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Collaborative Memory: Cognitive Research and Theory

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Abstract
People often form and retrieve memories in the company of others. Yet, nearly 125 years of cognitive research on learning and memory has mainly focused on individuals working in isolation. Although important topics such as eyewitness memory and autobiographical memory have evaluated social influences, a study of group memory has progressed mainly within the provinces of history, anthropology, sociology, and social psychology. In this context, the recent surge in research on the cognitive basis of collaborative memory marks an important conceptual departure. As a first aim, we review these empirical and theoretical advances on the nature and influence of collaborative memory. Effects of collaboration are counterintuitive because individuals remember less when recalling in groups. Collaboration can also lead to forgetting and increase memory errors. Conversely, collaboration can also improve memory under proper conditions. As a second aim, we propose an overarching theoretical framework that specifies the cognitive mechanisms associated with the costs and benefits of collaboration on memory. A study of the reciprocal influences of the group and the individual on memory processes naturally draws upon several disciplines. Our aim is to elucidate the cognitive components of this complex phenomenon and situate this analysis within a broader interdisciplinary perspective.

Keywords
collaborative memory, retrieval disruption, reexposure benefits, error pruning, social contagion errors, blocking and forgetting, collective memory

People often form and retrieve memories in the company of others. Yet, 125 years of cognitive research since Ebbinghaus's (1885) seminal work on learning and memory has mainly focused on individuals working alone in isolation. In this context, there has been an important shift in this orientation in the past decade as memory researchers have started to explore cognitive mechanisms that affect group memory and the effects of group processes on later individual memory (Barnier & Sutton, 2008; B.H. Basden, Basden, Bryner, & Thomas, 1997; Weldon, 2001). Weldon and Bellinger (1997) termed this newly emerging topic in cognitive psychology *collaborative memory.* In this article, we review the empirical and theoretical progress made in cognitive research on two interrelated phenomena: (a) the nature of collaborative memory and (b) the reciprocal influences of the group and the individual on memory development in a group context.

The Problem of Definition

Until recently, the study of group memory has progressed largely within the provinces of history, sociology, social psychology, and anthropology (e.g., Halbwachs, 1950/1980; Wegner, 1987; Wertsch, 2002). Across these disciplines, a variety of related terms have been used to capture the social influences on memory. These terms include *collective memory*, *shared or collected memories*, *cultural memory*, *group mind*, *joint remembering*, and *transactive memory* (see Hirst & Manier, 2008; Mannheim, 1952; McDougal, 1920; Olick, 1999; Ross, Blatz, & Schryer, 2008; Bartlett, 1932, in Wertsch, 2008; Wertsch & Roediger, 2008). Outside the domain of cognition, the term *collective memory* subsumes many of the other terms previously listed and occupies a central place in the social scientific literature. However, despite its widespread use, there are impressive disagreements in the actual usage of this term. In recent reviews, Hirst and Manier (2008) and Wertsch (2008) have clarified that central to the definition of

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collective memory is the notion of group identity. The notion of collective memory has also been implicated in shaping autobiographical memories at historic, cultural, and familial levels (Barnier, Sutton, Harris, & Wilson, 2008; Halbwachs, 1950/1980; Pasupathi, 2001; Reese & Fivush, 2008; Rubin, 1996; Wang, 2008).

Hirst and Manier's (2008) framework offered a solution to bridge the gap in the definitions across the disciplines by understanding the process of transmission of memories and thereby bringing cognitive research in contact with the ideas in the social science literature. Other researchers have also noted social transmission to be a critical process by which group memory may be shaped (see Bartlett, 1932; Ross, Blatz, & Schryer, 2008; Wertsch & Roediger, 2008). As we elaborate throughout this review, this process is inherent to the phenomenon of collaborative memory as well.

Finally, a related but distinct concept in this spectrum of terminologies is that of *transactive memory* (Wegner, 1987; Wegner, Giuliano, & Hertel, 1985). This concept has been successfully elaborated and tested in social psychological research, and it is also one that the lay public often intuits when thinking about socially distributed memories. In a transactive memory system, different group members hold nonoverlapping sets of information, as is usually the case for couples who have cohabitated long enough. Such couples develop nonoverlapping expertise about what to remember while being aware of what their partner knows (Barnier et al., 2008; Hollingshead, 1998; Wegner, 1987; Wegner et al., 1985).

With this history of cross-disciplinary concepts before us, it is no longer necessary to ask why we should study the social influences on memory, but rather how we should study these phenomena. Although some influential approaches in cognitive research speak to the importance of social contexts, such as eyewitness memory (Lindsay, 1993; Loftus, 1992), autobiographical memories, and the view that memory is a socially constructed process (Bartlett, 1932; Marsh, 2007; Marsh & Tversky, 2004), none of these approaches has focused directly on the nature of collaboration and group memory. This article reviews the recent theory and data in cognitive research that squarely address this concept and that have come to be organized under the umbrella term *collaborative memory*.

What is Collaborative Memory?—A Cognitive Approach

What sets the collaborative memory approach apart from other lines of interests in group memory is that this approach provides a critical experimental tool for isolating and identifying the cognitive mechanisms that shape various interactions within a group. In this section, we elaborate on the prototypical experimental paradigm of collaborative memory and describe the robustness of a counterintuitive finding that is central to the study of collaborative memory. We also review evidence that demonstrates the cognitive (rather than a social) basis of the collaborative memory phenomenon.

Collaborative Memory: The Experimental Paradigm

In a typical cognitive-experimental study on collaborative memory, adult participants study materials such as a list of unrelated words while working in isolation. A distracter period of variable length (e.g., 5 min to 1 week) follows. Participants then perform a memory test such as free recall in which they recall all the studied information in any order. Unlike the study phase, the test phase involves small groups (usually three participants) working together (Harris, Paterson, & Kemp, 2008).

Collaborative inhibition. The outcome of collaborative recall is counterintuitive: Individuals remember less when recalling in collaborative groups. Predictably, the recall of a collaborative group is greater than that of any one individual (Hinsz, Tindale, & Vollrath, 1997; Yuker, 1955). However, to assess group performance, collaborative groups are compared with nominal groups. For example, participants may individually study a list of items such as A, B, C, D, E, F, G, H, and I. In the collaborative group, group recall is calculated as the number of answers produced by the members working together. In nominal groups, recall is calculated as the number of nonredundant answers produced by three individuals working alone. If Participant 1 recalls items A, B, and C; Participant 2 recalls A, D, and E; and Participant 3 recalls A, E, F, and G, the pooled nonoverlapping nominal recall is seven items: A, B, C, D, E, F, and G. In this—more appropriate—comparison, collaborative groups' recall is significantly lower than that of nominal groups' (B.H. Basden et al., 1997; Weldon & Bellinger, 1997). Weldon and Bellinger termed this counterintuitive phenomenon *collaborative inhibition* (see Fig. 1). This memory deficit is similar to brainstorming research in which collaborative groups produce fewer new ideas compared with the nominal groups (Brown & Paulus, 2002; Paulus, 2000). Weldon (2001) also noted an experience that has become increasingly familiar to us:

