Chapter 4

Collaborative Inhibition in Group Recall: Cognitive Principles and Implications

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Until the 1990s, cognitive research on memory focused largely on the individual and thrived on paradigms inspired by the Ebbinghausian tradition. For about a century until then (Ebbinghaus, 1885), group memory was studied largely within the domains of sociology, social psychology, and anthropology (e.g., Halbwachs, 1950/1980; Wegner, 1987; Wertsch, 2002) whereas in cognitive psychology experiments, group influences were typically considered as factors to be controlled rather than studied (Gardner, 1985). In this highly controlled approach, Ebbinghaus even used nonsense syllables as study materials on the grounds that word meaning can bring about idiosyncratic variations across study participants and cloud conclusions regarding mechanisms that govern learning and remembering in the most fundamental forms. Experimental study of memory blossomed under this approach and led to a rich set of robust findings and enduring theories. These historical developments provided the platform for much of the laboratory research on collaborative memory, and it is in this context the present chapter reviews a major phenomenon to come out of laboratory research in the last two decades, namely collaborative inhibition in memory.

It is a commonly held belief that collaboration improves memory (Dixon, Gagnon, & Crow, 1998; Henkel & Rajaram, 2011). The collaborative inhibition phenomenon in group recall comes as a surprise in the context of this belief. Collaborative inhibition in memory refers to the counterintuitive finding that when an interacting—or collaborative—group jointly recalls information that all group members had studied earlier, this recall product is significantly less than the sum of nonredundant items that a "nominal group," that is, an equal number of individuals working alone, would recall. The procedure for testing and computing the collaborative inhibition effect is described in detail later, but suffice to say that when a series of experiments in the 1990s established this phenomenon strikingly and decisively (Andersson & Rönnberg, 1995, 1996; B. H. Basden, Basden, Bryner, & Thomas, 1997; Meudell, Hitch, & Boyle, 1995; Meudell, Hitch, & Kirby, 1992; Weldon & Bellinger, 1997; see Weldon, 2001, for a review; see also Blumen; Henkel & Kris, Chapters 8 and 24), these seminal findings set off an entire new field of investigation in memory research. This chapter presents a selective overview of this work. This review focuses largely on laboratory findings on the phenomenon of collaborative inhibition and it is not intended to be exhaustive. Instead, the goal is to familiarize the reader with selective evidence from our work and those of other groups to characterize the nature of the collaborative inhibition effect, to identify the conditions that promote or reduce this effect, to explore its occurrence across different group structures, and to point out some of its consequences on memory after the collaboration experience.

It is also useful to note at the outset that the collaborative inhibition effect is one among several important phenomena to have emerged in the study of social memory in the last two decades, as the topics of the chapters in this book illustrate. It is also one among several phenomena that our group has explored in our own research on social memory. This chapter focuses on this phenomenon to highlight at least two reasons for its importance[1]. Collaborative inhibition represents a counterintuitive yet robust effect in group memory. This effect is also related to several post-collaborative changes in memory, both at the individual and collective levels. This chapter covers a selection of findings from our group about these post-collaboration effects as well to illustrate how collaborative inhibition during group recall influences post-collaborative memory afterwards, both to reshape individual memory as well as to give rise to collective memory.

The Collaborative Inhibition Effect

Computing Collaborative Memory

The experimental procedure used in laboratory paradigms typically goes as follows: at study, participants carry out some sort of an encoding task to learn the materials for which their memory is later tested. For example, participants may be asked to make pleasantness judgments (i.e., how pleasant do you find this item on a scale from 1 to 5?). Typically, participants perform the encoding task individually so that the effects of collaboration on recall can be isolated to the retrieval phase when they work together. Group memory for these studied materials is computed by comparing the recall of interacting or collaborative groups with the recall of nominal groups, or groups in name only. Nominal groups consist of an equal number of individuals that are the designated group members who do not interact with one another during recall.

For example, participants may study a list of items such as A, B, C, D, E, F, G, H, I. After a distractor period that has varied from five minutes to one week across published studies, participants recall the studied information either working alone or in collaborating groups. The time given to complete recall varies somewhat across studies but within a study it is usually equated across the collaborative and nominal conditions. In the experiments in our lab, participants (in both group conditions) typically get 7 or 10 minutes to recall but they complete the task before this time period elapses, regardless of whether they work alone or together. For collaborative groups, participants are asked to collaborate to recall all the items they studied earlier. These collaborative groups typically consist of three members or a triad, but the size of this group can vary from two (dyad) to four (tetrad). Care is taken to ensure that all members of a group are either strangers or all of them know one another in a specific way (e.g., as friends or spouses, depending on the goals of the experiment). In this way, the level of familiarity among the group members is controlled, or systematically manipulated. Collaborative recall by such groups is the number of

[1] It is useful to clarify that this chapter focuses on collaboration at the time of retrieval rather than collaboration at the encoding stage. This is because the collaborative inhibition effect is associated with a group recalling rather than learning. Briefly with regard to collaborative encoding, a modest number of laboratory studies have examined this effect on later memory, and the findings are mixed (e.g, Andersson & Rönnberg, 1995; Barber, Rajaram, & Aron, 2010; Barber, Rajaram, & Fox, 2012; Barber, Rajaram, & Paneerselvam, 2012; Finlay, Hitch, & Meudell, 2000; Garcia-Marques, Garrido, Hamilton, & Ferreira, 2012; Harris, Barnier, & Sutton, 2013). Across these studies, collaborative encoding has been shown to impair, improve, or leave unaffected later retrieval when compared to individual encoding. The precise reasons for these differences are yet to be worked out as the procedures, materials, or type of participants have varied across studies. Further, in a study where we directly compared collaborative encoding with collaborative retrieval under identical experimental conditions and with a free recall task at retrieval (Barber, Rajaram, & Paneerselvam, 2012), collaboration at recall produced greater memory deficit than collaboration at encoding. This outcome is consistent with a greater focus of the field, in these early years of investigation, on the collaborative inhibition effect arising at retrieval.

correct items produced by members working together within each group to recall the information they had studied earlier. This recall is predictably greater than that of any one individual (Yuker, 1955). But to assess group performance, the recall of collaborative groups is compared to nominal groups that serve as a control. Nominal group recall is computed by pooling together the recall of individual participants in a nonredundant fashion, counting overlapping items only once. For example, if Participant 1 recalls items A, B, C, Participant 2 recalls A, D, E, and Participant 3 recalls A, E, F, G, the nominal group recall is seven items: A, B, C, D, E, F, G. This comparison between collaborative and nominal groups reveals the counterintuitive outcome of collaborative inhibition—collaborative groups recall significantly less studied information than do nominal groups (Weldon & Bellinger, 1997). This memory deficit is similar to brainstorming research showing that generation of novel ideas is reduced in collaborative groups (Brown & Paulus, 2002; Diehl & Stroebe, 1987; Paulus, 2000).

