE = .384, p = .053). In nominal groups, the incidence rate ratio for intrusions was 47.6% higher than for collaborative groups.

Although the interaction effect was not significant in Experiment 2, the collaborative inhibition effect was observed in free recall even when nominal groups used the turn-taking method. In serial recall, collaborative inhibition was not observed. These results suggest that the exposure to the outputs of the other group members (and not the recall method used) seems to be driving the lower performance observed in collaborative groups and further support the disruption of retrieval strategies hypothesis as an explanation for the collaborative inhibition effect.

General Discussion

The current studies examined how memory task (free vs. serial) and recall method (i.e., turn-taking) moderate collaborative inhibition. Experiment 1 compared nominal and collaborative groups in free and serial recall tasks. In free recall, the collaborative inhibition effect was replicated, that is, the recall of nominal groups was higher than that of collaborative groups. A free recall task allows participants to use their own retrieval strategies once they are free to recall the items in any order they wish (Ward et al., 2010). However, these retrieval strategies differ among group members, and retrieval disruption can occur during collaborative recall (see Marion & Thorley, 2016, for a review). This disruption reflects in the lower performance of collaborative groups compared to nominal ones. This pattern of results is consistent with the disruption of retrieval strategies hypothesis (Basden et al., 1997). When the recall was serial, memory performance in nominal groups was also higher than in collaborative groups. However, the effect size of the collaborative inhibition effect was substantially smaller. Serial recall tasks define a recall strategy based on the presentation order of the stimuli. Consequently, the retrieval strategies used by each participant in collaborative conditions tend to be more similar. These results align with previous studies reporting a reduction or elimination of collaborative inhibition in tasks that encourage similar encoding and recall strategies across group members (e.g., Barber et al., 2012;

Finlay et al., 2000; Garcia-Marques et al., 2012; Harris et al., 2013; Saraiva et al., 2016). However, another plausible explanation for the observed reduction of collaborative inhibition in serial recall is that participants in both collaborative and nominal conditions are forced to abandon their idiosyncratic strategies. In other words, the collaborative inhibition effect is reduced because serial recall disrupts retrieval strategies in both groups. Our results seem to support this argument. Indeed, the collaborative inhibition effect was not reduced in serial recall because collaborative group performance was raised to the level of nominal group recall. Instead, as suggested by the drop in nominal groups' performance in serial recall, the lower collaborative inhibition effect observed in serial recall appears to be consistent with a disruption of retrieval strategy for both collaborative and nominal groups. While prior research had already established that collaborative inhibition is often eliminated or attenuated when the recall format constrains the use of individual retrieval strategies (e.g., in cued recall versus free recall), the current experiment introduced the comparison between free and serial recall tasks and provided a conceptual replication of these findings. Moreover, these results further support the disruption of retrieval strategies hypothesis as an explanation for the collaborative inhibition effect (Basden et al., 1997), namely the role of participants' retrieval strategies in the emergence of collaborative inhibition.

The results also revealed that memory performance is higher in free recall than in serial recall tasks, a result already reported in the literature (Bhatarah et al., 2006; Bruder, 1970). A possible explanation advanced for this result is based on task difficulty. Serial recall is more difficult than free recall since participants must recall as many words as possible and remember them in their presented order (Bhatarah et al., 2006; Grenfell-Essam & Ward, 2012). Imposing a strategy for encoding and retrieving information (i.e., same order) prevents using idiosyncratic strategies that would likely be more advantageous for recall performance (e.g., Basden et al., 1997).

Experiment 2 examined whether the recall method (i.e., the turn-taking) typically imposed on the collaborative group contributes to the collaborative inhibition effect. Specifically, when the turn-taking method is used, the individual strategies are constantly disrupted by group members' recall output. Additionally, the time individuals wait between each turn to recall can also interfere with their retrieval process. This seems to occur to a lesser extent in the free-for-all method used in other studies, as suggested by the larger effect sizes of the collaborative inhibition observed for the turn-taking method compared to the free-for-all method (see Marion & Thorley, 2016, for a review). Notably, this procedure used during collaborative recall contrasts with the unconstrained free recall allowed in nominal group conditions. We argued that this procedural difference is likely to maximize the collaborative inhibition effect.

