Journal of Experimental Psychology: General
2017, Vol. 146, No. 9, 1247–1265

0096-3445/17/$12.00 http://dx.doi.org/10.1037/xge0000327

# Mnemonic Transmission, Social Contagion, and Emergence of Collective Memory: Influence of Emotional Valence, Group Structure, and Information Distribution

Hae-Yoon Choi
Stony Brook University

Elizabeth A. Kensinger
Boston College

Suparna Rajaram
Stony Brook University

Social transmission of memory and its consequence on collective memory have generated enduring interdisciplinary interest because of their widespread significance in interpersonal, sociocultural, and political arenas. We tested the influence of 3 key factors—emotional salience of information, group structure, and information distribution—on mnemonic transmission, social contagion, and collective memory. Participants individually studied emotionally salient (negative or positive) and nonemotional (neutral) picture–word pairs that were completely shared, partially shared, or unshared within participant triads, and then completed 3 consecutive recalls in 1 of 3 conditions: individual–individual–individual (control), collaborative–collaborative (identical group; insular structure)–individual, and collaborative–collaborative (reconfigured group; diverse structure)–individual. Collaboration enhanced negative memories especially in insular group structure and especially for shared information, and promoted collective forgetting of positive memories. Diverse group structure reduced this negativity effect. Unequally distributed information led to social contagion that creates false memories; diverse structure propagated a greater variety of false memories whereas insular structure promoted confidence in false recognition and false collective memory. A simultaneous assessment of network structure, information distribution, and emotional valence breaks new ground to specify how network structure shapes the spread of negative memories and false memories, and the emergence of collective memory.

*Keywords:* social transmission of emotional information, group structure, information distribution, collective memory, false memory

*Supplemental materials:* http://dx.doi.org/10.1037/xge0000327.supp



Individuals constantly form and retrieve memories about past events with others in social settings, sometimes with people within a relatively small and insular network (e.g., family, friends, colleagues from one's own institution) and at other times with people in a relatively large and diverse network (i.e., family's friends, friends' friends, colleagues from other institutions, social media connections). In a given social network, members may share some but not all experiences, and as the network becomes larger, the likelihood of a larger variety of information flowing in the network is also expected to increase. As a result, social sharing can promote the spread of not only shared experiences but also unshared experiences that can result in the spread of false memories. For example, three individuals may jointly reconstruct their recent trips to Paris, during which they visited the Louvre. In one scenario (a) all three individuals saw the *Mona Lisa* as well as another painting across the room, the *Wedding at Cana*. Later, all of them remembered the *Mona Lisa* whereas only one of them remembered the *Wedding at Cana*. This group member's recall of the *Wedding at Cana* could trigger others' memory for that painting thereby making the group correctly remember all that they saw. Or, the solo rememberer might discount her own memory of the *Wedding at Cana*, and this would result in the entire group's collective forgetting of parts of their Louvre experience, that is, having seen the *Wedding at Cana*. In another scenario (b) three individuals saw the *Mona Lisa* but only one of them took notice of the *Wedding at Cana.* When these individuals with discrepant initial exposure to the paintings jointly recall the trip later, their shared experience of seeing the *Mona Lisa* has a higher chance of being rehearsed and

This article was published Online First June 8, 2017.

Hae-Yoon Choi, Department of Psychology, Stony Brook University; Elizabeth A. Kensinger, Department of Psychology, Boston College; Suparna Rajaram, Department of Psychology, Stony Brook University.

The research reported herein was in part presented at the 55th annual meeting of Psychonomic Society (Long Beach, CA), at the International Meeting of the Psychonomic Society, 2016 (Granada, Spain), and at the International Conference on Memory 6 (Budapest, Hungary). This research was part of Hae-Yoon Choi's doctoral thesis and in part supported by an American Psychological Association Dissertation Research Award to Hae-Yoon Choi, and by the National Science Foundation Grant 1456928.

Correspondence concerning this article should be addressed to Hae-Yoon Choi, who is now at the Department of Nuclear Medicine, Yonsei University College of Medicine, Seoul, South Korea. E-mail: haeyoon.choi@gmail.com

strengthened while the unshared experience of seeing the *Wedding at Cana* has a higher chance of either being forgotten or being falsely incorporated into the memories of the other two friends. These social networks properties—different group structures and varied distribution of information in the network—describe common yet complex real-world scenarios in which the past is socially shared. How does information from the past flow and coalesce in such social scenarios?

Of related interest in the present study was the question of how social sharing of memories influences the flow of emotional information. Imagine that the three individuals described above were not recounting their visit to the Louvre but instead the details of a robbery they witnessed. These individuals may have had the same vantage point and noticed the same occurrences, in which they would have fully shared information. Or, these individuals may have arrived at the scene at different times, had different vantage points, or noticed different elements of the crime, leading them to have only partially shared information. While extensive cognitive research on memory speaks to how emotional memories are remembered or forgotten by individuals, empirical investigations of socially sharing of emotional memories are sparse. Research in the domain of social psychology suggests that individuals are indeed more likely to socially share information that is emotionally salient (Berger, 2011; Berger & Milkman, 2012; Luminet, Bouts, Delie, Manstead, & Rimé, 2000), and that they do so in order to regulate the negative affect associated with that information, to boost their own positive affect, or to enhance social bonds (see Rimé, 2009 for a review). Such regulatory functions of social sharing have been also investigated in the context of developmental aspects of emotion socialization. For example, cross-cultural studies on mother–child conversations of emotionally salient events have shown that social reminiscence of emotional experience helps children build affiliation with their caregivers as well as develop emotion-coping strategies (Fivush & Wang, 2005; Wang & Fivush, 2005). Meanwhile, research on social sharing of emotion among adults has focused on the act of talking about emotional events such as narrating to someone an experience of watching an intensely negative film (Luminet et al., 2000), or people's intentions or patterns of forwarding emotional news (Berger & Milkman, 2012; Heath, 1996). Such evidence suggests that social sharing is particularly relevant for emotional information, further motivating such questions about its role in shaping transmission of memories as to how sharing emotional information shapes individual and collective memories, how such memories transmit in social networks, and whether the transmission of memories differs for emotional information compared to nonemotional information.

In the present study, we addressed these questions by testing the influence of group structure and information distribution within each group structure on the transmission of emotional and nonemotional information. We leveraged the collaborative memory paradigm to compare insular versus diverse group structures within which social interactions took place (Choi, Blumen, Congleton, & Rajaram, 2014), and we included both shared and unshared information that group members could recall during collaboration (Meade & Gigone, 2011). We presented participants with both emotional and nonemotional information to directly compare the transmission of these two types of memories. A simultaneous test of these dimensions created a rich yet systematic design and provided a prime opportunity to assess the influence of group collaboration on each group member's subsequent individual memory. This design thus provided a highly controlled yet complex simulation of real-world network scenarios in which social transmission of varied memories take place, false memories develop, and collective memories emerge. To further explicate our focus on these factors, we first review key information about the collaborative memory paradigm, past findings on the influences of emotion on individual memory, the phenomenon of social contagion of false memories, and the emergence of collective memory.

## The Collaborative Memory Paradigm

In the collaborative memory paradigm, participants engage in group collaboration to recall information they studied earlier. The group can vary in size, collaborate once or multiple times, working with the same collaborating partners when more than one collaboration opportunity is available. This procedure has yielded a wealth of information about the consequences of social remembering as well as the underlying cognitive mechanisms that influence it (see Rajaram & Maswood, 2017; Rajaram & Pereira-Pasarin, 2010, for reviews). We recently devised a new, reconfigured group methodology to assess how the structure of a group can influence the flow of memories because changes in group structure bring changes in the patterns of collaboration (Choi et al., 2014). We compared identical groups of three members who collaborated twice—thus creating insular networks—to reconfigured groups who also consisted of three members but where the collaborating partners changed across the two collaboration opportunities—thus creating diverse networks. Particularly relevant here are the findings about the influence of group structure on two opposing mechanisms that operate during collaborative recall—*retrieval disruption* and *reexposure*—known to shape group and individual memory (e.g., Basden, Basden, Bryner, & Thomas, 1997; Blumen & Rajaram, 2008) as well as the formation of collective memory (e.g., Congleton & Rajaram, 2011, 2014).

Retrieval disruption is hypothesized to operate during collaboration and produce *collaborative inhibition* in group recall (Basden et al., 1997; Weldon & Bellinger, 1997). Collaborative inhibition is a robust phenomenon where the recall of collaborating groups is lower than the pooled, nonredundant recall of the same number of individuals who recalled alone. Although the collaborative inhibition effect is not a focus of the present study, we briefly review the cognitive mechanisms involved in this phenomenon, and its related consequences, as they relate to questions about mnemonic transmission that is a focus of the present study. According to a prevalent account of collaborative inhibition, namely the retrieval disruption hypothesis, each group member develops an idiosyncratic organization of information at encoding and this organization is disrupted during group recall because listening to the outputs of other group members' recall (that is based on their idiosyncratic organization) during collaboration lowers the recall of each member and thus for the group as a whole.

While collaborative inhibition in group recall occurs readily among collaborating partners, under specific circumstances this robust and disruptive effect can be reduced or eliminated. For example, collaborative inhibition was reduced when participants performed tasks that called for similar retrieval strategies such as cued recall (Finlay, Hitch, & Meudell, 2000) or a recognition task (Clark, Hori, Putnam, & Martin, 2000), or were given the opportunity to strengthen their retrieval organization through repeated study (Pereira-Pasarin & Rajaram, 2011). Further, collaborative inhibition was eliminated or reversed, respectively, when participants repeatedly recalled information prior to collaboration, thereby considerably strengthening their retrieval organization (Congleton & Rajaram, 2011), or when the collaborating group included members with expertise on the subject matter, who could take advantage of a strongly organized knowledge base (Meade, Nokes, & Morrow, 2009). Collaborative inhibition is also eliminated when collaborators work with different partners across two collaboration sessions (Choi et al., 2014), because the disruption effects caused by working with new partners are far exceeded by the benefits of another process, *reexposure* (Blumen & Rajaram, 2008).