The Collaborative Inhibition Effect in Recall is Both Counterintuitive and Robust

People commonly believe that two heads are better than one, and this is certainly true in memory experiments. Collaborating groups, whether large in number or consisting of only dyads, recall previously encountered experiences more, and more accurately, than a single individual would. However, when the recall products of equal-sized groups are considered, working together is less productive than working as individuals. That is to say, two heads working together are not better than two heads working apart. This cost of collaboration flies in the face of the intuitive idea that collaboration facilitates recall through group members cross-cueing each other's memories. Cross-cueing refers to the ideas that items recalled by one member of the group can serve as cues to trigger recall of items that another group member would not otherwise recall. Cross-cueing ought to then increase the overall levels of collaborative recall in groups and produce collaborative facilitation rather than collaborative inhibition, or at least cross-cueing ought to eliminate collaborative inhibition. The potential operation of cross-cueing is discussed later in the chapter; briefly, this effect has been difficult to capture in laboratory studies despite its intuitive appeal (Meudell *et al.*, 1992; Meudell *et al.*, 1995).

The collaborative inhibition effect is also highly robust. Since the time Weldon and Bellinger (1997) and B. H. Basden *et al.* (1997) published their seminal studies, dozens of articles have reported the collaborative inhibition effect and done so under a variety of experimental conditions. It occurs routinely in the free recall tasks where participants receive no test cues and simply recall all studied items in any order (the outcome for cued recall and recognition tasks is discussed later). Collaborative inhibition occurs for a variety of study materials including unrelated words (e.g., Blumen & Rajaram, 2008; Weldon & Bellinger, 1997), related (categorized) words (Basden, B. H., *et al.*, 1997; Congleton & Rajaram, 2011; Pereira-Pasarin & Rajaram, 2011), related words that produce high false alarm rates (DRM lists, Deese, 1959; Roediger & McDermott, 1995; see Basden, B. H., Reysen, & Basden, 2002; Wright & Klumpp, 2004), stories (Weldon & Bellinger, 1997), materials that convey negative valence (Yaron-Antar & Nachson, 2006; Wessel, Zandstra, Hengeveld, & Moulds, 2015), socially relevant materials that lead to general improvement in recall (Kelley, Reysen, Ahlstrand, & Pentz, 2012) including powerful social materials such as gossip (Reysen, Talbert, Dominko, Jones, & Kelley, 2011), and personal narratives (Coman, Manier, & Hirst, 2009; Cuc, Ozuru, Manier, & Hirst, 2006).

Collaborative inhibition occurs regardless of the type of collaboration instructions participants are asked to follow. Three types of collaboration instructions have been commonly used in collaborative recall studies: turn-taking (e.g., B. H. Basden *et al.*, 1997), free for all (e.g., Weldon

& Bellinger, 1997), and consensus (Meudell, *et al.*, 1995; Ross, Spencer, Linardatos, Lam, & Perunovic, 2004). In turn-taking, as the name implies group members recall one item each by taking turns until as a group they exhaust all the items they can recall. With free-for-all instructions, group members can go in any order to recall information as they remember. In consensus reaching, all group members are required to agree on each item before it is included as a part of the group recall product. While the magnitude of intrusions—items not presented during study but erroneously included in the group recall product—decreases in order across these three types of collaboration, respectively (Harris, Barnier, & Sutton, 2012; Thorley & Dewhurst, 2007), the collaborative inhibition effect remains robust regardless of the type of collaboration. The persistence of collaborative inhibition in recall across all instruction types is striking because collaboration is expected to confer memory benefits through error pruning (Rajaram & Pereira-Pasarin, 2010; Rajaram, 2011). The process of error pruning involves group members correcting one another's intrusions. Despite this benefit, collaboration nonetheless reduces the overall magnitude of group recall. For instance, the free-for-all collaboration method consistently lowers intrusions in collaborative group recall compared to nominal group recall (Blumen & Rajaram, 2008, 2009; Finlay *et al.*, 2000, Experiments 2 and 3; Hyman, Cardwell, & Roy, 2013; Johansson, Andersson, & Rönnberg, 2000; Johansson, Andersson, & Rönnberg, 2005; Pereira-Pasarin & Rajaram 2011; Takahashi & Saito, 2004; Weldon & Bellinger, 1997; Yaron-Antar & Nachson, 2006). Yet, even after the total amount of recall is corrected for intrusions across collaborative and nominal group recall conditions, the collaborative inhibition effect remains robust (Congleton & Rajaram 2011).

The collaborative inhibition effect occurs across the age span. It has been observed in laboratory studies not only for young adults who are the typical participants in such experiments, but also for older adults (Johansson *et al.*, 2000; 2005; Ross *et al.*, 2004; see Blumen, Rajaram, & Henkel, 2013). Not only do older adults exhibit the collaborative inhibition effect, they display a comparable magnitude of this effect with young adults (Henkel & Rajaram, 2011; Meade & Roediger, 2009; Ross, Spencer, Blatz, & Restorick, 2008). Extending the generality of this phenomenon, studies have also reported the collaborative inhibition effect in children for collaborating dyads aged seven, nine, and 15 years (Andersson, 2001; Leman & Oldham, 2005).