In Experiment 2, the turn-taking method was used by collaborative but also by nominal groups (see Wright & Klumpp, 2004, for a similar procedure). Critically, even when taking turns to recall, nominal groups' performance was higher than collaborative ones, replicating the collaborative inhibition effect - a result also found by Wright and Klumpp (2004). This result does not support production blocking (Dihel & Sroebe, 1987) as an explanation for collaborative inhibition and suggests that social and motivational group processes are of little importance for this effect (for a comprehensive review, see Weldon et al., 2000). As observed in Experiment 1, participants' performance was higher in the free recall task (vs. serial), reinforcing the argument that serial recall is a more challenging task (Bhatarah et al., 2006; Grenfell-Essam & Ward, 2012). Planned contrasts testing our specific hypothesis indicated a collaborative inhibition effect in free recall and its absence in serial recall. Once again, the elimination of the collaborative inhibition effect seems to have resulted from the decrease in the performance of the nominal groups to levels close to those observed in collaborative ones.

Although comparisons between experiments should be cautious (e.g., different participants, different recall methods), in the free-recall task, the recall difference between nominal and collaborative groups and the effect size of the collaborative inhibition were smaller in Experiment 2 (and the confidence interval included zero). This is not surprising given the decrease in the nominal group's recall when using the turn-taking method. These findings suggest that turn-taking can impair memory performance in individual recall (as expected, the collaborative performance was similar in both experiments). This might have been the case because participants cannot immediately recall all the information as they have to delay their recall until the next turn.

Still, as collaborative inhibition was observed even when participants in nominal groups took turns to recall, the results from Experiment 2 support the argument that collaborative inhibition results from the interference caused by the recalled product itself and not from the structure of the recall process. This argument reinforces the disruption of the retrieval strategies hypothesis (Basden et al., 1997) as the explanation for the collaborative inhibition effect.

The number of errors and intrusions observed in both experiments was very low but higher in nominal than in collaborative groups. Previous studies have already compared the production of errors between nominal and collaborative groups using the turn-taking method, obtaining mixed results (e.g., Basden et al., 1998; Saraiva et al., 2017; Thorley & Dewhurst, 2007). However, these studies used the DRM paradigm, so direct comparisons are not recommended. In the present study, the observed difference between conditions may simply result from the fact that nominal groups recall more words than collaborative ones. By remembering more information, participants may be more likely to produce errors. In Experiment 1, the memory task was also

a significant predictor of the number of errors. Again, a greater number of errors in the free recall task may result from the higher recall levels observed (vs. serial recall), which is likely to increase the probability of producing errors.

Most collaborative memory studies have used a between-participants design (e.g., Blumen & Rajaram, 2008; Thorley & Dewhurst, 2007). In our studies, the group manipulation was within participants allowing a more powerful comparison of the collaborative performance with the potential performance (nominal recall) of the same dyads (see Barnier et al., 2018; Ekeocha & Brennan, 2008; Harris et al., 2011; Hinds & Payne, 2016; Saraiva et al., 2016, for a similar procedure). Additionally, this manipulation constitutes a potentially interesting approach to disentangling the role of cognitive and social factors in the emergence of the collaborative inhibition effect. Despite keeping the same participants and the same experimental setting, nominal group recall outperformed collaborative recall (in the free recall task), confirming the little influence of social factors in collaborative inhibition (Weldon et al., 2000; Wright & Klumpp, 2004). The use of a within-participants design yielded a few task order effects. Overall, performance in the second recall task was higher than in the first, suggesting that participants in both groups became more effective when performing a similar task for the second time. However, the observed order effects should be interpreted cautiously since the lower bound of the confidence interval of all significant effects was near the null hypothesis (see SM).

Despite the contributions of the current studies, some issues remain to be addressed. First, the interaction effect observed in Experiment 2 was not significant. While running planned contrasts after a non-significant interaction is still a matter of debate, contrasts are recommended when defined a priori based on scientific goals requiring these comparisons (e.g., Rosenthal & Rosnow, 1985). Moreover, to further strengthen the interpretation of results, we compared changes in effect sizes and ran equivalence tests (Lakens, 2017), confirming that the reported results were reliable. While the non-significant interaction might have resulted from the lower magnitude of the collaborative inhibition effect observed in free recall (likely due to the turn-taking procedure introduced for nominal groups), future studies replicating these findings with larger samples might be warranted. Second, we suggest that future studies include a post-collaborative individual memory task. This task will allow testing the role of alternative mechanisms for the collaborative inhibition effect, such as retrieval inhibition (see Barber et al., 2014). Third, in our experiments, encoding instructions were slightly different between free and serial recall (read the stimuli to recall later vs. read the stimuli to recall in the same order). This difference leaves the question of whether the results observed in serial conditions were due to recall manipulation or encoding instructions. However, previous studies have already shown that the encoding