Reexposure refers to a mechanism wherein the process of collaborative recall provides a second opportunity to learn the studied information recalled by other group members that a given group member might have failed to recall had she worked alone. As a result, such reexposure increases this group member's postcollaborative individual memory (Basden, Basden, & Henry, 2000; Blumen & Rajaram, 2008; Congleton & Rajaram, 2011; Thorley & Dewhurst, 2007; Weldon & Bellinger, 1997; but see Finlay et al., 2000). In Choi, Blumen, Congleton, and Rajaram (2014), during the second recall opportunity the reexposure benefits were considerably greater for the reconfigured groups than for the identical groups where participants collaborated with the same partners twice. This was because the reconfigured group structure made it possible for participants to be exposed to information they themselves did not recall and their first collaborating partners also did not recall, but the new partners did during collaboration. Participants in the identical group did not have such an opportunity during their second collaboration sessions. In other words, both the identical groups and, to a greater extent, the reconfigured groups suffered retrieval disruption but the reconfigured groups overcame the consequences of disruption by offsetting these with far greater reexposure benefits. These varied patterns of reexposure can be particularly relevant when collaborating partners have been exposed to different information in their past, a scenario we explored in the present study by manipulating the distribution of encoded information among collaborative partners.

## Emotional Memory

The vast majority of information about how retrieval disruption and reexposure mechanisms shape collaborative recall comes from studies where memory for nonemotional or neutral information has been examined. As we noted earlier, social sharing of the past frequently involves sharing of emotional information, and yet scarce evidence is available for how collaborative recall would be modulated by emotionality of the information being remembered. The few studies that have examined this question have focused on the collaborative inhibition effect and reported that it does occur for negatively valenced emotional information (Wessel, Zandstra, Hengeveld, & Moulds, 2015; Yaron-Antar & Nachson, 2006). However, experimental evidence published to date remains sparse as to whether negative valence disrupts socially driven propagation of memories to a greater or lesser extent compared with positively valenced or neutral information, or about the nature of collective memory for emotional information.

When the effect of emotion on memory in individual memory is considered, a large literature shows that individuals typically remember emotionally salient information better than nonemotional information (see Buchanan, 2007; Hamann, 2001 for reviews). This mnemonic advantage for emotion is attributed to various factors that facilitate the prioritized processing of emotional information (e.g., distinctiveness, semantic or conceptual relatedness, arousal, attention, fluency in processing; see Bennion, Ford, Murray, & Kensinger, 2013 for a review). Such benefits for facilitating the prioritized processing of emotion mainly explain the effects of emotion on true memory (i.e., memory accuracy) whereas the findings are less clear and are mixed for memory errors. Errors for emotional information can increase (Brainerd, Stein, Silveira, Rohenkohl, & Reyna, 2008; Gallo, Foster, & Johnson, 2009), decrease (Kensinger & Corkin, 2004; Pesta, Murphy, & Sanders, 2001), or remain unchanged (Choi, Kensinger, & Rajaram, 2013), depending on the methodological details. As such, the predictions for emotional effects on memory errors in a social context are also less clear-cut.

In the present study, we investigated how the robust finding of an emotional enhancement effect in true individual memory manifests in social contexts. As discussed earlier, past empirical research on social sharing of emotion has focused on the act of talking about emotional events (Luminet et al., 2000) or the patterns of online forwarding of emotional news (Berger & Milkman, 2012), and the interesting findings motivate questions about how such behaviors of sharing would shape each individual's emotional memory as well as the memory transmission of emotional information in a network in which the sharing occurs. Recent research shows that online sharing of information (via reposting or forwarding function on social networking sites such as Twitter) can disable information comprehension because making the decision to repost requires cognitive resources that would otherwise be used for cogitating the information (Jiang, Hou, & Wang, 2016). Although this intriguing finding does not specifically speak to the impact on the memory for emotional versus nonemotional information, it suggests that sharing news items may impair the encoding of and the subsequent memory for the information. Together, these lines of work motivate questions about consequences for memory in the social transmission of emotional versus nonemotional information, and the present study directly investigated this question.

## Social Contagion of Memory

A consequence of collaboration is the spread of memory from one person to another by means of interpersonal interactions, a phenomenon also called the social transmission of memory. Memories spread in at least two important ways, one where veridical or true memories are shared and another where people incorporate into their memories information they never experienced but that was passed along by the interacting partner. The concept of social contagion is frequently applied in this second sense to refer to the spread of nonstudied information or false memory (Roediger, Meade, & Bergman, 2001; see Hirst & Echterhoff, 2012 and Rajaram & Pereira-Pasarin, 2010 for reviews). In a typical social contagion paradigm designed to investigate social contagion of errors (Meade & Roediger, 2002; Roediger et al., 2001), participants first study target materials and then engage in a collaborative memory task with a confederate who produces misinformation during the collaboration. Studies employing the social contagion or similar paradigms (e.g., the memory conformity paradigm; Wright, Self, & Justice, 2000) consistently show that memory becomes contaminated with misinformation introduced by others during recall (Basden, Reysen, & Basden, 2002; Meade & Roediger, 2002; Roediger et al., 2001). We have recently shown that emotional memories are not immune to the social contagion of errors in a dyadic situation, although the effect was significantly lower for emotional compared with nonemotional information (Kensinger, Choi, Murray, & Rajaram, 2016).

In the context of these findings, in the present study we examined whether insular networks (consisting of identical groups) versus diverse networks (consisting of reconfigured groups) propagate emotional false memories differently. To probe this question, we introduced both unshared information (known to only one of the three group members) or partially shared information (known to two of the three group members), frequent real-world scenarios where people have in common some but not all of their past experiences (Meade & Gigone, 2011). We then assessed the extent to which such information became a part of a group member's postcollaborative memory via social contagion.

## Collective Memory

Previous work (Choi et al., 2014; Congleton & Rajaram, 2014; Rajaram & Pereira-Pasarin, 2010) has addressed how the aforediscussed mechanisms related to collaborative remembering—retrieval disruption, reexposure, and mnemonic transmission including social contagion of false memories—play a critical role in emergence of another phenomenon of social remembering, namely collective memory (Hirst & Manier, 2008; Roediger, Zaromb, & Butler, 2009; Wertsch & Roediger, 2008). In the social science literatures, the concept of collective memory refers to a shared representation of the past that shapes group identity. In experimental paradigms within psychological research, collective memory is operationally defined as the number of overlapping items that all group members remember or all group members forget in their postcollaborative individual memory (Choi et al., 2014; Congleton & Rajaram, 2014; Cuc, Ozuru, Manier, & Hirst, 2006; Stone, Barnier, Sutton, & Hirst, 2010). We will use the term collective memory in this latter sense. Past work shows that repeated collaborations within the same group promote the formation of collective memory by increasing the overlapping memories among group members (Blumen & Rajaram, 2008), and the joint operations of retrieval disruption and reexposure play an important role in creating such memory convergence (Congleton & Rajaram, 2014). When the role of group structure is considered, collaborative recall within the identical (i.e., insular) as well as the reconfigured (i.e., diverse) groups leads to equivalent amounts of collectively remembered information, but the amount of collectively forgotten information is significantly greater in the identical than in the reconfigured groups (Choi et al., 2014). This outcome occurs because members in reconfigured groups work with a greater diversity of partners who provide a greater variety of information during recall compared with the members in identical groups who are exposed to a smaller number of partners who repeatedly provide comparatively less variety of information. By repeatedly retrieving the same memories with the same partners, the individuals in the identical groups have more collectively forgotten memories.

Because past empirical research on the formation of collective memory has focused on emotionally neutral memories, little is known about collective memory formation for emotionally salient memories in comparison. Would collective memories develop more for emotional than for nonemotional information because emotional information is more memorable? If so, what would be the effect of emotional valence? We drew upon an influential theoretical view that negative valence has a more powerful impact than positive valence—on one's perception about events, interpersonal relationship, information processing, learning, and memory, both in intensity and duration (Baumeister, Bratslavsky, Finkenauer, & Vohs, 2001). This "bad is stronger than good" view is also consistent with the widely reported negativity advantage in individual memory (Kensinger, 2007). If negative valence has such a widespread effect on the individual representation of an event, then it is reasonable to predict that a negativity effect would be observed for shared representations of the event, and that social sharing of emotional information during collaboration would lead to a greater amount of collective memory formation for negative than for positive information. In the present study, we examined this possibility.

Together, the present study addressed the question of how three distinct dimensions that usually coexist in a real-world scenario for social remembering—the emotionality of the remembered information, the network structure of the interacting groups, and the extent to which initial experiences are shared among interacting members—would modulate the consequences of collaboration on the transmission of memory and the formation of collective memory. Specifically, we tested (a) whether collaboration would increase or decrease the correct recall of emotional versus nonemotional information, and/or of negative versus positive information; (b) whether the social contagion of memory for nonstudied information would be different for emotional information; (c) whether the formation of collective memory would be greater or lesser for emotional information, and critically; (d) whether aforementioned questions are modulated by different network structures and/or by initial sharing of the information among group members.

# Method

## Participants and Design

The experiment consisted of a 3 × 3 × 3 mixed design with group structure (III = individual-individual-individual; CCI = collaborative-identical collaborative-individual; and CRI = collaborative-reconfigured collaborative-individual) as a between-subjects factor. Emotional valence (negative, positive, and neutral) and distribution of information among group members (shared, partially shared, unshared) were manipulated as within-subject factors. A total of 216 Stony Brook University students participated for course credit, with 24 triads per condition. Each triad was formed with strangers. With regard to the selection of the sample size, past research (e.g., Basden et al., 1997; Weldon & Bellinger, 1997) has typically used 16 triads (48 participants) per condition and reliably reported the effect of collaboration in recall (i.e., the collaborative inhibition effect). Based on the calculations of effect size of previously reported collaboration effects ($d$ = .44 to $d$ = 2.52;

Basden et al., 1997; Finlay et al., 2000; Weldon & Bellinger, 1997), and using the average effect size ($d$ = 1.11), an alpha level of .05, and two-tailed significance tests, a sample size of 14 triads per condition was needed to ensure power of .80. Additionally, in our previous study (Choi et al., 2014) where we used the group reconfiguration method (identical vs. reconfigured; CCI vs. CRI) with 18 triads per condition, we reported a reliable effect of group configuration in collaborative recall with effect size of $d$ = 1.32. Based on the effect size, an alpha level of .05, and two-tailed significance tests, a sample size of 11 triads per condition was needed to ensure power of .80. Thus, considering the existing literature and our own previous study, we chose to use a sample size of 24 triads per condition to ensure sufficient power for this experimental design and the counterbalancing across study lists for each condition demanded by the design.