The cost of recalling in groups does diminish, disappear, and even reverse under well-specified conditions, as elaborated later in this chapter. But under standard conditions of experimentation, this deficit occurs readily and widely. The robustness of this cost in group recall, and its malleability under the well-defined conditions described later, tell us that collaborative remembering changes something fundamentally important in the processes that guide and shape memory.

Why Does Collaborative Inhibition Occur?

An obvious explanation for the collaborative inhibition effect is the diffusion of responsibility that arises through social loafing (Latane, Williams, & Harkins, 1979). That is, when more than one individual is responsible for carrying out the same task, each relies on the other to contribute, and consequently contributes less than her own potential. But studies show that reduced motivation or diffusion of responsibility does not explain this deficit (Weldon, Blair, & Huebsch, 2000). Instead, the evidence so far suggests that collaborative inhibition is largely cognitive in nature. Two distinct cognitive mechanisms are implicated in producing the collaborative inhibition effect—retrieval disruption and retrieval inhibition (Barber, Harris, & Rajaram, 2015; Basden, B. H., *et al.*, 1997).

The retrieval disruption account. In considering the underlying mechanisms, B. H. Basden *et al.* (1997) proposed the role of retrieval disruption (also sometimes called retrieval strategy disruption) and its influence is now widely established through experimental studies. According to this hypothesis, when individual participants study the to-be-recalled materials (e.g., word lists), each individual develops an idiosyncratic organization of the studied materials which varies from individual to individual. This idiosyncrasy develops because each individual has a relatively unique learning history and preferences and thus encodes and organizes the input within the framework of this cognitive history (see Rajaram & Pereira-Pasarin, 2010, Figure 1). Later, when group members collaborate to recall, one member's recall output interferes with the idiosyncratic organization that the other members bring to the collaborative session during their own process of remembering. This process of disruption lowers each member's recall and produces collaborative inhibition. B. H. Basden *et al.* (1997) noted that this mechanism is similar to yet another counterintuitive effect and one that occurs in individual recall—the part-set cuing effect (D. R. Basden & Basden, 1995; D. R. Basden & Basden, & Galloway, 1977; Roediger & Neely, 1982; Slamecka, 1968; but also see Kelley, Pentz, & Reysen, 2014). In this phenomenon, participants produce fewer studied items during recall if the experimenter provides them with a subset of studied items than in the absence of any studied item. That is, the subset of presented items reduces the probability of recalling the remaining items, instead of functioning as retrieval cues that can promote the probability of recall. Like part-set cues in individual recall, during collaboration one group member's recall serves to disrupt and reduce another group member's recall (and vice versa) and thereby reduce the group's total recall.

Several lines of evidence support the retrieval disruption hypothesis. One line of evidence comes from the presence or absence of this effect depending on the demands of the memory task. Collaborative inhibition is observed most consistently when the memory task heavily relies on the participant's idiosyncratic organization of studied information such as in free recall tasks. This effect is reduced, eliminated, or even reversed when the task provides retrieval cues, for example cued recall and recognition tasks, where participants cannot rely on their own retrieval organization even when performing these memory tasks alone because their retrieval is guided by the retrieval cues (Barber *et al.*, 2010; Clark, Hori, Putnam, & Martin, 2000; Finlay *et al.*, 2000; Meade & Roediger, 2009).

Another line of evidence comes from increases in the magnitude of the collaborative inhibition effect as the collaborating groups increase in size. As group size increases, there are more members to disrupt one another's recall and the retrieval disruption hypothesis predicts an increase in collaborative inhibition under these conditions. Experimental evidence on group size is limited but is consistent with this prediction such that collaborative inhibition is less reliable in dyads, reliably reported in triads, and increases from dyads to triads to tetrads (B. H. Basden, Basden, & Henry, 2000; Thorley & Dewhurst, 2007). Naturalistic social contexts not only include dyads, triads, and tetrads, but also much larger groups both in one's social and work environments and beyond, as in larger networks in communities. These increasingly large group sizes are not feasible to test in the laboratory, especially using controlled conditions. But we have successfully simulated group sizes of dyads to 128 people using agent-based modeling. Collaboration inhibition continued to increase with group size of dyads to group size of seven and then began to decline (Luhmann & Rajaram, 2015). Notably, nominal group recall reached its ceiling earlier than collaborative group recall. Nonetheless, the collaborative inhibition effect persisted in groups larger than seven, indicating the robustness of this effect, even though the potential for contribution during collaboration increased.

The retrieval inhibition account. Evidence for the role of retrieval disruption has rapidly grown since B. H. Basden *et al.* (1997) published their theoretical account, as the findings covered in "The role of retrieval organization in recall" also show. Nonetheless, some findings have been inconsistent with this account (e.g., Barber & Rajaram, 2011; Meade & Gigone, 2011), indicating the role of retrieval blocking or retrieval inhibition (Bäuml, 2008). For instance, collaborative inhibition has now been reported in recognition (Danielsson, Dahlström, & Andersson, 2011) and in cued recall (Kelley, *et al.*, 2012; Meade & Roediger, 2009), outcomes that are inconsistent with the retrieval disruption account. As described earlier, unlike the free recall task these memory tasks constrain or even eliminate reliance on individual organization of information because participants in both group and individual recall conditions are presented with specific (and the same) cues to guide recall. As such, no collaborative inhibition should occur if retrieval disruption is the only mechanism that underlies this effect. Although early evidence supported this rationale for recognition or cued recall (Barber *et al.*, 2010; Thorley & Dewhurst, 2009; Finlay *et al.*, 2000), more recent findings have been problematic. Similarly, although several studies have shown that when encoding and retrieval strategies align, collaborative inhibition reduces in line with the retrieval disruption hypothesis (Barber, Rajaram, & Fox, 2012; Finlay *et al.*, 2000; Garcia-Marques *et al.*, 2012; Harris *et al.*, 2013), other studies have failed to observe this pattern (Barber & Rajaram, 2011; Dahlström, Danielsson, Emilsson, & Andersson, 2011).