> In presenting findings on collaborative inhibition, I am often met with extreme resistance by the audience. The results seem to fly in the face of most peoples' intuitions or assumptions about what should happen, which is that collaboration should be beneficial. (p. 99)

Why does collaborative inhibition occur? The leading theoretical explanation, and one we discuss through much of this review, is the *retrieval disruption hypothesis* proposed by B.H. Basden et al. (1997). According to this hypothesis, the harmful effects of collaboration arise because individual retrieval strategies are disrupted during group recall. When people study information (e.g., word lists), each individual develops an idiosyncratic organization of that information. Later, when people recall the information together as a group, the output of one member disrupts the idiosyncratic organization and retrieval strategies of the others. This disruption lowers the output of each contributing member and, in turn, lowers the output of the group as a whole.

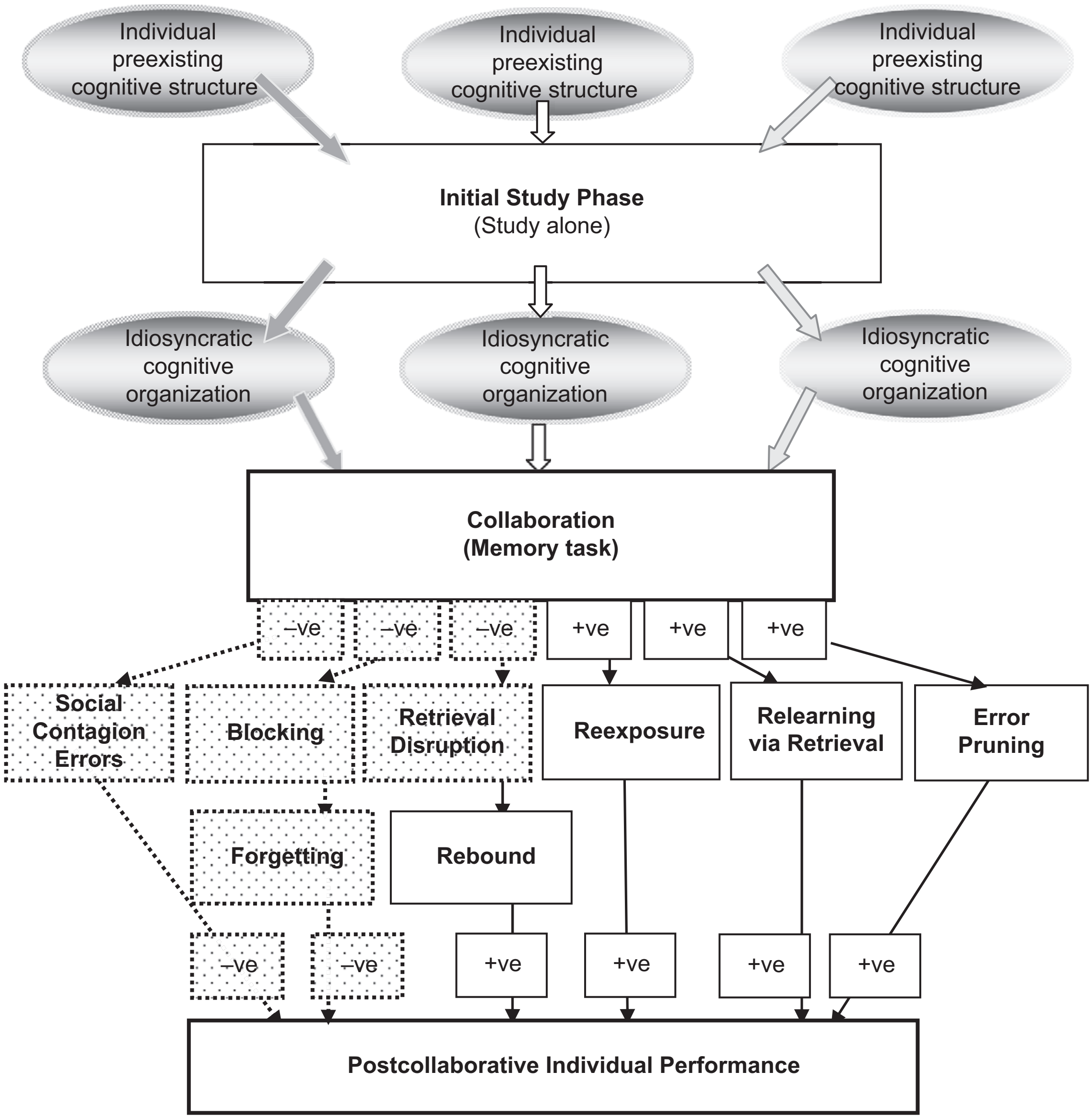

Fig. 1. A theoretical framework for the cognitive mechanisms underlying the effects of collaboration on memory. The top three ovals refer to the preexisting cognitive structures that three individuals (later to serve as a collaborating triad) might bring to the experimental situations. The bottom three ovals represent the idiosyncratic organization of the study materials each individual develops for the study materials. The symbol "−ve" refers to a negative influence of collaboration (a process that impairs accurate retrieval), and the symbol "+ve" refers to a positive influence.

Collaborative inhibition occurs for a variety of study materials. Collaborative inhibition in recall is a robust finding. As with much of basic memory research, collaborative inhibition in group recall has been most extensively studied with word stimuli. However, suboptimal group recall has been reported for a wide variety of stimuli that include not only unrelated word lists (e.g., Andersson, Hitch, & Meudell, 2006; Blumen & Rajaram, 2008; Meudell, Hitch, & Kirby, 1992; Weldon & Bellinger, 1997; Experiment 1) but also story recall (Takahashi & Saito, 2004; Weldon & Bellinger; Experiment 2), categorized lists (B.H. Basden et al., 1997; B.H. Basden, Basden, & Henry, 2000), word pairs (Finlay, Hitch, & Meudell, 2000; Experiment 2 and 3), associatively related items (B.H. Basden, Reysen, & Basden, 2002) such as Deese-Roediger-McDermott (DRM) lists (Roediger & McDermott, 1995), semantic versus episodic tasks (Andersson & Rönnberg, 1996), pictures in a matrix organization (Finlay et al.; Experiment 1), short film clips (Andersson & Rönnberg, 1995; Meudell et al.), and emotionally laden events (Yaron-Antar & Nachson, 2006). In other words, not only is collaborative inhibition counterintuitive, it also generalizes to all sorts of study materials. Such generalizability underscores the need for a theoretical framework that (a) explains the collaborative inhibition phenomenon and its consequences on shaping the individual memory of the participating members and (b) helps predict the conditions in which collaborative inhibition may be negated or even reversed. The need for such

Table 1. A Selection of the Key Phenomena Related to Collaborative Inhibition in Memory

Factors	Collaborative inhibition
Different types of study materials	Present
Stimulus organization	
Large categories	Present
Small categories	Absent
Repetition at study–test	Declines and disappears
Repetition at study	Attenuates
Repetition at test	Disappears
Distraction at study	Disappears
Long study–test delay	Disappears
Increases in group size	Increases
Type of memory task	
Free recall	Present
Cued recall	Absent
Recognition	Absent
Age and relationships	
Children, young adults, older adults	Present
Couples and friends	Present, but sometimes attenuates
Experts	Disappears and reverses
Group cohesion and personal accountability	Present

a theoretical framework is also underscored by the evidence that the magnitude of collaborative inhibition varies as a function of several factors. We review this evidence next, and we provide a descriptive summary of these findings in Table 1.