## Materials

The stimuli were identical to those used in Choi et al. (2013) and Kensinger, Choi, Murray, and Rajaram (2016). The normative stimuli consisted of 360 categorized photo objects and corresponding word labels in each emotional valence of negative, positive, and neutral (see Figure 1 for an example of each type). There were 15 categories per valence. Based on prior norming studies with 20 college students sampled from the Boston-area, on a valence scale of 1–9 (1 being *the most negative*, 9 being *the most positive*), all negative photo objects were rated as lower than 4, all positive photo objects were rated as higher than 5, and all neutral photo objects were rated between 3 and 6. On an arousal scale of 1–9 (with 1 being *the lowest arousal*, 9 being *the highest arousal*), both negative and positive objects were rated higher than 5 and did not differ ($p > .25$), and all neutral objects were lower than 5. When placing stimuli into the different classes of positive, negative, and neutral, we used the combination of valence and arousal ratings. Therefore, for example, an object rated 3 on valence was classified as neutral if the arousal rating of the object was lower than 5. Also, we use the term *valence* as a shorthand to differentiate the pure effect of valence from the combinational effect of valence and arousal, because both negative and positive stimuli were more arousing than the neutral stimuli but differ along the valence dimension. The items across the three valences did not differ in frequency, familiarity, imageability (norms from the MRC database, all $p > .15$) or in visual complexity ($F$s $< 1.5$, $p$s $> .25$). There were also equivalent numbers of sets that included people, inanimate objects, animals, or landscapes across valence and categories.

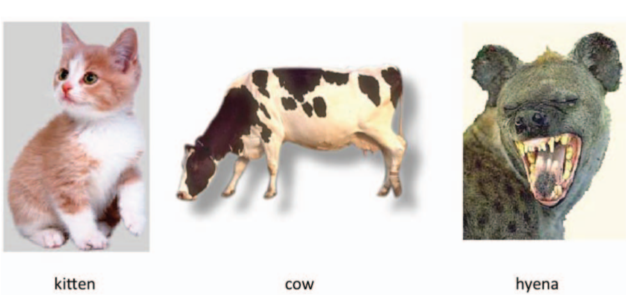


*Figure 1.* Sample pictorial stimuli and verbal labels for each valence (kitten: positive, cow: neutral, hyena: negative). See the online article for the color version of this figure.

There were 15 categories per emotional valence with eight items per each category, resulting in 120 items per valence. Four versions of study lists were created; each study list consisted of three to-be-studied and five not-to-be-studied items from each category, resulting in 135 (45 per valence) studied and 225 nonstudied items associated with each list presented to a given participant. Six different subversions of each study list were created so that 90 study items were shared among all group members, 45 study items were partially shared between two group members, and 45 study items were unshared. The shared, partially shared, unshared items were counterbalanced across study lists.

## Procedure

**Study phase.** In the study phase, each participant was seated at a separate computer and presented with randomly intermixed pictorial stimuli with corresponding word labels, and was asked to provide arousal ratings based on a scale from 1 to 5 (*very low* to *very high*). Each trial included a fixation (1 s) and a study display (5 s). The participants were informed about the upcoming memory test but the nature of the test was unspecified.

In each to-be-triad (that is, participants who would later form nominal triads in the III condition or collaborative triads in the CCI or CRI conditions), all three members studied a total number of 135 items; two of the three members studied 90 identical items (*shared*) and additional 45 identical items (*partially shared*), and the third member studied 90 identical items (shared) and additional 45 items that were not studied by the other two members (*unshared*). The participants were not informed about the unequal distribution of information among group members for the following reasons: First, the main reason to inform the participants about the unequal distribution of information would be to minimize the possibility that they would find the collaborative process unnatural (when listening to other group members producing items not seen before). However, in the present study, the overall number of to-be-unshared items was as small as one item per category. Given that the list of to-be-studied item was relatively long (135 items), we reasoned that participants would be more likely to accept the possibility that they might have forgotten the unshared items recalled by group members than finding the collaborative session strange and unnatural.

Second, it is common practice in the social contagion of memory/misinformation effect/memory conformity paradigms that participants are led to believe that they have studied the same information that their partners have seen. Even when participants were explicitly warned about the possibility that during collaboration partners (confederates) might produce new information that they themselves have not seen, the social contagion effect (i.e., endorsing socially introduced unseen items into one's final memory) persisted, though it reduced in magnitude when compared with the no-warning condition (Meade & Roediger, 2002). Thus, if informing the participants about the possibility of being introduced to unseen information during collaboration would still induce the social contagion effect reliably but would reduce it in magnitude, we reasoned that it was better not to inform the participants so that a stronger test of contagion could be conducted.

**Filled delay.** Immediately following the study phase, participants were given a distractor task (computerized solitaire) for 20 min.

**Recall phase.** The recall test phase was conducted in the same manner as in Choi et al. (2014). Each triad of participants was randomly assigned to one of the three different retrieval conditions. The participants in the individual condition (III) completed three recall sessions individually to serve as the baseline recall. The participants in the identical collaborative condition (CCI) completed the first recall session collaboratively in a group of three, completed the second recall session with the same group of people, hence creating an insular network, and then completed the last recall session individually. Finally, the participants in the reconfigured collaborative condition (CRI) completed the first recall session collaboratively in a group of three, and unlike the identical condition, they completed the second recall session in a different group of three people (see Figure 2). This meant that nine participants were tested at the same time to ensure full reconfiguration in any given experimental session, hence creating a diverse network. Each of these nine members in the reconfigured groups completed the third recall session individually, like the participants in the other two conditions.

For each recall session, participants were instructed to write down in any order as many words as they could recall as a group (in the case of the first and second sessions in the CCI and CRI conditions) or individually (in the case of all three recall sessions in the III condition and the last recall session in the CCI and CRI conditions) from the list they originally studied. Participants in collaborative conditions were instructed to collaborate in a free-flowing form (Weldon & Bellinger, 1997) where they were free to contribute in any order, discuss their recall and settle their disagreements as they wished. This procedure is more naturalistic than and differs from a turn-taking approach (Basden et al., 1997) procedure where participants are required to wait until it is their turn to recall, and thus are not able to correct or comment on each other's output. Each recall session was set for a maximum of 10 min as this duration was found to be sufficient in pilot experiments. There were 2-min breaks between the recall sessions. During the break, participants were asked to remain seated and to not chat with their group partners. The entire experimental session took approximately 2 hr.

**Recognition phase.** Following the completion of recall sessions, a self-paced individual recognition task was given to all participants in order to assess the final individual memory with an additional measure. Participants were shown 360 items (135 studied, 225 nonstudied; these 225 nonstudied items were unshared items that potentially could have been introduced during collaboration by other group members), and completed a recognition/confidence rating task. When an item is prompted on the screen, participants were asked to decide between *old* (meaning they studied the word) and *new* (meaning they did not study the word), followed by confidence ratings about their old/new judgment based on a scale from 1 to 5 (1 being *not confident at all*, 5 being *very confident*). The participants were instructed, with emphasis, that the old/new decision must be made with respect to only their own study list that they saw during the first study phase.

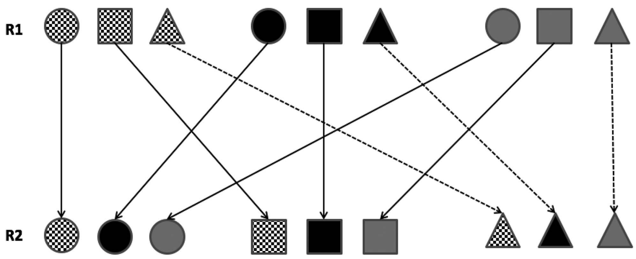


*Figure 2.* Group configuration across Recall 1 to Recall 2 in the reconfigured (CRI) groups. Each different shape or filled pattern denotes an individual within a group.

## Results

The goal of the present study was to examine how social interactions influence memory for negative, positive, and neutral information within each of two different group structures where information was either seen by all or by only some group members. We examined these consequences on group recall during collaboration, on individual memory after collaboration (postcollaborative individual recall and individual recognition memory), on the social contagion of false memories, and on the emergence of collective memory. Unless specified, the analyses were conducted on measures of accurate memory, and an overview of the accurate memory performance for each retrieval condition is shown in Figure 3. Intrusions on recall assessments did not occur with enough frequency to analyze (0%–2% range), and thus, are not presented.

Analyses of variance (ANOVAs) were conducted primarily with the between-subjects factor of group structure (III = individual-individual-individual; CCI = collaborative-identical collaborative-individual; CRI = collaborative-reconfigured collaborative-individual) and the within-subject factor of emotional valence (negative, neutral, positive). Where appropriate, additional ANOVAs examined the effect of information distribution at encoding (shared = items that all three group members studied initially; partially shared = items that two of the three group members studied initially; unshared = items that only one of the three group members studied initially.) Bonferroni correction was used for all multiple comparisons, with a significance level of .015.

The results are presented in the following order: (a) baseline analyses of recall and recognition from the individual (control-III) condition; (b) memory transmission as a function of information distribution and emotion in (b1) group recall and (b2) postcollaborative individual memory; (c) social contagion of false memory; and (d) the emergence of collective memory.

### Baseline Analyses:[1] Individual Memory Findings

In the III condition, only the variable of emotional valence was relevant since the variables of information distribution and group structure were manipulated specifically in the collaboration con-

[1] The baseline analyses included a calculation of the collaborative inhibition effect in group recall (i.e., the first recall of the CCI and the CRI conditions). The goals of the present study did not focus on the collaborative inhibition effect, but because the design offered an opportunity to assess the effect, we present these findings in the Appendix.