The prevalent account of retrieval disruption can be compared to part-set cueing effects in individual recall. Interestingly, in explaining the part-set cueing effect, memory disruption is only one possible basis. While some have argued that part-set cues disrupt organizational strategies in recall (D. R. Basden & Basden, 1995), in which case these items can be recalled later, another possibility is that part-set cues block the nonrecalled items (Rundus, 1973; Bäuml, 2008) during collaboration in which case although these items cannot be recalled later, they can be nonetheless recognized. Yet others have argued that the part-set cues strengthen memory due to their presence and this process inhibits the nonrecalled items to make them unavailable (Anderson, Bjork, & Bjork, 1994; Bäuml, 2008; Bäuml & Aslan, 2004, 2006). If this is the case, then these items could be neither recalled nor recognized later. Evidence for forgetting through slowed reaction time measures (Cuc, Koppel, & Hirst, 2007) and post-collaborative forgetting (Blumen & Rajaram 2008; Congleton & Rajaram 2011) support this possibility but none of these studies sought to test the contributions of disruption, blocking, and inhibition in recall accuracy. We compared these three accounts to examine the basis of collaborative inhibition by first presenting groups members with completely nonoverlapping lists to study individually, then asking them to collaborate together to recall their respective lists, and finally asking them to perform an individual test of either free recall (Experiment 1) or recognition (Experiment 2) (Barber *et al.*, 2015).

The nonoverlapping study lists across group members ensured that if participants forgot some study items during collaboration they would not be exposed to them via another member's recall. Thus, if a nonrecalled item was recalled on a later individual test, this outcome would support release from disruption and support the retrieval disruption account. If an item not recalled during collaboration was not recalled later but was recognized on the later individual test, it would support the idea that the item was blocked earlier. If an item not recalled during collaboration was neither recalled nor recognized on the later individual test, it would indicate that retrieval inhibition also operates during collaborative recall. Findings showed that participants were impaired on final individual recall and recognition tasks in the collaboration condition compared to the nominal condition, supporting the retrieval inhibition account. At the same time, participants recalled significantly more on the final individual recall test than during collaborative recall, indicating a partial release from collaboration inhibition. This finding supports the retrieval disruption account. Together, these experiments show that collaborative inhibition results from both disruption and inhibition of memories.

Reducing, Eliminating, or Reversing Collaborative Inhibition in Group Recall

Our understanding about the role of retrieval inhibition is recent. But the link between retrieval disruption and collaborative inhibition has already received considerable empirical scrutiny. In addition to showing how retrieval disruption leads to collaborative inhibition, this link also shows how reducing or eliminating disruption can lead to concomitant changes in the magnitude of collaborative inhibition in group recall. A selection of these studies is discussed next.

The role of retrieval organization in recall. People show a propensity to cluster information during recall into some type of higher order units (Gates, 1917). This process where people cluster information during recall according to some strategy is called retrieval organization. For example, if the studied information consists of exemplars from various taxonomic categories (animal names, types of profession), people tend to recall related exemplars in clusters (Bousfield, 1953). While such clustering reflects broadly shared understanding of related information, people also bring their unique past experiences and learning histories when they encode and recall study information. As such, retrieval organization also reflects some extent of internally driven, idiosyncratic organization, also called subjective organization (Gates, 1917; Tulving, 1962). For instance, study information that generally lacks external organization (e.g., unrelated words) is likely to increase such idiosyncratic use of retrieval organization.

The manner in which an individual organizes studied information during recall is central to understanding how retrieval disruption affects group recall. As noted earlier, retrieval disruption refers to the process where the order in which one group member recalls studied information disrupts the order in which another group member might organize her recall output. Such divergence in the retrieval organization across group members disrupts each member's ability to recall to his/her maximum potential.

Disruption to one's retrieval organization may be reduced in different ways. One approach involves aligning retrieval organization across group members. Here, given that a mismatch in the idiosyncratic retrieval organization across group members lowers group recall, an increase in the match across their respective retrieval organizations should improve group recall. B. H. Basden *et al.* (1997) showed exactly this pattern; when participants studied a small number of exemplars from each category, which can be organized more similarly compared to when they studied a large number of exemplars, collaborative inhibition reduced or disappeared. Collaborative inhibition also disappears when participants are required to encode the study items in the same order, thereby imposing a similar organization (Finlay *et al.*, 2000). Similarly, collaborative inhibition reduced in a context of impression formation when the encoding recall organizations were aligned for participants (Garcia-Marques *et al.*, 2012).

Aligning retrieval organization across group members is one way to reduce retrieval disruption and consequently collaborative inhibition. In this approach, the experimenter determines the manner in which retrieval would be organized. Another approach tested in the literature allows the learner, that is, the participant, to develop her own retrieval organization but do so in a manner that it is not susceptible to disruption during collaborative recall. We have referred to this approach as the *influence of learning methods* (Congleton & Rajaram, 2011). Consistent with the retrieval disruption hypothesis, collaborative inhibition in group recall increases when study materials are not well organized, because such information requires the learner to impose greater idiosyncratic organization on the material than they would need to do if the presented information was already well organized (Basden, B. H. *et al.*, 1997). This reasoning implies that strengthening the organization of study materials prior to collaboration by implementing specific learning methods should reduce retrieval disruption and, consequently, collaborative inhibition. We observed exactly this outcome when we strengthened the organization by giving participants repeated (in contrast to a single) study opportunities (Pereira-Pasarin & Rajaram, 2011). Classic work, dating back to the 1970s, has shown that repeated study of categorized words increases the magnitude of recall (Cepeda, Vul, Rohrer, Wixted, & Pashler, 2008; Crowder, 1976; Glenberg, 1979; Greene, 1989) and the extent to which recalled information is organized by categories (Roenker, Thompson, & Brown, 1971; Rundus, 1971). We observed both these effects in participants' recall, such that repeated study increased recall and the organization of recalled information in terms of increased clustering of exemplars from categories. Critical for the retrieval disruption hypothesis, this increased organization in recall was associated with lowered collaborative inhibition.