Factors Affecting Collaborative Inhibition

Stimulus Organization

According to the retrieval disruption hypothesis, the organization of the study stimuli plays a critical role in modulating collaborative inhibition in recall (B.H. Basden et al., 1997). Several compelling demonstrations have supported this hypothesis.

Category size of the study stimuli. B.H. Basden et al. (1997) manipulated stimulus organization by requiring participants to learn either 15 instances of 6 categories or 6 instances of 15 categories (Experiment 1). Fifteen instances from a given category can be organized in many more ways than can 6 instances from a given category. Thus, for the same number of items that are learned across these two conditions and are to be recalled, the organization of the study words is likely to be more varied across participants with 15 instances per category than with 6 instances per category.

Consistent with the predictions of the retrieval disruption hypothesis, more varied organization (with a larger category size) increased collaborative inhibition in recall of exemplars (collaborative group recall = 6.86; nominal group recall = 8.11) compared with a tighter organization with, for example, a smaller category size (collaborative group recall = 2.89; nominal group recall = 2.88). As a variant of this logic, collaborative inhibition should occur when each participant follows his or her own idiosyncratic organization, but it should disappear if a specific organizational scheme for recall is imposed on all participants. This prediction was also supported when all participants were asked to recall according to category (B.H. Basden et al., 1997; Experiment 3). Collaborative inhibition was observed when participants were able to switch between categories during recall (collaborative group recall = 0.49; nominal group recall = 0.58), but it disappeared when participants recalled items for specified categories (collaborative group recall = 0.31; nominal group recall = 0.34). Other evidence in line with the retrieval disruption hypothesis shows that collaborative inhibition also disappears when the organization of the to-be-recalled information is aligned across group members (see Finlay et al., 2000).

Repetition: Multiple study–test cycles. Accumulating evidence suggests that repeated study or repeated testing can change the extent of collaborative inhibition in group recall, and this outcome is associated with improved retrieval organization. It is well known that repeated study presentations improve individual memory compared with a single presentation (Greene, 1989). Using a design with three study–test cycles, B.H. Basden et al. (2000) reasoned that repeated exposure to studied information should increase the mnemonic strength of the studied items (see Glenberg & Smith, 1981), and such increased mnemonic strength should decrease the disruption of individual retrieval strategies. This is because people are better able to hold on to their strengthened idiosyncratic organization when mnemonic strength increases. As a result, collaborative inhibition should occur in the first group recall test, but not on the subsequent tests of group recall. Furthermore, retrieval organization should also increase with each recall. Their findings supported these predictions.

Repetition at study. In the study just described, B.H. Basden et al. (2000) manipulated repeated study and repeated retrieval in an interleaved fashion, leaving open the question whether repeated study or repeated retrieval can uniquely affect collaborative recall. We isolated the effects of repeated study to answer this question (Pereira-Pasarin & Rajaram, 2010b). Classic findings in the memory literature show that spaced repetition (as opposed to massed repetition or a single presentation) increases rehearsal of study items (Rundus, 1971; Experiment 3) and that participants organize categorized stimuli into clusters during rehearsal (Rundus, 1971; Experiment 4). Together, these findings imply that increased rehearsal of repeated items should increase stimulus organization and consequently make retrieval strategies less susceptible to disruption during collaborative recall. To test this prediction, we presented participants with target exemplars presented once or repeated three times in a spaced fashion. Replicating previous findings, study repetition improved overall recall for both nominal and collaborative triads. In critical support for the prediction, collaborative inhibition was present in the single presentation condition (nominal recall = 0.64 (*SD* = 0.13); collaborative recall = 0.48 (*SD* = 0.17)), but it was significantly attenuated (and was only marginal) in the repeated presentation condition (nominal recall = 0.83 (*SD* = 0.06); collaborative recall = 0.79 (*SD* = 0.08)).

Repetition at test. The main question here is whether repeated recall by itself can improve organization and reduce collaborative inhibition. Some hints of this pattern occurred in a study in which repeated collaborative and/or individual recalls were used (Blumen & Rajaram, 2008). We recently tested this question directly in a study by comparing the effects of repeated study and repeated testing (Congleton & Rajaram, 2010). The two learning histories, study–study–study or study–recall–recall, occurred prior to collaboration and involved working alone to learn a categorized word list. On a later test of group recall (collaborative or nominal), collaborative inhibition occurred only after repeated study history (i.e., study–study–study) and entirely disappeared after repeated testing history (i.e., study–recall–recall). Consistent with this outcome, we also found that the measure of organization (adjusted ratio of clustering scores; Roenker, Thompson, & Brown, 1971) was significantly higher after repeated testing than repeated study in both collaborative and nominal group recalls.

Together, these findings show that study and test repetitions clearly play an important role in enhancing retrieval organization and reducing disruptive effects of collaboration. We return to these issues in the last section on collaborative learning and implications for educational practices.

Distraction at study. In a logical reversal of the organizational effects, collaborative inhibition in recall might also disappear or reduce when each member brings a weak organizational scheme to the collaborative recall situation. This is because when retrieval organization is weak, there is not much to disrupt and under these conditions group members may be less impaired at recalling the few studied items they do remember. We tested this rationale by manipulating study conditions that consisted of either *full-attention encoding*, in which participants studied a list of categorized words, or *divided-attention encoding*, in which participants performed an additional secondary task (Pereira-Pasarin & Rajaram, 2010b).