strategies for free and serial recall are very similar even when participants are made aware of the type of memory task they will be subsequently asked to perform (Bhatarah et al., 2008). This suggests that the observed difference between the two tasks derives from participants' recall strategy.

Moreover, we did not ask participants which recall strategies did they use. Even in the serial recall task, participants may use different strategies to recall the same information in the same order (e.g., mnemonic). Future studies may try to access these retrieval strategies. Finally, it would be interesting to test other constraint variations of the recall method (e.g., cued recall) to further test the disruption of retrieval strategies hypothesis.

In conclusion, the results observed in the two experiments manipulating the recall task and the recall method can be explained by the disruption of retrieval strategies account, thus providing additional support for this theoretical explanation of the collaborative inhibition effect. Providing further empirical evidence for the collaborative inhibition effect is relevant from a replicability perspective. Notably, showing that this effect is sensitive to different experimental manipulations contributes to theoretical advances in collaborative memory research.

References

Abel, M., & Bäuml, K.-H. T. (2017). Collaborative remembering revisited: Study context access modulates collaborative inhibition and later benefits for individual memory. *Memory & Cognition*, *45*(8), 1319–1334. https://doi.org/10.3758/s13421-017-0737-9

Andersson, J. (2001). Net effect of memory collaboration: How is collaboration affected by factors such as friendship, gender and age? *Scandinavian Journal of Psychology*, *42*(4), 367–375. https://doi.org/10.1111/1467-9450.00248

Andersson, J., Hitch, G., & Meudell, P. (2006). Effects of the timing and identity of retrieval cues in individual recall: An attempt to mimic cross-cueing in collaborative recall. *Memory*, *14*(1), 94–103. https://doi.org/10.1080/09658210444000557

Andersson, J., & Rönnberg, J. (1996). Collaboration and memory: Effects of dyadic retrieval on different memory tasks. *Applied Cognitive Psychology*, *10*(2), 171–181. https://doi.org/10.1002/(SICI)1099-0720(199604)10:2<171::AID-ACP385>3.0.CO;2-D

Barber, S. J., Harris, C. B., & Rajaram, S. (2014). Why two heads apart are better than two heads together: Multiple mechanisms underlie the collaborative inhibition effect in memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *41*, 559–566. https://doi.org/10.1037/xlm0000037

Barber, S. J., & Rajaram, S. (2011). Exploring the relationship between retrieval disruption from collaboration and recall. *Memory*, *19*(5), 462–469. https://doi.org/10.1080/09658211.2011.584389

Barber, S. J., Rajaram, S., & Aron, A. (2010). When two is too many: Collaborative encoding impairs memory. *Memory & Cognition*, *38*(3), 255–264. https://doi.org/10.3758/MC.38.3.255

Barber, S. J., Rajaram, S., & Fox, E. B. (2012). Learning and remembering with others: the key role of retrieval in shaping group recall and collective memory. *Social Cognition*, *30*(1), 121–132. https://doi.org/10.1521/soco.2012.30.1.121

Barnier, A. J., Harris, C. B., Morris, T., & Savage, G. (2018). Collaborative facilitation in older couples: Successful joint remembering across memory tasks. *Frontiers in Psychology*, *9*, 2385. https://doi.org/10.3389/fpsyg.2018.02385

Basden, B. H., Basden, D. R., Bryner, S., & Thomas III, R. L. (1997). A comparison of group and individual remembering: Does collaboration disrupt retrieval strategies? *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *23*(5), 1176–1191. https://doi.org/10.1037/0278-7393.23.5.1176

Basden, B. H., Basden, D. R., & Henry, S. (2000). Costs and benefits of collaborative remembering. *Applied Cognitive Psychology*, *14*(6), 497–507. https://doi.org/10.1002/1099-0720(200011/12)14:6<497::AID-ACP665>3.0.CO;2-4