While repeated study opportunities were associated with subsequent reduction in collaboration inhibition, in another study we found that if each group member worked alone to first repeatedly recall the study items, collaborative inhibition disappeared in their later group recall (Congleton & Rajaram, 2011). There is powerful evidence that repeated recall greatly improves both memory and retrieval organization (e.g., Congleton & Rajaram, 2012; Karpicke & Roediger, 2008; Roediger & Karpicke, 2006; Zaromb & Roediger, 2010). In both studies (Congleton & Rajaram, 2011; Pereira-Pasarin & Rajaram, 2011) we computed a measure of clustering in recall to determine the extent to which recall was organized into conceptual units (Roenker *et al.*, 1971). As noted earlier, repeated study increased retrieval organization compared to a single study opportunity (Pereira-Pasarin & Rajaram, 2011) and repeated recall increased retrieval organization further compared to repeated study (Congleton & Rajaram, 2011). These patterns are consistent with the prediction that strengthened retrieval organization reduces retrieval disruption during collaboration and correspondingly reduces or eliminates collaborative inhibition.

Asking participants to engage in repeated study or repeated retrieval prior to collaboration are examples of situations where we can see how emerging organization reduces disruptive effects of collaboration. In other words, these experimental manipulations provide an "online" view of developing organization and the associated reduction in collaborative inhibition. What would happen during collaborative recall if the knowledge and expertise that the participants had acquired prior to the study could facilitate the to-be-recalled information to become tightly organized? Meade, Nokes, and Morrow (2009) provide an excellent test of this question. In this study, expert pilots, novice pilots, and nonpilots were presented with aviation scenarios and were later asked to recall these scenarios alone or with partners matched for expertise. Collaborative inhibition was observed for only those groups that consisted of novices and nonexperts, individuals who would not have had the knowledge base to construct a strong conceptual organization of the study materials. In striking contrast, expert pilots showed collaborative facilitation. This reversal supports the idea that prior knowledge and expertise lead to strong and aligned organization of study materials among expert partners and prevent disruption during recall. Furthermore, because disruption was reduced or eliminated, this condition also created an opportunity for certain benefits of collaboration to take effect. Meade *et al.* (2009) discussed these benefits in terms of collaboration skills. Coding of recall narratives showed that experts were more likely to acknowledge others' contributions and elaborate on the ideas produced by others compared to novices and nonexperts (also see Nokes-Malach, Meade, & Morrow, 2012 for further work). This skill is reminiscent of the idea of cross-cueing benefits where participants can use others' recall to trigger their own recall of information that would have otherwise not been recalled (Meudell *et al.*, 1992; 1995). However, it is useful to bear in mind that the operation of cross-cueing is not limited to collaborating partners who are experts in a particular domain and that cross-cueing can also operate in a variety of other situations (e.g., see Congleton & Rajaram, 2011, where collaborating partners were strangers and nonexperts). In brief, strong conceptual organization can protect individuals from experiencing disruption during collaboration. As such, the intuitive benefits expected from collaboration can be realized under these circumstances.

Turning to a logical reversal of the relationship, how does retrieval disruption operate when participants' recall is neither strongly organized nor even moderately organized, as is typically the case in standard encoding recall situations? Instead, participants' recall is impoverished in terms of organization. If participants bring relatively few idiosyncratic organizational strategies to collaboration, then there is less to disrupt compared to when participants develop moderately organized strategies. As a result, and for an opposite reason from that seen for highly organized retrieval, collaborative inhibition would be less likely to occur when group members' recall is impoverished for organization. This counterintuitive prediction has received support from studies that have used either an encoding manipulation or a postencoding manipulation that can reduce retrieval organization.

We investigated the effects of weakened individual strategies with an encoding manipulation where participants studied categorized lists of words under conditions of full attention or divided attention. In the latter condition, they performed an additional, secondary task of monitoring tones (Pereira-Pasarin & Rajaram, 2011). Relevant to present concerns, dividing attention at study not only lowers later recall, it also reduces organization of recall output in individual recall compared to full attention encoding (Baddeley, Lewis, Eldridge, & Thomson, 1984; Craik, Govoni, Naveh-Benjamin, & Anderson,1996; Craik & Kester, 2000). First, we replicated both effects; recall was lower following divided attention compared to full attention encoding, and the extent of retrieval organization (adjusted ratio of clustering, Roenker *et al.*, 1971) was also lower following divided attention encoding. Next, critical for the rationale behind this experiment, collaborative inhibition was robust following full attention encoding, but disappeared following divided attention encoding even though recall levels were well above floor (around 26%).

Evidence for a postencoding manipulation comes from studies that examined the collaborative inhibition effect as a function of delay between study and recall. As the delay increases between study and test, individual retrieval strategies that are formed while studying information presumably weaken. This change creates a situation where there is less organization to disrupt through collaborative input when collaboration occurs after a delay compared to shortly after the study phase. As a result, delay ought to reduce or eliminate collaborative inhibition. In line with this reasoning, collaborative inhibition appears to be a time-bound phenomenon such that a delay of two hours (compared to seven minutes; Congleton & Rajaram, 2011) between study and recall diminishes the costs in collaborative recall compared to nominal group recall and a delay of one week even reverses the effect and produces collaborative facilitation (Takahashi & Saito, 2004).

The role of reexposure benefits. As the preceding review shows, retrieval disruption (and protection from such disruption) plays a substantial role in modulating the collaborative inhibition effect. The process of collaboration also yields at least two positive consequences for improving recall that can influence the extent of collaborative inhibition, namely reexposure and cross-cueing. These mechanisms are considered here.

Reexposure during collaboration refers to the idea that listening to the recall of other group members provides exposure to items one would not have recalled otherwise, essentially creating a second study opportunity (Blumen & Rajaram, 2008, 2009; Rajaram & Pereira-Pasarin, 2007). Because members are exposed to one another's recall output during collaboration, the benefits of reexposure cannot be accrued within that recall episode. Instead, these benefits emerge on a subsequent memory measure taken from either post-collaborative individual performance or a second session of collaborative recall. For present purposes, the latter case (i.e., collaborative recall), is relevant.