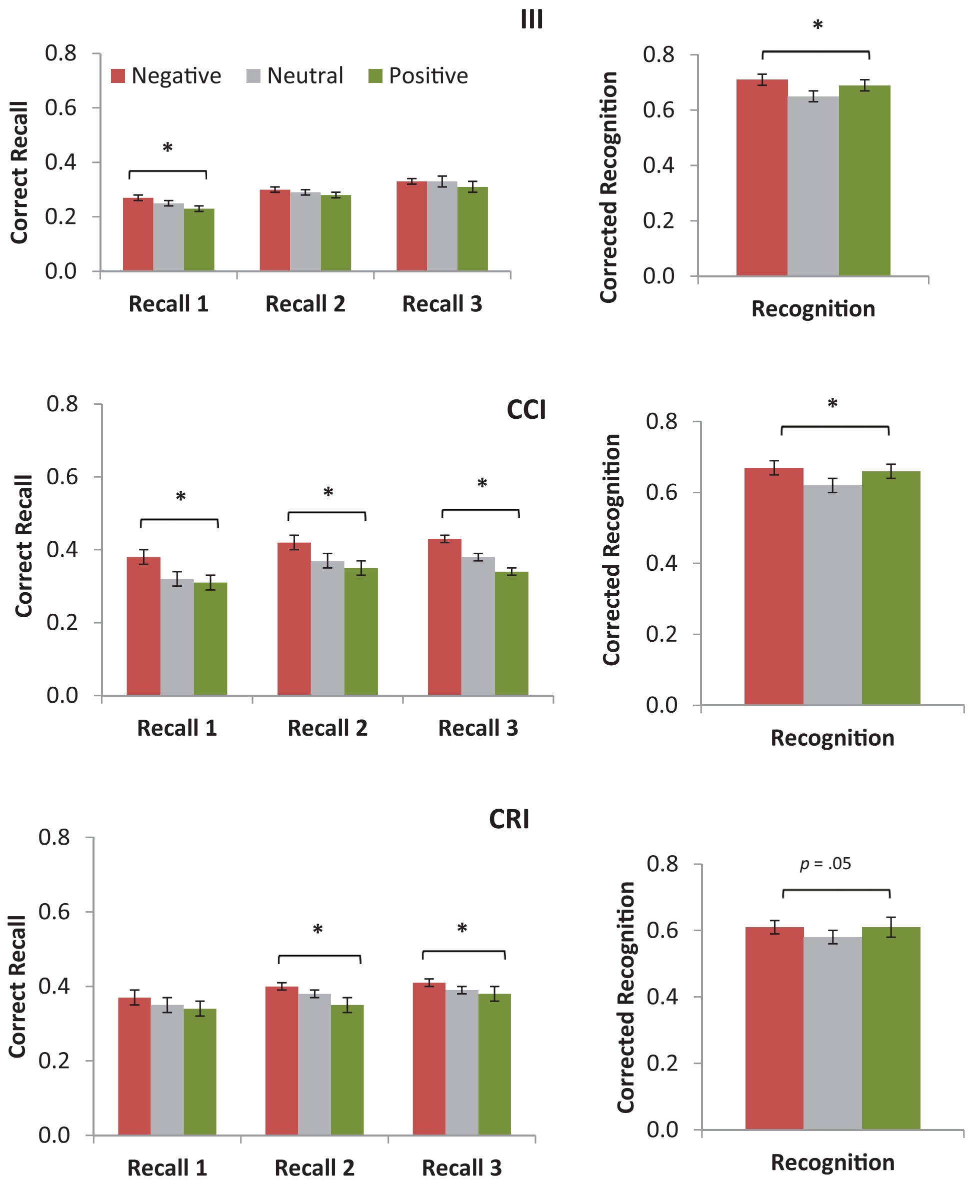


*Figure 3.* Overall correct recall and corrected recognition performance for each retrieval condition. * $p < .05$. See the online article for the color version of this figure.



ditions (CCI and CRI). As such, the effect of emotional valence was tested in the III condition to assess the baseline recall levels when individuals worked alone (see Figure 3). During the first recall session (Recall 1), a repeated measures of ANOVA revealed a significant effect of emotion, $F(2, 142) = 4.76$, $MSe = .006$, $p = .01$, $\eta_p^2 = .06$. The effect was directional, where the recall rates were highest for negative ($M = .27$, $SE = .01$), intermediate for neutral ($M = .25$, $SE = .01$), and lowest for positive items ($M = .23$, $SE = .01$). Subsequent *t* tests indicated a significant difference between the recall rates for negative and positive items, $t(71) = 3.20$, $SE = .01$, $p = .002$, $d = .42$, with no difference between negative and neutral, nor between neutral and positive items, $ps > .10$.

Interestingly, the negativity effect observed during Recall 1 disappeared in the subsequent individual recall sessions, $ps > .30$. To examine this disappearance of the valence effect, we tested *hypermnesia* (i.e., improved recall over time as a function of repeated recall attempts without additional study; Payne, 1987). Recall rates across Recall 1 to Recall 2 significantly increased, indicating a hypermnesia effect, $F(1, 71) = 101.89$, $MSe = .001$, $p < .001$, $\eta_p^2 = .59$. A significant interaction between valence and recall sequence, $F(2, 142) = 3.73$, $MSe = .001$, $p = .03$, $\eta_p^2 = .05$, indicated that the magnitude of hypermnesia varied for each valence, with the largest magnitude for positive (4.7%), intermediate for neutral (3.5%), and the smallest for negative items (2.5%). Hypermnesia across Recall 2 to Recall 3 was also significant, $F(1, 71) = 56.42$, $MSe = .002$, $p < .001$, $\eta_p^2 = .44$. The magnitude of the effect also varied for each valence (2.7% for negative, 4.4% for neutral, and 2.9% for positive) although the interaction did not reach significance, $p = .12$. These results indicate that when individuals are confronted with the task of recalling by themselves a large number of memories, they are, at first, prone to recall negative memories. But as they continue to search their memories across repeated retrieval attempts, they increasingly start to recall neutral and positive memories, finally resulting in no emotional valence effect in recall. We return to this novel finding in the General Discussion section.

Importantly, although the recall benefit for emotional information attenuated in the recall measure across the three attempts, an emotional memory advantage was present in the recognition task that followed the completion of the recall sessions, as revealed by a main effect of valence on the corrected recognition measure, $F(2, 142) = 9.55$, $MSe = .01$, $p < .001$, $\eta_p^2 = .12$. Pairwise comparisons indicated that both negative and positive information were recognized with better accuracy than neutral information, $ps < .01$, with no difference between negative and positive valence, $p = .18$. These recognition results provide a replication of the standard enhanced memory effect of emotion in individual memory. We return to the individual memory findings again when we consider the findings from the group recall and postcollaborative memory stages.

## The Effect of Emotional Valence and Information Distribution on Memory Transmission

We first report the effects of emotional valence and information distribution for participants within a single group recall condition (CCI or CRI). We report the results within each of these conditions separately for the first recall session (denoted by **C**CI or **C**RI, where the bolded text indicates the session being analyzed) and the second recall session (C**C**I or C**R**I), both of which constitute group recall sessions. We then directly compare the effects of group assignment by comparing the final, individual recall, as a function of the condition assignment (CC**I**, CR**I**, or baseline II**I**).

**Group recall.** The group retrieval conditions were designed to test both the influence of unequal information distribution at study and the influence of emotional valence on mnemonic transmission across different group structures. Table 1 displays the proportions of correct recall as a function of information distribution (i.e., whether study items were shared, partially shared, or unshared among group members) and emotional valence for the two group retrieval conditions—CCI (identical groups) and CRI (reconfigured groups).

**CCI condition.** At Recall 1(**C**CI), a 3 (Information Distribution; Shared, Partially shared, Unshared) × 3 (Emotional Valence; Negative, Neutral, Positive) repeated ANOVA revealed a significant effect of information distribution, $F(2, 46) = 76.86$, $MSe = .01$, $p < .001$, $\eta_p^2 = .77$, as the shared items were recalled more frequently than the partially shared items, $t(23) = 6.51$, $SE = .02$, $p < .001$, $d = 1.46$, and the partially shared items were recalled more frequently than the unshared items, $t(23) = 5.51$, $p < .001$, $SE = .02$, $d = 1.63$. The effect of emotional valence was also significant, $F(2, 46) = 4.49$, $MSe = .02$, $p = .02$, $\eta_p^2 = .16$, and this effect was largely driven by higher recall rates for negative items than positive items. The interaction between information distribution and emotional valence was not significant, $p = .33$, indicating an equivalent boost from collaboration on the recall of negative information for shared, partially shared, as well as unshared information during the first collaborative recall attempt. A numerical pattern was nonetheless present such that the contrasts between recall rates for negative and positive items were greater for shared (.08) and partially shared (.11) items than for unshared items (.02).

During the second recall session, C**C**I, both the effect of information distribution and emotional valence continued to be significant, $F(2, 46) = 75.31$, $MSe = .02$, $p < .001$, $\eta_p^2 = .77$, $F(2, 46) = 3.31$, $MSe = .02$, $p = .045$, $\eta_p^2 = .13$, respectively. Interestingly, there was a marginally significant interaction, $F(4, 92) = 2.22$, $MSe = .02$, $p = .07$, $\eta_p^2 = .09$. While the marginal nature of the interaction calls for caution, this pattern is consistent across the CCI condition and the CRI condition below, and it shows greater recall of negative items than positive items when the items were shared and partially shared, but an increase in the recall of unshared positive items. These results suggest that collaborative recall promotes recall of negative information when such information is largely shared but this negativity effect is attenuated for unshared information.

**CRI condition.** The first recall (**C**RI) revealed a significant effect of information distribution, $F(2, 46) = 67.47$, $MSe = .02$, $p < .001$, $\eta_p^2 = .75$, but the effect of emotional valence was not significant, $p = .57$. The interaction did not reach significance, $p = .11$, although the numerical contrasts between recall rates for negative and positive items showed that negative items were remembered better than positive items when they were shared (.04) or partially shared (.05), but such patterns were numerically reversed for unshared items (−.03; see Table 1). This reversed pattern for the unshared items likely led to the overall absence of

Table 1
*Mean Proportion of Shared, Partially Shared, and Unshared Items Correctly Recalled as a Function of Retrieval Condition and Emotional Valence*

| Information distribution | Shared | | | Partially shared | | | Unshared | | |
|---|---|---|---|---|---|---|---|---|---|
| Emotional valence | Negative | Neutral | Positive | Negative | Neutral | Positive | Negative | Neutral | Positive |
| Recall 1 | | | | | | | | | |
| CCI | .47 (.02) | .40 (.02) | .39 (.02) | .37 (.03) | .31 (.03) | .26 (.02) | .20 (.03) | .15 (.02) | .19 (.02) |
| CRI | .47 (.02) | .43 (.02) | .43 (.03) | .33 (.03) | .34 (.02) | .28 (.03) | .20 (.02) | .20 (.02) | .23 (.03) |
| Recall 2 | | | | | | | | | |
| CCI | .52 (.03) | .46 (.02) | .44 (.02) | .41 (.03) | .37 (.03) | .31 (.02) | .21 (.03) | .17 (.03) | .22 (.03) |
| CRI | .58 (.02) | .54 (.02) | .52 (.02) | .26 (.02) | .24 (.02) | .19 (.02) | .20 (.02) | .23 (.03) | .25 (.02) |

*Note*. Standard errors are shown in parentheses.

valence effect by reducing the negativity effect that was present for the shared and partially shared items.

For the analyses on the second recall, CRI, an ANOVA was conducted for each level of information distribution separately because the variable was, by design, different across Recall 1 and Recall 2 in the CRI condition. Unlike the first collaborative recall session of the same condition where every triad had all shared, partially shared, and unshared items, during the second collaborative recall session, two thirds of the triads always had only shared or partially shared items from the previous session of collaboration whereas one third of the triads always had only shared and unshared items. Thus, such distribution required separate analyses for each level of the variable.