Basden, B., Basden, D., Thomas III, R., & Souphasith, S. (1998). Memory distortion in group recall. *Current Psychology: Developmental, Learning, Personality, Social*, *16*, 225-246. d https://doi.org/10.1007/s12144-997-1001-4

Bhatarah, P., Ward, G., & Tan, L. (2006). Examining the relationship between free recall and immediate serial recall: The effect of concurrent task performance. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *32*(1), 215–229. https://doi.org/10.1037/0278-7393.32.2.215

Bhatarah, P., Ward, G. & Tan, L. (2008). Examining the relationship between free recall and immediate serial recall: The serial nature of recall and the effect of test expectancy. *Memory & Cognition*, *36*, 20–34. https://doi.org/10.3758/MC.36.1.20

Blumen, H. M., & Rajaram, S. (2008). Influence of re-exposure and retrieval disruption during group collaboration on later individual recall. *Memory*, *16*(3), 231–244. https://doi.org/10.1080/09658210701804495

Blumen, H. M., Young, K. E., & Rajaram, S. (2014). Optimizing group collaboration to improve later retention. *Journal of Applied Research in Memory and Cognition*, *3*(4), 244–251. https://doi.org/10.1016/j.jarmac.2014.05.002

Bruder, G. A. (1970). Analysis of differences between free and serial recall. *Journal of Experimental Psychology*, *83*(2), 232–237.

Diehl, M., & Stroebe, W. (1987). Productivity loss in brainstorming groups: Toward the solution of a riddle. *Journal of Personality and Social Psychology*, *53*(3), 497–509. https://doi.org/10.1037/0022-3514.53.3.497

Drewnowski, A., & Murdock, B. B. (1980). The role of auditory features in memory span for words. *Journal of Experimental Psychology: Human Learning and Memory*, *6*(3), 319–332. https://doi.org/10.1037/0278-7393.6.3.319

Ekeocha, J. O., & Brennan, S. E. (2008). Collaborative recall in face-to-face and electronic groups. *Memory*, *16*(3), 245–261. https://doi.org/10.1080/09658210701807480

Finlay, F., Hitch, G. J., & Meudell, P. R. (2000). Mutual inhibition in collaborative recall: Evidence for a retrieval-based account. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *26*(6), 1556–1567. https://doi.org/10.1037//0278-7393.26.6.1556

Garcia-Marques, L., Garrido, M. V., Hamilton, D. L., & Ferreira, M. B. (2012). Effects of correspondence between encoding and retrieval organization in social memory. *Journal of Experimental Social Psychology*, *48*(1), 200–206. https://doi.org/10.1016/j.jesp.2011.06.017

Garrido, M. V., Garcia-Marques, L., & Hamilton, D. L. (2012a). Enhancing the comparability between part-list cueing and collaborative recall: A gradual part-list cueing paradigm. *Experimental Psychology*, *59*(4), 199–205. https://doi.org/10.1027/1618-3169/a000144

Garrido, M. V., Garcia-Marques, L., & Hamilton, D. L. (2012b). Hard to recall but easy to judge: Retrieval strategies in social information processing. *Social Cognition*, *30*(1), 56–70. https://doi.org/10.1521/soco.2012.30.1.56

Grenfell-Essam, R., & Ward, G. (2012). Examining the relationship between free recall and immediate serial recall: The role of list length, strategy use, and test expectancy. *Journal of Memory and Language*, *67*(1), 106–148. https://doi.org/10.1016/j.jml.2012.04.004

Harris, C. B., Barnier, A. J., & Sutton, J. (2013). Shared encoding and the costs and benefits of collaborative recall. *Journal of Experimental Psychology. Learning, Memory, and Cognition*, *39*(1), 183–195. https://doi.org/10.1037/a0028906

Harris, C. B., Keil, P. G., Sutton, J., Barnier, A. J., & McIlwain, D. J. F. (2011). We remember, we forget: Collaborative remembering in older couples. *Discourse Processes*, *48*(4), 267–303. https://doi.org/10.1080/0163853X.2010.541854

Hinds, J. M., & Payne, S. J. (2016). Collaborative inhibition and semantic recall: Improving collaboration through computer-mediated communication. *Applied Cognitive Psychology*, *30*(4), 554–565. https://doi.org/10.1002/acp.3228