Divided attention at study reduces the extent to which study items are processed for their conceptual properties and lowers performance on a variety of memory tasks (Baddeley, Lewis, Eldridge, & Thomson, 1984; Geraci & Rajaram, 2002; Mulligan & Hartman, 1996). It also reduces the organization of recall output in individual recall compared with full-attention encoding (Craik & Kester, 2000). We replicated these findings for nominal and collaborative groups. Critical for the retrieval disruption hypothesis, we replicated collaborative inhibition after full-attention encoding (collaborative group recall = 0.44, *SD* = 0.10; nominal group recall = 0.61, *SD* = 0.11); further, this effect completely disappeared after divided-attention encoding (collaborative group recall = 0.26, *SD* = 0.09; nominal group recall = 0.26, *SD* = 0.09). In line with this finding, the measure of recall output organization (adjusted ratio of clustering) was also significantly lower for the stimuli studied in the divided-attention condition (*M* = 0.13, *SE* = 0.03) compared with the full-attention condition (*M* = 0.28, *SD* = 0.03). In other words, when retrieval organization was weak, collaboration produced less disruption during recall.

Study–test delay. Collaborative inhibition has been usually studied in the context of immediate memory tests with study–test delays lasting no more than 5 min (B.H. Basden et al., 1997; Blumen & Rajaram, 2008, 2009; Finlay et al., 2000; Weldon, 2001; Weldon & Bellinger, 1997). However, Takahashi and Saito (2004) used a study–test delay of 1 week to test the prediction that delay and the associated interference would reduce the participants' reliance on their idiosyncratic retrieval strategies (see Raaijmakers & Phaf, 1999). Consistent with this rationale, the expected collaborative inhibition was present in the collaborating dyads' recall after a 15-min study–test delay, but it disappeared after a 1-week test delay. Recently, we have observed a similar pattern after a study–test delay of 2 hr (Congleton & Rajaram, 2010).

Group Size

Group size is an important variable for at least two reasons. One, in a social context people retrieve the past in groups that vary in size, and two, the retrieval disruption hypothesis predicts more disruption during collaboration as group size increases (see B.H. Basden et al., 2000). Direct comparisons of group size are not plentiful, but the available evidence is consistent with the retrieval disruption hypothesis. The most commonly used group size consists of triads, which reliably produce collaborative inhibition (B.H. Basden et al., 1997; Blumen & Rajaram, 2008; Congleton & Rajaram, 2010; Fox, Rajaram, & Barber, 2009; Pereira-Pasarin & Rajaram, 2010b; Weldon & Bellinger, 1997). The smallest group size of dyads also usually produces collaborative inhibition (Andersson & Rönnberg, 1995; Finlay et al., 2000; Thorley & Dewhurst, 2007; however, see also B.H. Basden et al., 2000; Meudell, Hitch, & Boyle, 1995; Meudell et al., 1992). Furthermore, the few studies that have directly compared dyads and tetrads—groups of four—(e.g., B.H. Basden et al., 2000); or dyads, triads, and tetrads (e.g., Thorley & Dewhurst) within one design have reported an increase in the size of the collaborative inhibition effect as the group size increased.

Type of Memory Tasks

The choice of memory task also determines when collaboration is detrimental. Retrieval tasks, such as free recall, that produce robust collaborative inhibition also require the greatest reliance on subjective retrieval organization. However, tasks such as cued recall (Finlay et al., 2000; Experiment 2) and recognition (Clark, Hori, Putnam, & Martin, 2000) provide external cues to guide retrieval. Consistent with this task format, performance on these tasks does not typically show collaborative inhibition (however, see Ross, Spencer, Linardatos, Lam, & Perunovic, 2004). This is presumably because the presence of cues creates equivalent retrieval disruption in both the collaborative and nominal groups.

Age and Relationships

Children and young adults. The scant evidence available comes from studies that compared dyads of 7-year-old children versus 15-year-old children (Andersson, 2001) or dyads of 7-year-old children, 9-year-old children, and mixed (7-year-old children and 9-year-old children) pairs (Leman & Oldman, 2005). Collaborative inhibition occurred for all age groups, suggesting that collaborative memory is sensitive to developmental factors. However, age comparisons across these studies painted a murky picture, indicating that much work is needed before researchers can derive clear conclusions and theoretical mechanisms.

Older adults. Only a few studies have compared collaborative and nominal group recalls in older adult dyads and have found that older adults consistently exhibit collaborative inhibition (Johansson, Andersson, & Ronnberg, 2000; Ross et al., 2004). Two recent studies included both the group factor (collaborative vs. nominal) and the age factor (young vs. old) and provide a direct comparison of age (Meade & Roediger, 2009; Ross, Spencer, Blatz, & Restorick, 2008). Despite various methodological differences, both studies showed that collaborative recall for dyads was lower than for nominal dyads, and this collaborative inhibition effect was comparable across age. We have recently demonstrated a comparable collaborative inhibition effect in older adults for the first time with a larger group size of triads (Henkel & Rajaram, 2009).

Relationships. Findings show that although collaborative inhibition sometimes reduces in friend dyads compared with nonfriend dyads (Andersson, 2001; Andersson & Rönnberg, 1995, 1996) and in married couples compared with stranger dyads (Johnasson et al., 2000; Ross et al., 2004), this effect does not disappear. This reduction is usually attributed to the use of a transactive memory system by friends and couples who have known each other for some time.

Expertise

In light of the overwhelming evidence of collaborative inhibition in group recall, the question arises as to what it would take to reverse this finding. The evidence for collaborative facilitation is rare, but Meade, Nokes, and Morrow (2009) recently reported a collaborative facilitation effect in dyadic recall if participants had expertise in the study domain. Expert pilots, novice pilots, and nonpilots recalled scenarios of flight situations that they had individually studied earlier. Only expert pilots exhibited collaborative facilitation, whereas nonpilots and novice pilots showed the standard collaborative inhibition effect. Meade et al. accounted for these findings in the context of the retrieval disruption hypothesis; experts jointly spent time discussing the same scenario before proceeding to the next one. This elaborative recall process reduced disruption of organized recall that would occur if the members frequently jumped back and forth from one topic to the next. Experts thus provide a special case in which knowledge and organization converge to produce benefits in collaborative recall.

Theories and Mechanisms: Collaborative Recall

In this section, we first review the origins of the retrieval disruption hypothesis in the individual memory phenomenon of part-list cuing inhibition. We then propose a new theoretical framework of collaborative memory specifying various cognitive mechanisms that operate during collaboration and that exert cascading influences on later memory performance. The organization presented here provides both a framework for summarizing the key empirical findings about the effects of collaboration on group memory and on postcollaborative individual performance and a predictive framework for as-yet-untested questions. Finally, this framework also brings together cognitive processes that likely interact and underlie the larger and broader group phenomena outside the laboratory discussed at the outset of this review.

In Figure 1, we depict the typical collaborative memory paradigm with triads used as the group size. Each participant brings to the study situation a learning history and a preexisting cognitive structure that is unique to that person. This history is represented with the three circles labeled *individual preexisting cognitive structure*. This history shapes the organization each participant imposes on the information presented during the study phase. As a result, each individual develops a unique organization of the study material, represented in the figure with the three circles labeled *idiosyncratic cognitive organization*, who then enters the collaborative discussion session. The same process can be assumed for smaller or larger groups. Next, the proposed theoretical framework outlines both the negative (denoted with a "−ve" label) and positive (denoted with a "+ve" label) effects of collaboration that can occur on memory. These distinct effects are described next.