For shared items, there was a significant effect of emotional valence, $F(2, 46) = 4.92$, $MSe = .01$, $p = .01$, $\eta_p^2 = .18$. Negative items were recalled significantly better than positive items, $t(23) = 2.64$, $SE = .03$, $p = .015$, $d = .54$, with no difference between negative and neutral items, nor between neutral and positive items, $p = .10$, $p = .07$, respectively. For partially shared items, a similar pattern emerged such that there was a significant effect of emotional valence, $F(2, 30) = 5.25$, $MSe = .004$, $p = .01$, $\eta_p^2 = .26$, and negative items were recalled significantly better than positive items, $t(15) = 3.30$, $SE = .02$, $p = .01$, $d = .87$, with no difference between negative and neutral items, nor between neutral and positive items, $p = .37$, $p = .04$, respectively. The differences across emotional valence were not significant for the unshared items, $p = .13$, although the numerical patterns were consistent with what was found in the CCI condition (positive > neutral > = negative) as well as in the first recall of the CRI. These patterns cohered with the findings in the CCI condition above, as the results for the CRI condition again show that even when people switch into new groups and collaborate with new partners, they remembered more negative information than positive information when the information was fully or partially shared with the other group members. However, when information was unshared, the propensity to recall more negative than positive memories disappears, regardless of group structure or attempts at recall.

In summary, collaboration boosted the recall of negative information to a greater extent than the recall of positive information. Also, across both the identical group (CCI) and reconfigured group (CRI) conditions, there was a consistent pattern of emotional valence such that negative items were remembered the best during group recall whenever the items overlapped during study across at least two of three group members. In other words, people are more likely to remember shared negative memories when they interactively retrieve the past, and this effect is robust enough to persist even when the retrieval interactions take place with different partners. Together, these patterns show that collaboration enhances recall of negative memories especially when the initial exposure to the negative information largely overlapped among the collaborating partners. In sum, the negativity effect persists with repeated group recall whereas, in contrast, it disappears in repeated individual recall as we reported earlier.

**Postcollaborative individual memory.** The postcollaborative memory was measured via the final individual recall task, along with a following individual recognition task. Each measure included both correct memory (i.e., correct recall or recognition of studied items) as well as false memory from social contagion (i.e., false recall or false recognition of items that were not studied but were produced by the partners during either of the previous collaborative recall sessions). We present the correct memory results in this section and the false memory results in the next section (Social Contagion of False Memory).

**Final individual recall.** In order to examine the effect of emotional valence of studied information and subsequent collaboration on final individual memory, the first set of analyses on the recall data focused on the group structure (including the III baseline) and emotional valence, collapsing across information distribution. A 3 × 3 ANOVA revealed a significant effect of group structure, $F(2, 213) = 10.06$, $MSe = .03$, $p < .001$, $\eta_p^2 = .09$, a significant effect of valence, $F(2, 426) = 13.89$, $MSe = .01$, $p < .001$, $\eta_p^2 = .06$, as well as a significant interaction, $F(4, 426) = 3.69$, $MSe = .01$, $p = .01$, $\eta_p^2 = .03$. Subsequent ANOVAs examined these main effects and interaction. When the III and CCI retrieval conditions were compared, there was a main effect of collaboration, $F(1, 142) = 14.80$, $MSe = .03$, $p < .001$, $\eta_p^2 = .09$, and a main effect of emotional valence, $F(2, 284) = 10.85$, $MSe = .01$, $p < .001$, $\eta_p^2 = .07$, as well as a significant interaction, $F(2, 284) = 5.83$, $MSe = .01$, $p = .003$, $\eta_p^2 = .04$. Follow-up comparisons indicated that the effect of collaboration was significantly greater only for negative items, $t(142) = 5.25$, $SE = .02$, $p < .001$, $d = .87$, while it was marginal for neutral items ($p = .03$) and nonsignificant for positive items ($p = .12$) items. When the III and CRI retrieval conditions were compared, there was a main effect of collaboration, $F(1, 142) = 14.32$, $MSe = .04$, $p < .001$, $\eta_p^2 = .09$, as well as a marginal effect of emotional valence, $F(2, 284) = 3.12$, $MSe = .01$, $p = .05$, $\eta_p^2 = .02$, but no interaction, $p = .31$. Finally, when the CCI and CRI retrieval conditions were compared, only the main effect of emotional valence reached significance, $F(2, 284) = 16.67$, $MSe = .01$, $p < .001$, $\eta_p^2 = .11$, with no main effect of group structure, $F < 1$. However, the interaction between the two factors was significant, $F(2, 284) = 3.37$, $MSe = .01$, $p = .03$, $\eta_p^2 = .02$, revealing a greater negativity effect in the CCI than in the CRI conditions. In brief, identical group collaborations led to a greater negative effect in postcollaborative memory compared with the baseline individual recall as well as reconfigured group collaborations. In other words, the more people collaborate, and collaborate with the same partners, the more likely they are to recall negative information.

Next, we examined the effects of information distribution and emotional valence in the two collaborative conditions (see Figure 4). In the CCI condition, significant effects of emotional valence were found both for shared and partially shared items, $F(2, 142) = 11.34$, $MSe = .01$, $p < .001$, $\eta_p^2 = .14$, $F(2, 94) = 7.10$, $p < .001$, $MSe = .01$, $\eta_p^2 = .13$, and in both cases the effect of emotional valence was directional (negative > neutral > positive). For shared items, recall rates were higher for negative items than both neutral and positive items, $t(71) = 2.84$, $SE = .02$, $p = .006$, $d = .48$, and $t(71) = 4.65$, $SEM = .02$, $p < .001$, $d = .75$, respectively, with no difference between neutral and positive items, $p = .09$. For partially shared items, recall rates for both negative and neutral items were higher than positive items, $t(47) = 3.19$, $SE = .03$, $p = .003$, $d = .61$, $t(47) = 3.27$, $SE = .02$, $p = .002$, $d = .58$, with no difference between negative and neutral items, $t < 1$. Lastly, there was no effect of emotional valence for unshared items, $p = .30$. These patterns in the CCI condition for postcollaborative individual recall (Recall 3) were similar to the patterns observed in group recall (Recall 2), and underscored the pattern that, in insular

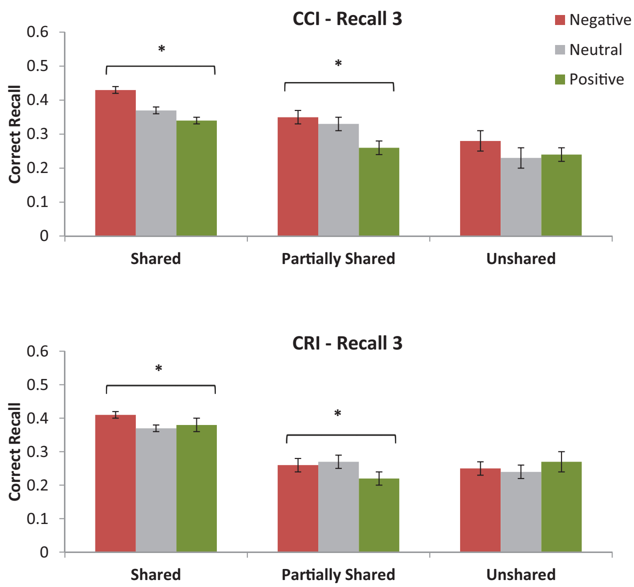


*Figure 4.* Proportions of correct recall from the postcollaborative individual recall in the CCI and CRI condition as a function of information distribution and emotional valence. * $p < .05$. See the online article for the color version of this figure.

groups, mnemonic transmission was more pronounced for negative information compared with positive and neutral information.

Next, in the CRI (reconfigured group) condition, the effect of emotional valence for shared items was once again significant, $F(2, 142) = 3.57$, $MSe = .01$, $p = .03$, $\eta_p^2 = .06$. Pairwise comparisons indicated that this effect was driven by a significant difference between negative and neutral items, $t(71) = .02$, $SE = .02$, $p = .005$, $d = .42$. The difference between negative and positive items, which was significant in the CCI condition, failed to reach significance, $p = .07$ after Bonferroni correction. Neutral and positive items did not differ, $p = .60$. For partially shared items, the effect of emotional valence was also significant, $F(2, 94) = 3.37$, $MSe = .01$, $p = .04$, $\eta_p^2 = .07$, and was driven by a marginally significant difference between neutral and positive items, $t(47) = 2.4$, $SE = .02$, $p = .02$, $d = .3$. Again, pairwise comparisons revealed that the difference between negative and positive items, which was significant in the CCI condition, was numerically reduced and not significant $p = .08$. There was no difference between negative and neutral items, $p = .82$. Lastly, as it was in the CCI condition, there was no effect of valence for unshared items, $p = .62$.

In brief, postcollaborative individual recall showed a consistent negativity effect in the recall of shared items and an absence of this effect in the recall of unshared items for all participants, regardless of whether they previously collaborated in identical (insular) or reconfigured (diverse) groups. The difference between the influence of identical and reconfigured groups on the mnemonic transmission of emotional information emerged for partially shared items. Specifically, the negativity effect was weaker or disappeared in the recall of partially shared items for participants who previously collaborated in the reconfigured (diverse) group condition compared with those who collaborated in the identical (insular) group condition. This effect of group structure shows that collaboration with an increased number of partners—where the number of partially shared items also increases—attenuates the negativity effect in postcollaborative individual recall. As a general note about these and the other results we have reported, we treat the conclusions derived from the null findings or from marginal trends with caution, and the conclusions we have drawn are based on the convergence of patterns across different conditions and measures.

Together, findings from postcollaborative recall converge to show that jointly recalling the past with same partners repeatedly makes negative memories stronger, and particularly so if these memories were a part of everyone's past, compared to recalling with a wider set of partners where a larger set of memories may be discussed.

**Final individual recognition.** The final recognition task served as an additional measure to assess the effect of emotional valence on postcollaborative individual memory in the group retrieval conditions (CCI and CRI). We analyzed the recognition data for hits and false alarms separately (in addition to the corrected recognition measure; see Figure 3) because it enabled an assessment of the confidence judgment for each recognition response, and our theoretical interests also called for a separate examination of false alarms (reported in the next section on Social Contagion).