Hinsz, V. B., Tindale, R. S., & Vollrath, D. A. (1997). The emerging conceptualization of groups as information processors. *Psychological Bulletin*, *121*(1), 43–64. https://doi.org/10.1037/0033-2909.121.1.43

Kelley, M. R., Pentz, C., & Reysen, M. B. (2014). The joint influence of collaboration and part-set cueing. *The Quarterly Journal of Experimental Psychology*, *67*(10), 1977–1985. https://doi.org/10.1080/17470218.2014.881405

Lakens, D. (2017). Equivalence Tests: A Practical Primer for t Tests, Correlations, and Meta-Analyses. *Social Psychological and Personality Science*, *8*(4), 355–362. https://doi.org/10.1177/1948550617697177

Larson, J. R., & Christensen, C. (1993). Groups as problem-solving units: Toward a new meaning of social cognition. *British Journal of Social Psychology*, *32*(1), 5–30.

Maki, R. H., Weigold, A., & Arellano, A. (2008). False memory for associated word lists in individuals and collaborating groups. *Memory & Cognition*, *36*, 598–603. https://doi.org/10.3758/MC.36.3.598

Marion, S. B., & Thorley, C. (2016). A meta-analytic review of collaborative inhibition and postcollaborative memory: Testing the predictions of the retrieval strategy disruption hypothesis. *Psychological Bulletin*, *142*(11), 1141–1164. https://doi.org/10.1037/bul0000071

Marques, J. F. (2005). Normas de imagética e concreteza para substantivos comuns. *Laboratório de Psicologia*, *3*(1), 65–75. https://doi.org/10.14417/lp.784

Maswood, R., & Rajaram, S. (2019). Social transmission of false memory in small groups and large networks. *Topics in Cognitive Science*, *11*(4), 687-709. https://doi.org/10.1111/tops.12348

Meade, M. L., Nokes, T. J., & Morrow, D. G. (2009). Expertise promotes facilitation on a collaborative memory task. *Memory*, *17*(1), 39–48. https://doi.org/10.1080/09658210802524240

Rajaram, S., & Maswood, R. (2017). Collaborative memory: A selective review of data and theory. In J. H. Byrne (Ed.), *Learning and memory: A comprehensive reference* (2nd ed.). Elsevier. https://doi.org/10.1016/B978-0-12-809324-5.21050-X

Rajaram, S., & Pereira-Pasarin, L. P. (2010). Collaborative memory: Cognitive research and theory. *Perspectives on Psychological Science: A Journal of the Association for Psychological Science*, *5*(6), 649–663. https://doi.org/10.1177/1745691610388763

Rosenthal, R., & Rosnow, R. L. (1985). *Contrast analysis: Focused comparisons in the analysis of variance*. Cambridge University Press.

Rossi-Arnaud, C., Cestari, V., Rezende Silva Marques, V., Gabrielli, G., & Spataro, P. (2017). Collaboration in implicit memory: evidence from word-fragment completion and category exemplar generation. *Psychological Research*, *81*, 55–65. https://doi.org/10.1007/s00426-015-0725-2

Saraiva, M., Albuquerque, P. B., & Arantes, J. (2016). Elimination of collaborative inhibition effect using theMethod of Loci. *Psicothema*, *28*(2), 181–186. https://doi.org/10.7334/psicothema2015.241

Saraiva, M., Albuquerque, P. B., & Arantes, J. (2017). Production of false memories in collaborative memory tasks using the DRM paradigm. *Psicológica*, *38*, 209-229.

Saraiva, M., Garrido, M. V., & Albuquerque, P. B. (2021). Emergence and transmission of misinformation in the context of social interactions. *Memory & Cognition*, *49*(1), 1–13. https://doi.org/10.3758/s13421-020-01081-x

Takahashi, M., & Saito, S. (2004). Does test delay eliminate collaborative inhibition? *Memory*, *12*(6), 722–731. https://doi.org/10.1080/09658210344000521

Thomas, J. G., Milner, H. R., & Haberlandt, K. F. (2003). Forward and backward recall: Different response time patterns, same retrieval order. *Psychological Science*, *14*(2), 169–174. https://doi.org/10.1111/1467-9280.01437