Costs of Collaboration on Memory

Retrieval disruption. As we have already noted, retrieval strategy disruption provides the leading cognitive account of the collaborative inhibition effect in recall. This proposed basis of the collaborative inhibition effect is an extension of the well-known account of part-list cuing inhibition in individual recall (D.R. Basden & Basden, 1995; D.R. Basden, Basden, & Galloway, 1977; Roediger & Neely, 1982). In general, and consistent with intuitive predictions, when participants receive a single retrieval cue (e.g., a category name) for recalling associated items, their recall improves (Tulving, 1974). However, when participants receive a subset of the studied items rather than a single retrieval cue, the cuing becomes detrimental and lowers their recall. This is because the part-list cues disrupt the organizational and retrieval strategies each individual developed and lead to suboptimal recall performance (D.R. Basden & Basden, 1995; D.R. Basden et al., 1977). Extending this argument to collaborative recall, study items retrieved by the other group members during group recall serve as part-list cues. These items disrupt individual retrieval organization of the remaining members and lead to less effective retrieval of their remaining items. Furthermore, just as retrieval organization plays an important role in collaborative recall (as described previously), its importance has also been previously demonstrated in part-list cuing recall (D.R. Basden & Draper, 1973).

Rebound: When the costs of collaboration are mitigated. In individual recall, part-list cuing inhibition disappears when cues are removed and the second task involves a free recall test. In other words, the items that are lost in the presence of cues (during part-list recall) reappear when participants are asked to recall the same items in the absence of cues (D.R. Basden et al., 1977; however, see Bäuml & Aslan, 2006). Thus, a "release" from part-list cuing occurs, such that once the cues are removed (e.g., on a second memory test), participants recall previously "blocked" studied words. Similarly, items that are lost during group recall reappear when individuals subsequently recall the same items alone (Finlay et al., 2000; Weldon & Bellinger, 1997). In both cases, it is argued that this outcome occurs because individual members are able to later recover their own retrieval organization. Thus, the memory impairment seen on the first recall test is temporary, and the initial cost arising from retrieval disruption is later mitigated.

Blocking/forgetting. As evidence has continued to mount for the retrieval disruption mechanism and the rebounding (or recovery) of items on later individual tests, relatively less attention has been directed toward the possibility of forgetting in either the individual or the group paradigms of disruption. One might even argue that the term *inhibition* is not an ideal choice for characterizing the disruption phenomena, because studies have frequently reported item recovery in later recall rather than continued forgetting (or inhibition) of those items. Nonetheless, as we subsequently describe, there is now growing evidence that collaboration can lead to forgetting as well. This trend is similar to the recent developments in the part-list cuing literature on individual memory showing that although part-list cues create retrieval disruption under some conditions, they can also create retrieval inhibition under other conditions and lead to persistent memory impairment (see Bäuml & Aslan, 2006).

Forgetting in collaborative recall. During collaboration, one must wait one's turn to contribute to the discussion. The process of waiting while others provide responses can block the recall of one's own information (Diehl & Stroebe, 1987; Finlay et al., 2000). In addition, just as study items with strong representations are assumed to be recalled first in individual recall (Raaijmakers & Shiffrin, 1981; Wixted, Ghadisha, & Vera, 1997), the same process can also occur during collaborative recall. Here, too, the stronger items can block and damage the episodic representations of the weaker to-be-recalled items. These mechanisms could induce not only disruption but also forgetting, and some evidence supports this possibility.

In one study, researchers found *reminiscence*—an increase in recall with successive attempts at recall (Payne, 1987)—to be inhibited as a function of collaboration (B.H. Basden et al., 2000). Participants who collaborated in larger groups showed less reminiscence in later individual recall compared with those who had collaborated in smaller groups. Such inhibition of reminiscence (B.H. Basden et al., 2000; see also Meudell et al., 1992) provides an indirect measure of forgetting. Recently, we found evidence for some forgetting in a design that compared a sequence of three recalls across individual-individual-individual and individual-collaborative-individual combinations. Both young and older adults showed not only reminiscence or gains from collaboration on the third recall, they also failed to recall on the third task a significant proportion of items they earlier recalled on the first test if collaboration intervened (Henkel & Rajaram, 2009).

Forgetting has also been shown for known, related details that were not recalled during group discussion, even for memories as salient as those for the September 11 attacks in New York (Coman, Manier, & Hirst, 2009). In this study, dyads of stranger participants engaged in a conversation about the memories that they had earlier reported in a questionnaire on the September 11 attacks. Related memories that were not mentioned during the conversation received longer RTs on a later recognition task compared with unrelated memories that were not mentioned. Much like the retrieval-induced forgetting effect in individual recall (Anderson, 2003; Cuc, Koppel, & Hirst, 2007), these findings show socially shared retrieval-induced forgetting; that is, collaborative recounting of respective memories can induce forgetting for those specifics that are related to the discussed details, but that were omitted from the discussion.

Social contagion errors. Among the consequences of collaboration, two entail rejecting or accepting responses provided by a group member. Regardless of the accuracy of the content itself, the rejection-acceptance process underlies the effects of social contagion—the method by which memories spread within a group. As social contagion increases, so do the shared memories within a group. As outlined in Figure 1, collaboration not only prunes memory errors, but it can also increase false memories.

Studies that typically focus on social contagion errors assess the effects of collaboration on postcollaborative, individual false memory (Barnier et al., 2008). A variety of experimental procedures show that nonstudied information recalled by group members often makes its way into the participant's final individual recall (e.g., B.H. Basden et al., 2002; French, Gary, & Mori, 2008; Gabbert, Memon, & Wright, 2006; Meade & Roediger, 2002; Reysen, 2003, 2005; Roediger, Meade, & Bergman, 2001), and these errors increase if participants believe the information comes from a social source, such as a perceived partner, than a nonsocial source, such as computer-generated responses (Gabbert, Memon, Allan, & Wright, 2004; Hoffman, Granhag, See, & Loftus, 2001; Meade & Roediger, 2002; Reysen & Adair, 2008). Also, social contagion errors can be reduced if there are dissenters in the group (Walther et al., 2002).