For accurate recognition, the corrected recognition and hits data produced the same patterns; therefore we report the analyses for hits along with their confidence ratings. Overall, a 3 (Group Structure) × 3 (Emotional Valence) ANOVA on hits revealed a main effect of emotional valence, $F(2, 426) = 18.79$, $MSe = .003$, $p < .001$, $\eta_p^2 = .08$, with no main effect of group structure, $F < 1$, nor interaction, $p = .31$. In the CCI condition, pairwise comparisons indicated that both negative ($M = .83$, $SE = .01$) and positive ($M = .82$, $SE = .02$) items were recognized better than neutral items ($M = .78$, $SE = .02$); for negative items, $t(71) = 4.26$, $SE = .01$, $p < .001$, $d = .42$, and for positive items, $t(71) = 3.47$, $SE = .01$, $p = .001$, $d = .31$, with no significant difference between negative and positive items, $t(71) = 1.70$, $SE = .01$, $p = .09$, after Bonferroni correction. The confidence ratings for the recognition judgments to each emotional valence followed the recognition patterns, with negative and positive items being recognized with greater confidence (for negative items, $M = 4.75$, $SE = .07$; for neutral items, $M = 4.72$, $SE = .07$; and for positive items, $M = 4.73$, $SE = .07$) although the differences were only marginally significant, $F(2, 142) = 2.57$, $MSe = .01$, $p = .08$, $\eta_p^2 = .04$.

In the CRI condition, pairwise comparisons revealed that negative items ($M = .83$, $SE = .02$) were recognized significantly better than neutral items ($M = .81$, $SE = .02$), $t(71) = 3.04$, $SE = .01$, $p = .003$, $d = .24$, and recognized marginally better than positive items ($M = .81$, $SE = .02$), $t(71) = 2.21$, $SE = .01$, $p = .03$, $d = .15$. There was no difference between neutral and positive items, $t < 1$. The confidence ratings for recognition judgments to each emotional valence followed the same patterns (for negative items: $M = 4.77$, $SE = .05$; for neutral items: $M = 4.67$, $SE = .06$; and for positive items: $M = 4.73$, $SE = .06$), and the differences reached statistical significance, $F(2, 142) = 10.12$, $MSe = .02$, $p < .001$, $\eta_p^2 = .13$.

In sum, like the recall data, recognition performance was also higher for the negative information than for neutral information.

However, unlike the recall data, recognition of positive information was also better than for neutral information especially in the CCI condition. These findings show a replication of past findings on the recognition memory for emotional information (e.g., Choi et al., 2013; Ochsner, 2000), and suggest that the easier recognition task produced equivalent advantage for negative and positive memories whereas the more difficult recall task revealed better access to negative memories. There are also a small number of studies in the literature that are broadly consistent with the pattern we report (Emery & Hess, 2008; Wang & Fu, 2011), whereby the benefit for negative over positive memory exists on tests of recall but not recognition. However, this difference is not consistently revealed in the literature examining individual recall and recognition of negative and positive stimuli, and since in our study the recognition task took place after three retrieval attempts at recall, a direct comparison with prior studies is also not feasible. We return to these findings in the General Discussion section.

## Social Contagion and Creation of False Memory

As one of the main interests in this study was to assess the influence of network structure on the transmission of false memories, we assessed whether social contagion creates false memory at two levels—the network level and the individual level. At the network level, we assessed the total amount of false memories floating in each of the two network structures, CCI (identical/insular) and CRI (reconfigured/diverse). At the individual level, we assessed the final, postcollaborative individual memory for items that a given participant had not initially studied but that were recalled by her partners during collaboration. In this analysis of individual-level false memory, we examined both false recall and false recognition along with the confidence judgment for the latter.

To measure network-level false recall, we pooled the nonredundant recall of initially nonstudied items in the final individual recall of participants who had earlier collaborated either in an identical (CCI) or a reconfigured (CRI) group (see Figure 5A). There was greater nonredundancy in pooled false recall in the CRI condition than in the CCI condition, $F(1, 46) = 33.40$, $MSe = .003$, $p < .001$, $\eta_p^2 = .42$. This pattern indicates that the total amount of social contagion distributed within an interacting group was much greater when people were exposed to more new information as they changed partners across recall attempts than when they collaborated with the same partners. These patterns were not

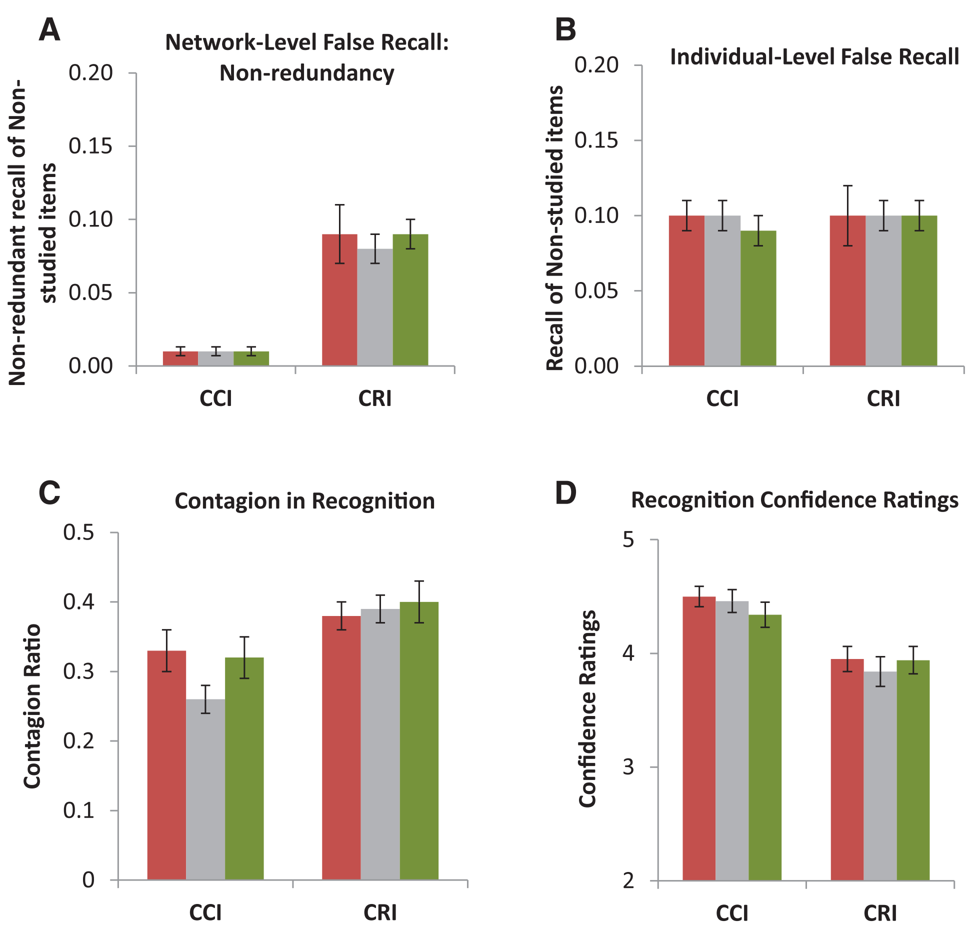


*Figure 5.* (A, top left) Nonredundant false recall in triads; (B, top right) Individual false recall; (C, bottom left) Contagion ratio in individual false recognition; (D, bottom right) Confidence ratings for false recognition of contagion items. See the online article for the color version of this figure.

affected by emotional valence, and there was no interaction between valence and group structure, $F$s $< 1$.

At the individual-level (see Figure 5B), false recall did not differ across the group structures of CCI and CRI, nor as a function of emotional valence or the interaction, $F$s $< 1$. However, the effects of social contagion were evident in recognition memory. To measure social contagion in recognition memory, a contagion ratio was computed. We first computed total false alarms (the proportions of incorrect *old* responses given to nonstudied items), and this measure included both pure false alarms (*old* responses to items that were neither studied nor produced by any of the partners during the previous collaborative recall sessions) and contagion false alarms (*old* responses to the items that were not studied by a target participant but were produced by any of her partners during either of the previous collaborative recall sessions). A contagion ratio was calculated as the ratio between the proportion of contagion false alarms and the total false alarms for each individual participant (see Figure 5C). The analysis of the contagion ratios revealed a significant difference across the two group structures of CCI and CRI, $F(1, 142) = 9.37$, $MSe = .08$, $p = .003$, $\eta_p^2 = .06$, such that the contagion ratio was significantly greater for CRI than for CCI. There was no effect of emotional valence, $p = .11$, or interaction, $p = .14$. These results indicate that social contagion increased in postcollaborative recognition memory when the number of collaborating partners increased; this finding is also in line with greater social contagion observed at the network-level in the CRI condition than in the CCI condition.

Interestingly, and in keeping with intuition, repeated collaboration with the same partners in the identical group (CCI) condition led to greater confidence in falsely recognizing contagion items as one's own studied items (see Figure 5D). In other words, although participants who worked in identical groups endorsed fewer nonstudied items as having been studied at the network level, they did so with much greater confidence than the participants in the CRI condition, $F(1, 118) = 10.57$, $MSe = 1.99$, $p = .001$, $\eta_p^2 = .08$. These confidence ratings were not influenced by emotional valence, and there was no interaction, $F$s $< 1$. The differential effects of network structures on confidence for socially acquired false memory was further underscored by an absence of differences across the network structures for Pure False Alarm judgments, where social influence was absent, $F$s$< 1$ (in the CCI condition: for negative, $M = 3.67$, $SE = .11$; for neutral, $M = 3.48$, $SE = .10$; and for positive, $M = 3.48$, $SE = .11$; and in the CRI condition: for negative, $M = 3.55$, $SE = .10$; for neutral, $M = 3.34$, $SE = .11$; and for positive, $M = 3.46$, $SE = .11$). Finally, it is interesting to note that participants in both conditions were confident about their false recognition judgments; ratings that were on the upper end of the scale (3 = *somewhat confident*, 5 = *very confident*) even with the explicit instructions to make the recognition judgment solely from their own study items. These findings are in line with past reports where people indicated strong confidence in their false recognition of misinformation induced through social influence (Basden et al., 2002; Cuc et al., 2006).

In brief, diverse networks with more members increased the availability of false information and led to higher levels of social contagion for each member's recognition memory whereas insular networks with repeated exposure to the same information reinforced the false memories and boosted the participants' confidence in false judgments despite an explicit warning against social influence. In other words, exposure to a wider network of people increases false memories whereas collaborating in a smaller, insular community increases false confidence. We will return to the spread of social contagion in the next section where we present the findings for the false memory contagion at the *collective* level.

## Collective Memory

Collective memory was computed in three ways. Following the standard practice in past works (e.g., Choi et al., 2014), (a) we first computed the overlaps in postcollaborative recall of three former group members, both for collectively remembered and collectively forgotten memories: (a1) collective recollection scores, the proportions of items that all group members initially studied and later remembered in their postcollaborative individual recall; (a2) collective forgetting scores, the proportions of items that all group members studied but collectively failed to remember in their postcollaborative individual recall. However, because this calculation involves only the *shared* items, it does not capture the process in which mnemonic convergence occurs for *partially shared* items. Thus, (b) we second computed the collective recollection and collective forgetting between two group members who studied *partially shared* items. Lastly, (c) we computed collective recollection of nonstudied items between two group members (i.e., collective false memory; the proportions of *unshared* items that two group members did not study but falsely recalled in their postcollaborative individual recall after being exposed to the items via the third member; see Figure 6).