When the same group carries out recall twice, the collaborative inhibition persists in second recall but it reduces in magnitude. A lack of independence across successive recalls precludes a statistical test of this reduction but this pattern consistently appears across studies that have included multiple sessions of collaborative recall (Blumen & Rajaram, 2008; Choi, Blumen, Congleton, & Rajaram, 2014; Congleton & Rajaram, 2014; Weldon & Bellinger, 1997). An inspection of average recall levels across these studies shows that nominal group recall increases across successive recalls, much like the hypermnesia effect observed in individual recall where the act of repeatedly recalling study information improves performance with each successive recall even when the information was studied only once (Payne, 1987). Collaborative group recall increases even more with repeated group recall sessions. This net benefit in collaborative recall becomes evident when the changes in reminiscence and forgetting are examined across successive recalls. Reminiscence refers to items that were not recalled during the first opportunity but were recalled during the second opportunity, whereas forgetting refers to items that were recalled during the first opportunity but not recalled during the second opportunity (hypermnesia is the net consequence of greater reminiscence than forgetting). For example, in Blumen and Rajaram (2008), reminiscence in collaborative recall was 11% and forgetting was 2% across two successive collaborative recalls, whereas across two successive individual recalls, reminiscence was lower at 8% and forgetting was higher at 4% (see also Choi *et al.*, 2014 for a similar pattern). One reason this increase in reminiscence and decrease in forgetting occur in collaborative recall is because group members are able to recall additional items during second recall that they did not recall in the first session as would be the case during individual recall. In addition, they are able to recall items they did not recall during Recall 1 but to which they were exposed through the recall of other group members. In this manner, reexposure during first group recall can reduce collaborative inhibition during second group recall. There is also a possibility that Recall 2 provides additional opportunities for cross-cueing as collaborative partners begin to secure their own recall through practice from Recall 1 and respond more to others' recalled items that serve as cues for additional retrieval, a process we have discussed elsewhere in a situation where the two recall opportunities were separated in time by an intervening week (Congleton & Rajaram, 2011).

A richer opportunity for reexposure benefits arises when a group member recalls the past twice, but with a new set of partners on the second occasion. An obvious consequence of recalling the past with two different set of partners (all of whom had been initially exposed to the same study materials) is that any given group member's memory is influenced by not only their own previous partners but also their current partners' previous partners. In other words, during second group recall each member brings reexposure benefits accrued from a different set of collaborating partners thereby increasing the potential to contribute a larger set of nonoverlapping study materials than possible if the same group collaborated twice. We tested this question by comparing the recall performance of triads where participants performed collaborative recall twice with the same partners (identical groups) or with two sets of different partners each time (reconfigured groups) (Choi *et al.*, 2014). Collaborative inhibition persisted (albeit it was numerically smaller) in identical groups on second recall but entirely disappeared in reconfigured groups. Interestingly, on second recall, reconfigured groups showed greater forgetting of items they had earlier recalled compared to the identical groups, supporting a reasonable assumption that switching partners would increase retrieval disruption because of different retrieval strategies of new partners. However, and consistent with rationale outlined already, the costs of such disruption were outweighed by the benefits of reexposure in the reconfigured groups because reminiscence—items recalled in the second session that she had not recalled in the first session—was far greater in this group than in identical groups. In brief, collaborative inhibition is shaped not only by the costs of retrieval disruption, but also by the benefits of reexposure.

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The role of cross-cueing benefits. As noted at the outset of this chapter, the idea that cross-cueing during collaboration can improve group performance holds intuitive appeal. The assumption behind this idea is that one member's recalled memories can cue another member's unrecalled memories and thereby lead to collaborative facilitation in group recall. However, the evidence for this facilitation has been relatively elusive (Andersson, Hitch, & Meudell, 2006; Congleton & Rajaram, 2011; Meudell *et al.*, 1992; Meudell *et al.*, 1995; Takahashi & Saito, 2004). One possibility may be that cross-cueing effects do arise during collaborative recall but are overshadowed by the effects of disruption. When participants have more to recall, there is more to disrupt (see Roediger, 1978). But when recall levels decline, other's recalled items can be more effective as retrieval cues (Takahashi & Saito, 2004). This reasoning is consistent with the finding that part-set cues, which disrupt and lower individual recall under the standard conditions of testing, improve individual recall when there is an increase in the delay between study and test (Raaijmakers & Phaf, 1999). Evidence supports this reasoning for cross-cueing benefits in collaborative recall, because collaborative group recall remains stable with a delay of two hours, whereas nominal group recall declines (Congleton & Rajaram, 2011, the Repeated Study conditions), and after a one-week delay, collaborative group recall is better than nominal group recall (Takahashi & Saito, 2004). This initial set of basic findings suggests that decreases in collaborative inhibition create conditions where cross-cuing benefits can be detected.

The role of partner characteristics. In the studies discussed so far, the collaborating groups have consisted of strangers. This procedure is employed to ensure a variety of experimental controls, as well as to understand the basic mechanisms that influence collaboration and memory. These fundamental mechanisms can then contextualize potential changes in collaborative remembering when groups consist of nonstrangers such as friends and couples. A number of variables can change when collaborating members know each other before entering an experimental study. The size of the groups (often dyads when considering friends or couples), the nature of their relationship (acquaintances, coworkers, friends, siblings, couples), the duration of the relationship (recent, long term, since childhood), and the topics of collaborative remembering (pleasant, contentious, factual, emotional) are but a few of the variables that can widely vary among group members that consist of nonstrangers. How does the phenomenon of collaborative inhibition play out in such groups?

It is reasonable to assume that if group members have prior experience with collaborative remembering with one another, they are likely to share considerable prior experience and information to have developed aligned retrieval strategies, or to have an understanding of and strategies for allocating complementary contents among themselves, thereby setting up what are known as transactive memory systems (Hollingshead, 1998; Wegner, 1987; Wegner, Erber, & Raymond, 1991; Wegner, Guiliano, & Hertel, 1985). As the previously discussed studies show, if such skills are brought to bear on collaborative recall, dyads or groups consisting of nonstrangers would exhibit a reduction, elimination, or even reversal of the collaborative inhibition effect. In other words, familiar collaborating partners are likely to have aligned retrieval strategies, suffer less from disruption, benefit more from cross-cueing, and have more developed collaborating skills with one another than would strangers. Extant findings are generally consistent with these expectations. For example, although collaborative inhibition persists it nonetheless reduces in well-acquainted groups (Andersson, 2001; Andersson & Rönnberg, 1995; 1996; 1997; Johansson *et al.*, 2000, 2005; Ross *et al.*, 2004). As another example, the use of coordinated, group-level strategies that incorporate both retrieval strategy alignment and transactive memory arrangements produce collaborative facilitation in older, married couples (Harris, Keil, Sutton, Barnier, & McIlwain, 2011). Similarly, possible benefits of collaboration and development of transactive memory systems are reported in long-married, older couples (Barnier *et al.*, 2014).