Several factors may be responsible for why collaborative processes yield false memories on later individual performance in some situations rather than prune the memory errors. One such factor may be the nature of study materials. Stimuli such as the DRM lists (Deese, 1959; Roediger & McDermott, 1995) are specifically designed to increase memory errors for specific stimuli, and the use of these stimuli may magnify these errors through a collaborative process (B.H. Basden et al., 2002). If study stimuli consist of unrelated word lists, collaboration does not increase memory errors even on a recognition test in which nonstudied stimuli are presented rather than generated (and could be therefore more prone to being selected) stimuli (Rajaram & Pereira-Pasarin, 2007). Further, collaboration can reduce recall intrusions (Ross et al., 2004) and recognition false alarms (Pereira-Pasarin & Rajaram, 2010a), even for related study stimuli such as grocery lists (Ross et al., 2004), everyday scenes (Ross, Spencer, et al., 2008), and categorically related stimuli (Pereira-Pasarin & Rajaram, 2010a). We have argued that error-pruning effects of collaboration for related stimuli (e.g., categorically related words) occur because such stimuli increase general memory errors, but are not designed to generate memory errors specific to certain words as is the case with the DRM lists (Mandler, 1979; Park, Shobe, & Kihlstrom, 2005). As a result, memory errors do not overlap in a collaborative group for all related stimuli, and group members are able to correct each other's recall or recognition errors (Pereira-Pasarin & Rajaram, 2010a; Ross et al., 2004; Ross, Spencer, et al. 2008).

Another factor responsible for increasing memory errors through collaboration may be the method of interaction during collaboration. The two commonly-used methods—turn taking and free flowing—both produce reliable collaborative inhibition across the body of literature (see Wright & Klumpp, 2004) but different effects on memory errors. In the turn-taking procedure, group members do not have the opportunity to comment on each other's output and are therefore unable to correct recall errors they might detect. Consistent with this procedure, intrusions increase when turn taking is used (B.H. Basden et al., 1997; Meade & Roediger, 2009; Thorley & Dewhurst, 2007). In contrast, in a free-flowing interaction, participants are instructed to find their own ways to solve disagreement and are at liberty to correct one another. Under these conditions, collaboration lowers false recall and recognition (e.g., Pereira-Pasarin & Rajaram, 2010a, 2010b; Rajaram & Pereira-Pasarin, 2007; Ross et al., 2004; Ross, Spencer, et al., 2008).

Benefits of Collaboration on Memory

Reexposure effects. Collaboration provides reexposure to the study material; listening to other group members' output provides a second study opportunity and should therefore improve learning (Blumen & Rajaram, 2008; Weldon & Bellinger, 2007). These reexposure benefits cannot be evident during group recall; however, they can be detected on a subsequent memory test, and they may be one of the main reasons why collaboration intuitively seems beneficial. Findings for a variety of study stimuli (that do not promote memory errors) show that veridical memory increases if collaboration precedes individual retrieval (Blumen & Rajaram, 2008, 2009; B.H. Basden et al., 2000; Congleton & Rajaram, 2010; Thorley & Dewhurst, 2007; Weldon & Bellinger, 1997; however, see Finlay et al., 2000). The benefits of past collaboration have been also observed in older adults (Gagnon & Dixon, 2008; Henkel & Rajaram, 2009) and on later individual tests of cued recall (B.H. Basden et al., 2000; Finlay et al., 2000) and recognition (B.H. Basden et al., 2002; Pereira-Pasarin & Rajaram, 2010a; Rajaram & Pereira-Pasarin, 2007). This positive cascade shows that collaboration provides reexposure benefits above the benefits of hypermnesia (i.e., the net improvement in individual recall in which gains exceeds losses with repeated attempts; Payne, 1987).

Reexposure benefits of collaboration have important educational implications for group learning practices, especially so in light of some of the costs of collaboration we have already discussed. A key question then is how the reexposure benefits of collaboration may be enhanced. Our recent findings show that study–test conditions that simultaneously strengthen and stabilize retrieval strategies and provide reexposure opportunities are the best for enhancing later individual memory (Blumen & Rajaram, 2008, 2009; Congleton & Rajaram, 2010).

Relearning through retrieval. Collaboration can also produce powerful effects on eventual individual learning by enabling rehearsal of study information. This is because the act of recalling during collaboration provides an opportunity to rehearse already known information. This process is similar to repeatedly retrieving studied information on one's own and, as such, not a uniquely collaborative effect. However, because collaboration affords, and to some extent ensures, such rehearsal through retrieval, it is important to assess the effects of this mechanism separately to clearly understand the distinct processes that combine to produce collaboration effects. For instance, considerable research on individual memory shows that repeated retrieval (that amounts to rehearsal) is more powerful than repeated study for improving long-term retention (Karpicke & Roediger, 2008; Roediger & Karpicke, 2006). As collaborative recall facilitates both *reexposure* and *relearning through retrieval*, the extent of opportunity for reexposure versus relearning could produce differential effects on the long-term retention of each group member (see Congleton & Rajaram, 2010). Further, as a complementary consequence of the process of relearning through retrieval, the likelihood of later recalling items that were not recalled during collaboration is lowered because these items do not benefit from relearning. This process may in part (and indirectly) account for some of the forgetting effects.

Error pruning. As a third benefit, collaboration can serve as an *error-pruning mechanism*. Listening to other group members and receiving their feedback during collaboration can prune the recall errors one might otherwise make in individual recall (Barber, Rajaram, & Aron, 2010; Ross et al., 2004; Ross, Spencer, et al., 2008) and individual recognition measures (Pereira-Pasarin & Rajaram, 2010a; Rajaram & Pereira-Pasarin, 2007; Ross et al.; Ross, Spencer, et al.). As noted in a previous section on social contagion errors, the free-flowing method of collaboration reduces memory errors whereas the turn-taking method increases these errors (for a direct comparison, see Thorley & Dewhurst, 2007).

With this cognitive theoretical framework in hand, we now consider evidence on how some social factors affect collaborative retrieval.

The Role of Social Factors

Consistent with the central thesis of this review, we consider the social factors from a cognitive perspective previously outlined. We use this perspective not to obfuscate the possible role of social dimensions, but instead to draw attention to the inherent cognitive dimensions operating under these conditions that may not be readily considered.

Social Loafing

In any context in which group interactions are involved to achieve task outcomes, a motivational account clearly seems important. As such, diffusion of responsibility through social loafing (Latane, Williams, & Harkins, 1979) seems like an obvious explanation for the collaboration inhibition effect. However, experiments that specifically manipulated personal accountability (e.g., by increasing group cohesion) and motivation (e.g., by offering monetary incentives) show that even with these manipulations collaborative inhibition persisted (Weldon, Blair, & Huebsch, 2000).

Social Pressure and Group Conformity

The absence of social loafing in collaborative memory tasks suggests that the role of other related social factors may also be negligible. However, some evidence indicates otherwise. As we noted in the section on social contagion errors, people incorporate erroneous interjections if they believe these come from another person than from a computer (Meade & Roediger, 2002; Reysen & Adair, 2008). Further, not only does social conformity lead people to accept the confederates' recognition errors (Schneider & Watkins, 1996; Wright, Self, & Justice, 2000), it also produces genuine memory impairments, as evidenced by poorer memory on a later individual task (Reysen, 2005).