**Collective memory for shared information.** As expected, collective recollection of shared items among three group members (see Figure 6A) was greater both in the CCI and CRI conditions compared with the baseline III condition, $p$s $< .001$. The comparison between CCI and CRI conditions revealed a significantly greater collective recollection in the CCI than in the CRI condition, $F(2, 69) = 5.67$, $MSe = .01$, $p = .02$, $\eta_p^2 = .11$, with a significant effect of emotional valence, $F(2, 92) = 5.24$, $MSe = .01$, $p = .007$, $\eta_p^2 = .10$. There was no interaction, $p = .35$. Subsequent ANOVAs revealed a significant effect of emotional valence in the CCI condition, $F(2, 46) = 3.52$, $MSe = .01$, $p = .04$, $\eta_p^2 = .13$, and pairwise comparisons revealed that collective recollection of negative items was marginally greater than for neutral and positive items after Bonferroni correction, $t(23) = 2.08$, $SEM = .03$, $p = .05$, $d = .62$, $t(23) = 2.18$, $SEM = .02$, $p = .04$. $d = .67$, respectively. In the CRI condition, the marginal effect of valence was in the same direction as in the CCI condition, $F(2, 46) = 2.56$, $MSe = .01$, $p = .09$, $\eta_p^2 = .10$.

Next we examined collective forgetting of shared items among three group members (see Figure 6A). In the comparison between the baseline III condition and the CCI condition, collective forgetting was greater in the CCI, $F(1, 46) = 14.60$, $p < .001$, $MSe = .02$, $\eta_p^2 = .24$, with no effect of valence, $p = .13$. However, interestingly, there was a significant interaction, $F(2, 92) = 4.02$, $p = .02$, $MSe = .01$, $\eta_p^2 = .08$, revealing greater collective forgetting in the CCI condition for both neutral and positive items ($p = .003$, $p < .001$, respectively) but not for negative items ($p = .41$). Next, in the comparison between the III and the CRI condition, collective forgetting did not differ between the two conditions ($F < 1$) and there was no effect of valence, either ($p = .35$), but the interaction between the two factors was marginal, $F(2, 92) =$

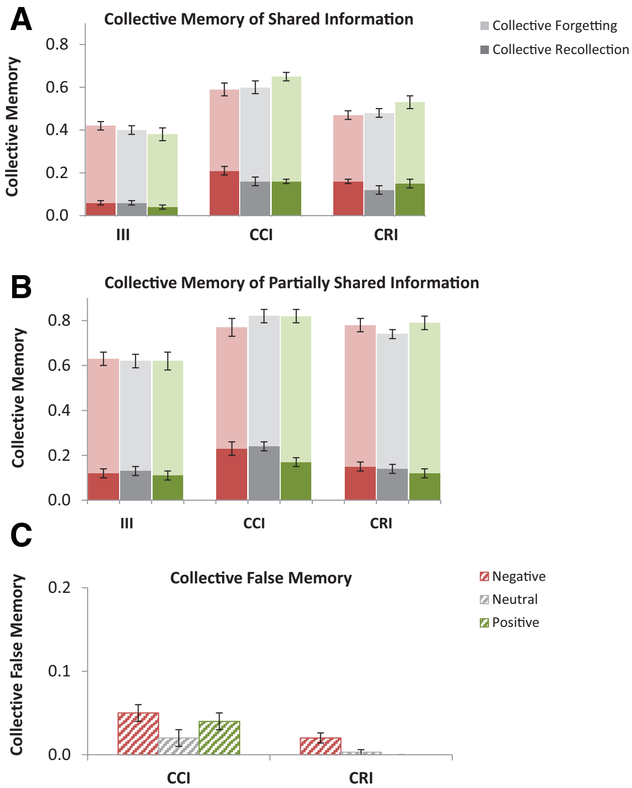


*Figure 6.* (A, top) Collective recollection and forgetting of shared information in triads; (B, middle) Collective recollection and forgetting of partially shared information in dyads; (C, bottom) Collective false recollection of unshared information in dyads. See the online article for the color version of this figure.

2.88, $p = .06$, $MSe = .01$, $\eta_p^2 = .06$. The marginal interaction stemmed from numerically lower collective forgetting in the CRI ($M = .31$) than in the III ($M = .36$) for negative items, while collective forgetting of neutral and positive items were greater in the CRI condition ($M = .34$ in the III and $M = .36$ for neutral items; $M = .34$ in the III and $M = .38$ for positive items). Overall, these results revealed a consistent pattern that collaboration, especially in the CCI, increased collective forgetting of positive and neutral items, while it did not produce a significant effect on collective forgetting of negative items.

Because in our past work, insular networks (CCI) led to greater collective forgetting than diverse networks (CRI; Choi et al., 2014), we examined whether this pattern persisted across emotional valence in this study. As expected, collective forgetting was significantly greater in the CCI than in the CRI condition, $F(1, 46) = 13.90$, $MSe = .02$, $p = .001$, $\eta_p^2 = .23$. The main effect of emotional valence was also significant, $F(2, 92) = 7.66$, $MSe = .01$, $p = .001$, $\eta_p^2 = .14$, with no interaction, $F < 1$. Pairwise comparisons indicated that collective forgetting was greater for positive items than negative items in the CCI condition, $t(23) = 3.21$, $SEM = .03$, $p = .004$, $d = .84$, and did not differ between negative and neutral items, $p = .16$, or between positive and neutral items, $p = .15$. The CRI condition revealed the same patterns of collective forgetting (positive > neutral > negative), but only the differences between positive and negative items reached marginal significance, $t(23) = 2.27$, $SEM = .03$, $p = .03$, $d = .58$, after Bonferroni correction. The null or marginal differences call for caution but cohered with the overall direction of the significant findings. Together, the patterns of collective remembering and collective forgetting of shared items reveal a consistent story—interactions within insular groups were likely to enhance negative memories and diminish positive memories at a collective level in comparison to diverse groups.

**Collective memory for partially shared information.** In the analysis on the collective recollection of partially shared items between two group members (see Figure 6b), collective recollection was significantly greater in the CCI compared with the baseline III condition, $F(1, 46) = 15.15$, $MSe = .02$, $p < .001$, $\eta_p^2 = .25$, but such an effect of collaboration was absent in the CRI condition, $F < 1$. As it was for shared items, the comparison between CCI and CRI conditions revealed a significantly greater collective recollection in the CCI than in the CRI, $F(1, 46) = 13.03$, $MSe = .02$, $p = .001$, $\eta_p^2 = .22$, with a significant effect of emotional valence, $F(2, 92) = 3.83$, $MSe = .01$, $p = .03$, $\eta_p^2 = .08$, and with no interaction, $F < 1$. Subsequent tests revealed that the effect of emotional valence was significant only in the CCI, $F(2, 46) = 3.39$, $MSe = .01$, $p = .04$, $\eta_p^2 = .13$, as collective recollection was lesser for positive items than for neutral items, $t(23) = 3.14$, $SE = .02$, $p = .005$, $d = .70$. The differences between positive and negative items, and between negative and neutral items, did not reach significance, $p = .07$, $p = .80$, respectively, after Bonferroni correction. This pattern, though less robust, is similar to that observed for fully shared information.

Collective forgetting of partially shared items (see Figure 6B) did not differ between the CCI and the CRI conditions, $p = .17$, but there was still an effect of emotional valence, $F(2, 92) = 6.58$, $MSe = .02$, $p = .003$, $\eta_p^2 = .13$, with no interaction, $p = .23$. Collective forgetting was marginally greater for positive than negative items in the CCI, $t(23) = 2.63$, $SE = .04$, $p = .02$, $d = .70$, after Bonferroni correction, but not in the CRI, $p = .18$. The equivalent collective forgetting of partially shared items between the CCI and the CRI conditions was driven by a numerical increase in collective forgetting of negative items in the CRI. The patterns of collective forgetting (positive > neutral > negative) was consistent across shared and partially shared items in the CCI condition. However, although the CRI condition had the same patterns (positive > neutral > negative) for shared items, the collective forgetting of negative items was relatively greater for partially shared items (positive > negative > neutral) compared to shared items. These results indicate that partially shared negative information was more strongly reinforced in CCI compared with CRI and, in turn, produced more collective forgetting of those items in CRI.

**Collective false memory.** In the previous section on individual-level false memory, we reported that exposure to a wider network of people increases false recognition memory whereas collaborating in a smaller, insular community increases confidence in these false memories. Here we report false memories at the collective level (i.e., the overlapping memories across former group members in their final individual performance). Collective false memory was assessed by computing collective recollection of unshared items in postcollaborative recall of two group members who did not study those items but that was studied only by the third member in their group (see Figure 6C). Collective false recollection was greater in the CCI than in the CRI condition, $F(1, 46) = 16.20$, $MSe = .002$, $p < .001$, $\eta_p^2 = .26$. There was a numerical trend in which collective false recollection was greater for negative than positive items, and the trend was more evident in the CRI condition where there was no observation for collective false recollection of positive items. This effect of group structure, where participants from identical (insular) groups exhibited more collective false memories compared to reconfigured (diverse) groups, differs in a meaningful way from the patterns of total levels of social contagion for false memories (the nonredundant pooling of false recall produced by former group partners) that we found to be greater for the reconfigured than identical groups (see previous section). These contrasting patterns show that while diverse social networks contained a greater variety of false memories to which group members could be exposed, participants were more likely to develop the same false memories when interacting within insular social networks. Greater overlap in false memories in insular groups is also consistent with greater confidence ratings that participants reported for socially acquired false memory in insular groups (see previous section).

To summarize, these findings on collective memory show that identical groups where collaboration remains insular facilitate greater collective recollection for both true and false memories, compared with reconfigured groups where collaboration is more diverse. With respect to true memories, identical groups are also likely to facilitate greater collective recollection of negative true memories than do reconfigured groups. Increased collective recollection in insular groups arises likely because this network structure reinforces convergence of negative true memories to a greater extent than does the diverse network structure. This pattern is in line with the consistently greater true recall of negative information we observed in identical groups during collaboration, a process that is likely to align memories for negative information for those who previously collaborated. By the same token, insular group interactions tend to make people collectively forget true positive memories to a greater extent than do diverse group interactions.