As the preceding review in "The role of cross-cueing benefits" shows, the collaborative inhibition effect in group recall is modulated by multiple mechanisms, with considerable experimental work so far having been directed toward the role of retrieval disruption. There are other mechanisms that can be also activated during collaborative recall, or that emerge as a consequence of collaborative recall, that interface with collaborative inhibition even if they are not directly responsible for the effect. Significant among these processes considered here are social contagion and the emergence of group-level retrieval organization.

Social Contagion Errors and Collaborative Inhibition

Social contagion errors refer to a phenomenon where others' erroneous or false recall of information influences one's own recall to create memory errors and it has been well documented across different memory paradigms (Loftus, 2005; see also Gabbert & Wheeler; Henkel & Kris; Paterson & Monds, Chapters 6, 8, and 20). These errors can also occur in collaborative memory, even though under some conditions collaboration enables the pruning of one another's erroneously recalled information. In social contagion of memory errors, recall of nonpresented but related items by one member often get incorporated in a later recall attempt of another member. Such contagion of errors has been reported for materials such as everyday scenes (Davis & Meade, 2013; Huff, Davis, & Meade, 2013; McNabb & Meade, 2014; Meade & Roediger, 2002; Roediger, Meade, & Bergman, 2001), pictures of crime scenes (Wright, Self, & Justice, 2000), and associatively related words (Basden *et al.*, 2002; Roediger & McDermott, 1995). It is quite powerful in that even when participants learn of their partner's poor memory, they still incorporate erroneous suggestions of the partner into their own memories (Numbers, Meade, & Perga, 2014). Social contagion of errors has the potential to change the magnitude of collaborative inhibition in group recall. For example, contagion errors increase under social pressure (Reysen, 2007), suggesting that collaboration instructions requiring consensus could increase social pressure to conform (Reysen, 2003) and in turn either reduce memory errors (by one member correcting the error made by another) or increase memory errors (by one member accepting another's error in order to reach consensus). Conversely, turn-taking during collaboration (where no back and forth discussion occurs) can propagate errors for different reasons as one member's erroneous recall can go uncorrected and get incorporated into others' memory. If recall errors increase (or decrease) during collaborative recall through the social contagion process, then the corrected memory performance (overall levels of recall corrected for errors in recall) in collaborative group recall can change differentially compared to nominal group recall. In this way, social contagion errors have the potential to influence collaborative inhibition in recall.

Collaborative Inhibition Changes Post-collaborative Memory of Group Members

A detailed description of the relationship between the processes that produce collaborative inhibition during group recall and their post-collaborative consequences on memory is beyond the scope of this chapter. However, a brief summary of the main findings is useful for understanding the far-reaching consequences of the collaborative recall process.

This chapter summarized the influence of three key mechanisms on the collaborative inhibition effect, namely retrieval disruption, retrieval inhibition, and social contagion errors. These mechanisms not only shape performance during group recall but also what each group member is likely to individually remember afterwards. The effects of retrieval disruption seem to be temporary such that many unrecalled items "rebound" in post-collaborative recall. But retrieval inhibition, as the name implies, results in later forgetting. Similar to this mechanism, omission of relevant details during conversation also produces forgetting later, through a mechanism termed *socially shared retrieval-induced forgetting* (Coman *et al.*, 2009; Cuc *et al.*, 2007; see also Hirst & Yamashiro, Chapter 5). Finally, social contagion of memory errors that operate during collaboration produce the opposite effect in post-collaborative memory by increasing memory errors in individual recall of former group members.

In addition to such reductions in the quantity or accuracy of post-collaborative memory, collaborative processes also produce considerable improvements in post-collaborative memory. Laboratory studies show that encoding conditions that reduce or eliminate collaborative inhibition lead to improvements in post-collaborative individual memory (e.g., Blumen & Rajaram, 2008, 2009; Choi *et al.*, 2014; Congleton & Rajaram, 2011, 2014). Further, additional processes that are activated during group recall also shape post-collaborative memory. For instance, reexposure effects during collaboration reliably improve later memory (e.g., Blumen & Rajaram, 2008, 2009; Choi *et al.*, 2014; Congleton & Rajaram, 2011; 2014). In fact, as the social networks get larger and increase opportunities for reexposure to unrecalled study materials during collaboration, post-collaborative memory improves correspondingly (e.g., Choi *et al.*, 2014). Cross-cueing effects also hold the potential for producing similar improvements. Together, post-collaborative individual memory reflects the combined influences of negative (memory lowering) and positive (memory improving) consequences of collaborative recall. These findings have important implications for the power of collaboration on improving or impairing performance in educational contexts, an issue that has received considerable attention in educational and social psychology (e.g., Cohen, 1994; Johnson & Johnson, 2009; Slavin, 1990), and one we have begun to explore through experimental work using both learning verbal materials (Blumen, Young, & Rajaram, 2014) and learning statistics (Pociask & Rajaram, 2014).

Collaborative Inhibition and Collective Memory

Collaborative remembering changes post-collaborative memory not only at the individual level but also at the collective level, such that there are greater overlapping memories among those who previously collaborated than their pre-collaborative memories or than those who did not collaborate. This section addresses these group-level, post-collaborative memories known as collective memory. Again, a lengthy treatment of this topic falls outside the scope of this chapter but some highlights that pertain to the link between collaborative inhibition and collective memory are considered here (see also Abel *et al.*; Hirst & Yamashiro, Chapters 5 and 16).