Some evidence speaks to the critical question of possible interactions between such social factors and the hypothesized cognitive factors in shaping collaborative memory. For instance, the mere participation in an ostensibly high-performing group improved the recall contributions of individuals, whereas participation in an ostensibly low-performing group lowered it, thus suggesting a role of social pressure (Reysen, 2003). At the same time, robust collaborative inhibition was also observed in both the high- and low-output groups, suggesting the operation of retrieval disruption (see also Reysen, 2007). Furthermore, the members from the low-performing group continued to exhibit lower performance on a later individual recall test, suggesting extended forgetting (see Fig. 1). Such evidence indicates that social variables can influence cognitive mechanisms. In cases of social conformity, the errors made while agreeing with the partner's responses can create interference with the correct responses and lower retrieval. At the same time, the failure to recall or recognize the correct response reduces the opportunity to relearn a response through retrieval (see Fig. 1). These mechanisms of forgetting, interference, and rehearsal do not explain why people respond to the social factors in the first place, but they may explain how such responding shapes memory.

Collaborative Encoding and Memory

As the preceding review of collaborative memory research shows, nearly all the studies have tested collaborative processes at the retrieval stage. This is surprising because in real life, people routinely experience new events together, making collaborative encoding an important process to understand. Further, this process also seems integral to understanding how people develop shared memories.

The scant current evidence on collaborative encoding suggests that different mechanisms may govern the collaborative process across encoding and retrieval. In one study, collaborative encoding did not produce recall impairments, but this outcome was expected because encoding was designed to align later retrieval organization between partners (Finlay et al., 2000). In another study that yielded somewhat mixed patterns (Andersson & Rönnberg, 1995), the first recall (always individual) was not affected by collaborative encoding, but the second recall, when collaborative, was surprisingly impaired after collaborative encoding. This impairment was attributed to reduced efficacy of a cue's distinctiveness when it was produced by others (see Andersson, Helstrup, & Rönnberg, 2007; Mantyla & Nilsson, 1983).

Recently, we tested the effects of collaborative encoding with a task designed to create joint construction and elaboration of study episodes (Barber et al., 2010). Stranger dyads or individuals constructed meaningful sentences from unrelated word pairs, and later recalled the second word when given the first word, in one of three conditions: (a) alone, (b) with the same partner, or (c) with a different partner. The findings were clear but counterintuitive: Collaborative encoding impaired recall in all conditions including the one in which the same dyads encoded and recalled together. We termed this phenomenon *collaborative encoding deficit*. Two reasons were associated with this deficit. One, individuals working alone produced more cohesive sentences than dyads working together, and this difference was related to recall levels. Two, even cohesive sentences did not improve recall for a participant if that sentence was produced by the other partner, supporting the role of the efficacy of self-generated cues versus other-generated cues (see Andersson & Rönnberg, 1995; Mantyla & Nilsson, 1983). In other words, collaborative encoding impairs memory just as does collaborative retrieval, but the bases of these effects seem to be different.

Collaboration and Memory: Implications and Significance

As Weldon (2001) noted, there persists resistance and disbelief to the reports of harmful effects of collaboration on memory, and this has been true in our experience as well. This finding is undoubtedly counterintuitive, but there is overwhelming evidence that collaboration (a) disrupts self-generated retrieval, (b) can sometimes result in extended forgetting, and (c) can result in socially induced false remembering. Should we then engage in collaboration at all? Balancing against the harm associated with collaboration are also many benefits. As Ross, Blatz, and Schryer (2008) argued, groups do perform better than a single individual and this can be useful in many situations in which the overall outcome rather than the individual performance is at stake. Further, collaboration provides reexposure benefits, and it can also help well-established collaborating groups (e.g., friends, couples) develop transactive memory systems. The use of these systems reduces or overcomes the ill effects of collaboration, and it enhances the benefits of working together. Last, just as there is evidence that under certain circumstances collaboration induces social contagion errors in memory, there is equally compelling evidence that collaboration often prunes memory errors (see Rajaram & Pereira-Pasarin, 2007; Ross, Blatz, & Schryer, 2008). The theoretical framework we present in this review provides a systematic way to explain and predict the operations of these offsetting processes during collaboration. Such a process analysis can help identify the conditions and sources that optimize the benefits and minimize the costs in terms of memory accuracy, as would be the goal in group learning practices in educational contexts. Such an analysis also maps well with the explanations of collaborative processes in which the goal is not so much to enhance memory accuracy but, as Hirst and colleagues have argued (e.g., Coman et al., 2009; Cuc, Ozuru, Manier, & Hirst, 2006), to arrive at a shared representation of the past.

We now discuss the present cognitive approach in these distinct contexts. First, we return to the notion of collective memory presented at the beginning of this article and explore the relation between collaborative processes and the formation of collective memory. Second, we consider the implications of the cognitive processes involved in collaboration for the popular educational practice of group learning.

Linking Collaborative Memory to Collective Memory

As we stated earlier, the term *collective memory* is typically associated with group identity. Hirst and colleagues (e.g., Coman et al., 2009; Cuc et al., 2006; Hirst & Manier, 2008) have also used this term to experimentally study the emergence of shared memories in small groups, in which *collective memory* is defined as the number of overlapping recalled items that the group members share together as a function of previous collaboration (see Cuc et al., 2006). This method provides an excellent way to assess the emergence of shared memories that can eventually relate the issues of group memory and identity (Coman et al., 2009; Cuc et al, 2006).

The theoretical framework of collaborative memory outlined in Figure 1 includes the cognitive mechanisms that might interact in shaping collective or shared memories. This processing framework also relates to research from a variety of related domains that speaks to the roles of goals, motivations, narrative roles, and silences in shaping individual or shared memory. For instance, studies on autobiographical memory both in the adult and the developmental literatures (Conway & Pleydell-Pearce, 2005; Pasupathi, 2001; Reese & Fivush, 2008; Wang, 2008) and on narratives and remembering (e.g., Marsh, 2007) show that people recall details during a conversation to meet specific goals. People select certain details (as opposed to other details) to resolve conflicts, to selectively endorse or silence information, to entertain the listeners, to obtain feedback, or to achieve certain communication goals (Dudukovic, Marsh, & Tversky, 2004; Echterhoff, Higgins, Kopietz, & Groll, 2008; Marsh, 2007; Marsh & Tversky, 2004; Pasupathi, 2001; Reese & Fivush, 2008). These goals differentially influence specific cognitive mechanisms that, in turn, shape the extent to which overlapping memories develop among participants.