Thorley, C., & Dewhurst, S. A. (2007). Collaborative false recall in the DRM procedure: Effects of group size and group pressure. *European Journal of Cognitive Psychology*, *19*(6), 867–881. https://doi.org/10.1080/09541440600872068

Ward, G., Tan, L., & Grenfell-Essam, R. (2010). Examining the relationship between free recall and immediate serial recall: The effects of list length and output order. *Journal of Experimental Psychology. Learning, Memory, and Cognition*, *36*(5), 1207–1241. https://doi.org/10.1037/a0020122

Weldon, M. S., & Bellinger, K. D. (1997). Collective memory: Collaborative and individual processes in remembering. *Journal of Experimental Psychology. Learning, Memory, and Cognition*, *23*(5), 1160–1175. https://doi.org/10.1037/0278-7393.23.5.1160

Weldon, M. S., Blair, C., & Huebsch, P. D. (2000). Group remembering: Does social loafing underlie collaborative inhibition? *Journal of Experimental Psychology. Learning, Memory, and Cognition*, *26*(6), 1568–1577. https://doi.org/10.1037//0278-7393.26.6.1568

Wright, D. B., & Klumpp, A. (2004). Collaborative inhibition is due to the product, not the process, of recalling in groups. *Psychonomic Bulletin & Review*, *11*(6), 1080–1083. https://doi.org/10.3758/BF03196740

Yuker, H. E. (1955). Group atmosphere and memory. *The Journal of Abnormal and Social Psychology*, *51*, 17–23. https://doi.org/10.1037/h0046464

Appendix. List of words presented in both experiments

Set A

Word	Imagery	Concreteness	Frequency
Screen	4.92	6.30	1.71
Hammer	6.50	6.80	5.75
Banana	6.69	6.80	5.97
Axe	6.19	6.74	7.18
Blade	5.90	6.64	4.45
Lock	5.96	6.58	2.15
Panic	3.23	2.20	16.09
Attic	5.46	6.12	2.60
Toaster	6.42	6.82	0.29
Mailer	6.42	6.58	5.21
Demon	3.73	2.54	6.09
Suitcase	6.08	6.66	14.10
Pliers	6.06	6.62	0.54
Sofa	6.56	6.62	5.80
Nun	5.98	5.64	5.65
Nose	6.52	6.58	13.18
Slave	5.02	4.76	11.76
Ark	5.85	6.46	3.21
Scissors	6.54	6.76	2.30
Crow	6.21	6.72	4.28
Sled	6.08	6.60	0.99
Carrot	6.56	6.86	3.25
Arc	5.65	5.86	16.11
Blouse	6.38	6.56	1.63
Carpet	6.25	6.58	10.59
Stamps	6.33	6.54	12.82
Brush	6.37	6.62	2.27
Hairbrush	6.19	6.56	1.50
Onion	6.44	6.78	6.76
Judge	5.62	5.28	0.07
Mean	**5.94**	**6.17**	**5.81**

Set B

Word	Imagery	Concreteness	Frequency
Goat	6.46	6.70	5.66
Tomato	6.73	6.76	9.60
Ice	5.96	6.08	13.10
Shell	5.38	6.16	4.20
Lamp	6.42	6.56	5.79
Yacht	5.73	6.46	11.61
Comb	6.58	6.74	3.04
Barrel	6.08	6.66	9.87
Vase	6.29	6.66	6.47
Watering can	6.23	6.62	0.21
Prayer	3.15	2.54	12.27
Scooter	5.96	6.58	0.04
Back	5.38	6.06	5.05
Train	6.62	6.58	0.00
Noise	3.33	4.14	15.01
Rocket	5.92	6.44	8.71
Bookcase	6.04	6.58	1.51
Pineapple	6.48	6.78	1.15
Pen	6.81	6.68	5.50
Asparagus	5.23	6.50	0.83
Cup	6.17	6.76	2.45
Devil	4.54	2.10	13.74
Fire	6.21	5.88	12.00
Brain	4.50	5.42	0.21
Wardrobe	6.06	6.54	0.45
Knife	6.58	6.82	12.56
Racket	6.44	6.80	0.38
Basket	6.12	6.56	7.27
Highchair	6.13	6.24	1.23
Motorized	6.10	6.58	3.84
Mean	**5.85**	**6.13**	**5.79**