The concept of collective memory has been prevalent across a number of disciplines including anthropology (Cole, 2001), history (Bodnar, 1992), and sociology (Halbwachs, 1950/1980). Although varied definitions of collective memory abound across these disciplines, this phenomenon has been typically conceptualized with reference to cultural identity, such that memories shared by a collection of individuals (communities, nations) speak to their shared identity. In recent years, memory psychologists have also become increasingly interested in this phenomenon (Hirst & Manier, 2008; Wertsch & Roediger, 2008). Laboratory tests of collective memory operationalize this concept without reference to identity and focus on the conditions and processes that shape these jointly held (and sometimes also jointly forgotten) overlapping memories (e.g., Cuc *et al.*, 2007; Cuc *et al.*, 2006; Stone, Barnier, Sutton, & Hirst, 2010). This version of collective memory may also be referred to as shared memory (Congleton & Rajaram, 2014).

Shared group memory. It is important to reiterate that several factors contribute to the formation of collective memory (see Rajaram & Pereira-Pasarin, 2010, for a discussion). For instance, we have discussed the role of reexposure to study materials during collaborative recall elsewhere (Choi *et al.*, 2014; Congleton & Rajaram, 2014). As another example, error pruning or contagion of errors during collaborative recall can also align post-collaborative memory. Here, the focus is on collaborative inhibition and on the evidence that this phenomenon can exert a strong influence on the formation, organization, and persistence of shared memory (Congleton & Rajaram, 2014). For example, in our early work we observed that collaborative recall (and the presence of collaborative inhibition) was associated with increased overlap in later individual memories (Blumen & Rajaram, 2008). These early findings supported a role for retrieval disruption and retrieval inhibition (i.e., forgetting) in shaping collective memory, and this connection has become increasingly clear in the ensuing evidence from our lab. For example, retrieval plays a more important role than encoding in shaping collective memory (Barber, Rajaram, & Fox, 2012). As collaborative inhibition increases (creating more retrieval disruption), subsequent shared memory also increases (Congleton & Rajaram, 2011; 2014). Repeated collaborative recall with the same group members increases shared memory compared to the same number of collaborative recalls but carried out with different group members each time (Choi *et al.*, 2014). Collaborative recall—repeated collaborative recall even more so—leads to increased persistence of shared memory relative to individual recall, as shown by increased shared memory after a delay of one week between collaborative recall and later individual recall (Congleton & Rajaram, 2014).

Shared group organization. The role of retrieval inhibition in shaping shared memory can be readily appreciated because it leads to forgetting and reduces the nonoverlapping, and presumably weaker, memories in later recall. But how might retrieval disruption bring about an increase in shared memory? Through a process of disruption, each group member suffers some loss in their idiosyncratic organization of the study materials and the group members begin to develop a group-level organization of materials being recalled (Weldon & Bellinger, 1997). In other words, in as much as collaboration disrupts each member's idiosyncratic organization during recall, it also creates conditions where each group member begins to develop a new version of the recall content and sequence, such that after collaborative recall there is greater alignment across group members, both for what they remember and how they organize their respective memories for that information. As such, later recall is less guided by one's own organization of study material and more by the group-level organization. If this hypothesis is correct, then post-collaborative memory should reflect not only an increase in shared memory, but also an increase in shared organization compared to pre-collaborative recall or to the recall of those who never collaborated. This is exactly what we found across several conditions (Congleton & Rajaram, 2014). As the size of the collaborative inhibition effect increased, so did the shared organization in post-collaborative recall (Congleton & Rajaram, 2014). Similarly, whereas a single collaborative recall opportunity increased shared organization compared to no collaboration, repeated collaborative recall opportunities with same group partners increased the shared organization even more (Blumen & Rajaram, 2008; Choi *et al.*, 2014; Congleton & Rajaram, 2014.)

Concluding Remarks

The collaborative inhibition effect in group recall is a surprising phenomenon where interacting groups recall less than their potential. This robust phenomenon flies in the face of the intuitive idea that when people collaborate together to recall previously learned information, each member's recalled information serves to cross-cue other members' memories to enhance group performance. Although much of this impairment in group recall is temporary, such that some unrecalled memories are recovered after collaboration, other unrecalled memories are indeed forgotten. Collaborative inhibition can decrease, disappear, or even reverse based on the learning history and prior knowledge of the group members, their circumstances for learning and remembering, and the nature of their relationship. These changes in group recall are well predicted by the current theories of why collaborative inhibition occurs.

Collaborative remembering produces a variety of other memory consequences in addition to collaborative inhibition, and some of these are summarized in this chapter such as social contagion of memory errors, enhancement of memory accuracy through reexposure to studied materials, pruning memory errors through collaboration, and the elusive (but sometimes detectable) improvement in group recall through cross-cueing. The collaborative inhibition effect interfaces with many of these consequences in shaping social influences on memory.

A key reason to understand when and why collaborative inhibition occurs is that collaborative inhibition during group recall produces powerful and important consequences on the post-collaborative memory of the group members. On the one hand, collaborative recall improves the quantity and accuracy of post-collaborative memory of former group members. On the other hand, collaborative recall can also increase post-collaborative memory errors picked up during group recall.

Regardless of whether former group members remember more, and more accurate, information or falsely remember more erroneous information as a consequence of collaboration, their memories become more aligned than before collaboration and give rise to collective or shared memory. Not only do former group members remember (and forget) more overlapping memories, they also organize these memories in an increasingly similar manner. In essence, collaborative inhibition not only shapes the contents of shared memory but also the structure, or the group-level organization, of these shared memories. Internalization of a new retrieval organization that is shared by many has powerful implications for the downstream acquisition of new information by former group members. A new memory organization can shape the future learning of group members; for example, shaping family lore through recalls, strengthening similar beliefs, biases among people within the same network or communities, and aligning how students in the same class or the same educational environment acquire educational knowledge. We have discussed these issues in details elsewhere (Choi *et al.*, 2014; Congleton & Rajaram, 2014) and their implications are far-reaching. An understanding of the cognitive principles that underlie collaborative inhibition provides an important key to these far-reaching consequences of social remembering.

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