In the developmental literature that focuses on mother–child interactions and family interactions, the implications of being validated in conversation or being silenced from participation (by negating or disputing the information that a participant provides) have been shown to be far reaching. For instance, silencing has been implicated in costs to the development of the self (Fivush, 2004). In contrast, validation of output during family reminiscing has been linked to increased self-efficacy and self-esteem in adolescents (Bohanek, Marin, Fivush, & Duke, 2006, Marin, Bohanek, & Fivush, 2008). In the parlance of the framework of collaborative memory (Fig. 1), the act of negating outputs can lead to blocking/forgetting by making participants reluctant to contribute to the conversation. Further, the case of disputing or negating information can also be similar to error pruning in cognitive terms, because if some information recalled by a participant is rejected by the group, it no longer remains a part of the accepted narrative. Such a process can result in the omission of these details in later individual recall (Merckelbach, van Roermund, & Candel, 2007).

In this vein, as Cuc et al. (2006) demonstrated, unmentioned details during a conversation can be later forgotten. Following a study of stories, participants first recalled the stories alone, next in a group context, and then once again alone. The critical comparison was between the first and third individual recalls, and the goal was to assess the fate of the related items that were first recalled individually but were not mentioned during group discussion. Findings showed that group members in later individual recall forgot such related studied details. Further, as Coman et al. (2009) demonstrated and argued, forgetting through conversations (i.e., a collaborative process) can give rise to collective memories by making the memories of listeners and speakers similar even though these memories previously differed.

In contrast with negating or forgetting, the act of endorsing or accepting a member's output can also simultaneously bring multiple cognitive mechanisms in play. As Brown, Coman, and Hirst (2009) and Cuc et al. (2006) have shown, dominant narrators in a conversation can shape the collective memories of a group such that individual recall of the listeners' postgroup recollection reveals more details from the dominant narrator's output (Cuc et al., 2006; for a similar but an independent influence of an expert, see Brown et al.). Thus, experts and dominant narrators can create social contagion effects within a group (Brown et al.). In the parlance of the theoretical framework presented in Figure 1, a dominant speaker creates three types of effects. One, the dominant speaker benefits most from relearning through retrieval by doing most of the talking. Two, the listeners suffer from more silences and hence blocking (or forgetting) of their own details, and three, the listeners receive reexposure effects to the dominant speaker's details. Similar to the effects of the dominant narrator are the effects of members who speak first in a postencoding discussion. Research from the eyewitness memory domain shows that speaking first matters (Gabbert et al., 2006), as does confidence in recall in terms of who persuades whom (Wright et al., 2000). A member who speaks first is less likely to change his or her own later memory after a dispute in group discussion compared with a member who speaks second (Gabbert et al.; Reysen, 2005), regardless of accuracy (Wright et al.).

Thus, silence—or, not contributing recall output—during collaboration can have lasting consequences. That is, memories not recalled during collaboration might not necessarily rebound in later recall. Conversely, relearning through retrieval and reexposure are likely to increase later recall. Together, these cognitive processes increase the overlap in recall among group members and reveal how collective memories are formed through these subcomponents of collaboration.

Consistent with this analysis, we observed increased overlap in postcollaborative individual recall in a traditional collaborative memory paradigm (Blumen & Rajaram, 2008). Participants individually studied a list of unrelated words and took part in different retrieval conditions. Of interest here are two conditions: in one condition, participants first recalled words in collaborative triads and then individually; in another condition, participants collaboratively recalled the words in both recall sessions. On the second recall, in which collaborative and nominal group recalls were compared, we found the seemingly surprising outcome of no collaborative inhibition effect; collaborative recall was no worse than nominal group recall. However, this outcome occurred not because the collaborative group performed better (compared with other collaborative recall conditions), but because the nominal group recall had dropped. This happened because the first collaborative recall session led to more overlap in individual recall later. The increased overlap in recall lowered the nonredundant group responses in the nominal group recall. In other words, the collaborative recall process leads to more overlapping—or shared—memories among the individuals. In line with such demonstrations of shared memories, social coordination through communication has been shown to also give rise to common category structures among people in the study of category acquisition (Markman & Makin, 1998). Thus, collaborative influence on cognition in general and memory in particular bears particular scrutiny in understanding how groups come to share cognitive representations as well as a past.

Collaborative Memory: Implications for Education

The cognitive research and theory on collaborative learning and memory have fundamentally important implications for group learning practices in classrooms. Educational and social psychological research has produced an impressive array of well-developed, group learning methods such as tutored learning, competitive learning, peer-mediated learning (Cohen, 1994) and the methods of cooperative learning (Johnson & Johnson, 2009; Kagan, 1990; Slavin, 1991). The social and interpersonal benefits of these group learning methods are well documented (Johnson & Johnson; Slavin). In light of the complex patterns of cognitive costs and benefits of collaboration we reviewed in this article, collaborative memory research on educationally relevant questions is of both timely and practical importance. Research in this domain has just started to emerge (Gadgil & Nokes, 2009; Meade et al., 2009). As we noted in previous sections, one main goal in our research has been to identify collaborative processes that improve or impair learning and retention and to explore the balance of conditions that maximize memory accuracy gains while minimizing loss or errors from the collaborative process (Barber et al., 2010; Blumen & Rajaram, 2008, 2009; Congleton & Rajaram, 2010; Pereira-Pasarin & Rajaram, 2010a, 2010b; Rajaram & Pereira-Pasarin, 2007). These basic findings have direct implications for exploring educationally relevant questions. Other research reviewed in this article on variables such as expertise (Brown et al., 2009; Meade et al., 2009), dominant narratorship (Cuc et al., 2007), social pressure and social conformity (Reysen, 2003, 2005), and differential learning histories (Congleton & Rajaram) also has direct significance for how learning groups may be formed and what preparation may be recommended for making optimal use of collaborative learning situations.

Concluding Comments

The surge of cognitive research on collaborative memory in recent years opens the path to asking questions of broader significance such as educational practices and group memory and identity from a cognitive perspective. Nearly 125 years of cognitive research on the individual working in isolation has produced the theoretical and empirical foundation upon which such integrative and cross-disciplinary research programs can be built. As research on collaboration and memory further develops to include a variety of other topics, the emerging theoretical analyses may be fruitfully applied also to other practical situations in which group discussions have the potential to shape individual memory such as the effect of political discourse on shaping memories of the public or the effect of business transactions on consequences for the members' later decisions.

In this article, we presented the key empirical findings on collaborative memory and introduced a theoretical framework to specify the cognitive mechanisms that shape memory in a social context. Our aim in presenting a cognitive perspective is not to negate the influence of noncognitive sources on social remembering. On the contrary, a study of social remembering provides a natural "intellectual terrain" for the confluence of social psychological and cognitive perspectives (see Roediger, 2010). As with most complex phenomena, the eventual understanding of social remembering and collective memory involves a multidisciplinary sensibility, one that includes not only social and cognitive psychology, but also perspectives from history, anthropology, sociology, and other related disciplines. We hope that we have elucidated the role of the cognitive processes in shaping socially influenced memories in the individual and within a group.

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The authors declared that they had no conflicts of interest with respect to their authorship or the publication of this article.

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