## General Discussion

Since the publication of Frederic C. Bartlett's seminal book (Bartlett, 1932), questions about how memories propagate in social networks and reshape individuals' and the collective's past have intrigued many memory scientists. To explore these questions in our work we have begun to deploy both experimental and computational tools to quantify and characterize the nature of these processes and the consequences of social sharing (e.g., Choi et al., 2014; Luhmann, & Rajaram, 2015). In the present study, we took an experimental approach to investigate the social propagation of information with different emotional valence in groups with different network structures. As in the real world, where initial exposure to information is often varied for people who later interact and socially share their experiences, the present study also systematically differentiated distribution of information across interacting group members at the time of initial exposure. To test the consequences of memory transmission under these conditions, we designed a study where (a) the studied information consisted of picture–word label pairs of stimuli that were positive, negative, or neutral (or nonemotional) in emotional valence; (b) participants who would later become group members first individually studied information that overlapped or did not overlap across their respective study lists such that some information was shared among all three participants, some other information was partially shared only between two members, and yet other information was unshared and studied by only one group member; and (c) after the study phase, groups of three members collaborated with identical group partners (identical group condition) or with different partners (reconfigured group condition) across two recall opportunities. Another group of participants studied and recalled information twice individually to serve as the control group. Lastly, (d) participants from all three conditions (control, identical, reconfigured) recalled the studied information individually, and then completed a final, individual recognition task.

The main findings showed that: (a) collaboration increased recall of negative memories more than it did of neutral or positive memories; (b) this effect of collaboration on negative memories was especially prominent for information that everyone initially saw, and further, especially for those who collaborated in insular networks working with the same group partners rather than those in diverse networks where they collaborated with different group members; (c) the total amount of socially transmitted false memories floating in a network was greater in the diverse networks than in the insular networks; however, false memories were reinforced with greater confidence in the insular networks compared to in the diverse networks and furthermore insular networks also gave rise to more collective false memories than did diverse networks, and (d) with respect to collective true memories, insular networks promoted both collectively remembered and collectively forgotten memories more than did diverse networks, and collaboration was likely to promote collective forgetting of positive information in both networks. We discuss the implications of these findings for three main foci of interest in understanding the social transmission of memory through different network structures—the propagation of emotional information, the social contagion of false memories, and the emergence of collective memory.

### Propagation of Emotional Information

The mnemonic advantage of emotional information (i.e., emotional memory enhancement effect) in individual memory and its underlying mechanisms are well documented (see Buchanan, 2007; Hamann, 2001 for reviews); yet to our knowledge, no data are available on the consequences of repeated retrieval attempts on emotional memory within a relatively short period of time (compared to longer delays such as days or weeks). When participants engaged in repeated recall in the present study, working individually by themselves (the III condition), we observed the classic emotional memory enhancement effect, especially for negative valence, in the first recall attempt. Yet interestingly, the effect disappeared in the subsequent individual recall attempts, suggesting a prioritized recall of emotional (especially negative) memories. That is, when participants have both emotional and nonemotional memories from which to draw, negative information appears to have high-priority, likely due to its higher distinctiveness, compared with positive or nonemotional information, but then the low-prioritized positive and nonemotional information is recalled in the subsequent recall attempts and cancels out the negativity effect. This proposed mechanism is also consistent with previous reports where the emotional memory enhancement effect has been more pronounced with mixed lists (where emotional and nonemotional stimuli are intermixed in a study list) than pure lists (where emotional and nonemotional stimuli are blocked across independent study lists; Talmi, Luk, McGarry, & Moscovitch, 2007).

While the emotional memory enhancement effect, especially the negativity effect, disappeared with repeated recalls in the control condition where no collaboration took place, it persisted in the collaboration conditions such that group recall, as well as the final individual recall by former group members, showed an advantage for negatively valenced information. Arousal (i.e., emotional intensity) is often discussed as one of the contributors to the emotional memory enhancement effect via distinct neural processes such as the activation of amygdala during encoding (see Kensinger, 2004 for a review). However, negative and positive memories can have different qualities even when arousal is equated (see Kensinger & Schacter, 2008 for review), as was the case in the current study. Thus, factors other than arousal would likely account for the negativity effect. How then does collaboration facilitate recall of negative but not of positive memories? Several explanations are possible.

For one, negative valence may have triggered more social sharing than did positive valence. The preferential social transmission of negative information is in line with a previous report by Luminet, Bouts, Delie, Manstead, and Rimé (2000) who showed that people were more likely to share their emotional experiences with others (i.e., conversations with friends) following exposure to a negatively valenced situation than to nonemotional situation. Such sharing could have occurred for a number of reasons. There is behavioral and neural evidence to suggest that negative information tends to be encoded with more vivid details whereas positive information tends to be encoded with increased familiarity (see Kensinger, 2009 for a review). It is then possible that collaboration facilitates the recollective process by triggering discussion of the vivid details of the negative stimuli, and strengthens negative memories while such collaborative facilitation cannot occur when retrieving alone. The results from the recognition task, where negative and positive information were recognized equally well, are also consistent with this explanation because the increased familiarity for positive information would have helped performance only in the recognition task and not in the recall task (Ochsner, 2000). Social sharing also can aid in emotion regulation (Rimé, 2007), and people may be motivated to discuss negative events in order to diminish the associated negative affect.

Two, there were likely greater reexposure and cross-cuing benefits for negative than positive information during collaboration. During group recall, the magnitude of collaborative inhibition did not differ significantly between negative and positive information, an outcome that suggests that the recall of both negative and positive information suffered similar levels of disruption (see the Appendix). If the amount of experienced disruption was not substantially different across the two types of emotional valence, the boost for negative memories during collaboration suggests benefits arising from the operations of other mechanisms such as reexposure benefits and cross-cuing. As we described in the introduction, reexposure benefits refer to an increase in recall from having heard other group members recall information that one might have forgotten otherwise. This benefit emerges on a subsequent memory measure. Cross-cuing (Congleton & Rajaram, 2011; Meudell, Hitch, & Boyle, 1995; Takahashi & Saito, 2004) refers to a mechanism whereby an item recalled by a partner serves as a retrieval cue and triggers the recall of an otherwise forgotten studied item, and this benefit emerges within the same recall session. An advantage for recall of negative information then suggests that during the first recall group members might have benefitted from more cross-cueing of negative than positive information and during second recall they could benefit from both more cross-cuing of and reexposure to negative than positive information. Further, the absence of any possibility for such reexposure and cross-cuing benefits in the repeated individual recall (III) condition also explains why participants working by themselves in the III condition were able, with repeated recall attempts, to search through their memories for positive and neutral items as well and overcome the negativity effect in recall.

Three, effects of social validation may have been greater for the recall of negative information than for positive or neutral information. The facilitating effect of collaboration for retrieval of negative memories was prominent only when multiple partners had initial exposure to the same information as no such effect was found for information that only one member of the group had previously viewed. These findings consistently showed a directional valence effect (negative > neutral > positive) for such fully shared and partially shared study items but not for unshared study items. Because only one out of three members of a group had previously seen the unshared study items, recall of such information was essentially like individual recall and group discussion of the distinctive aspects of negative stimuli was precluded. As a likely consequence, the negativity advantage in group recall that was seen for shared and partially shared information was absent for unshared information. Also, the negativity effect was reduced when participants worked with different partners (the CRI condition). These patterns suggest a role of social validation such as verbal feedback from other group members during collaboration (Stewart & Stasser, 1995; Stewart, Stewart, Tyson, Vinci, & Fioti, 2004; Meade & Gigone, 2011; Muller & Hirst, 2014), and indicate that its effects may be particularly pronounced for negative information. When group members are less likely to acknowledge and reinforce the recalled items during collaboration, either because they did not encode the same items (unshared) or because they worked with new partners with different memories (reconfigured group), this disruption in social validation selectively reduces the retrieval of negative information.

In sum, our findings show that negative information socially transmits more readily than positive information, and this is in line with the cross-species finding that reported social transmission of negative (fear) memories in rats (Bruchey, Jones, & Monfils, 2010). Together, these findings have important implications both for understanding people's proclivity for remembering negative events and for identifying scenarios where they can get past this proclivity; for example, when people repeatedly recall alone they eventually begin to recall additional neutral and positive information. In social interactions, negative memories are reinforced and propagate in a smaller network consisting of individuals who possess more overlapping information than do members in larger networks. This negativity effect persists but is reduced for memories that come from partially shared experiences among members who interact in a larger network and possess a greater variety of information.

## Social Contagion That Creates False Memory

The present study also investigated the social contagion of false memory in the insular versus diverse networks where participants were exposed to new, nonstudied information. During collaboration in two different networks, the nonstudied information was either lesser (the CCI condition) or greater (the CRI condition) in number and variety. The findings show that social contagion increased in diverse networks where people worked with more and different collaborative partners (CRI) than in insular networks where they worked with the same collaborative partners repeatedly (CCI). In our previous work (Choi et al., 2014) we showed the benefits of having more varied group partners on the magnitude of accurate memory. When all group members studied the identical information, working with different partners increased the reexposure benefits and enhanced postcollaborative memory to a greater extent than did working with the same partners. The current findings demonstrate the costs of having multiple social interactions with different collaborative partners when circumstances change, as far as memory accuracy is concerned; working with different partners can increase the social contagion of false memory if collaborating partners possess new and nonoverlapping study information. We observed this pattern in both recall and recognition memory. Yet, the confidence in false memory was sensitive to group structure in the opposite way; in insular groups where the same members repeatedly recalled presumably the same set of items (to a greater extent than would be the case in diverse groups), the confidence in false recognition was greater compared with the confidence reported by those in diverse group structures. Thus, amount of false memory and the confidence diverged systematically as a function of group structure and information distribution.

Interestingly, social contagion of false memory did not differ across emotional valence in this study. That is, while true negative memories are reinforced and transmitted further through repeated collaboration, under the same conditions of testing, negative valence does not differentially affect the transmission of false memories. This outcome at first may seem at odds with a recent report where social contagion of errors were observed for both emotional and nonemotional information as observed in the present study but were attenuated for emotional information (Experiment 2, Kensinger et al., 2016). Differences in methodological details between that experiment and the current study should be noted.

First, the delay between study and the critical memory tasks were much longer in prior work (48 hr compared with 20 min in the present study) thereby increasing the memory sensitivity to emotional information (Yonelinas & Ritchey, 2015). Also, when participants in the previous study first performed dyadic recall before taking a recognition test individually, they did so with a confederate who recalled half studied and half nonstudied items. This proportion of nonstudied items was far greater than observed in the present study that involved spontaneous recall by group members, thereby changing the likelihood of exposure to nonstudied items and their acceptance or rejection on a subsequent recognition memory task. It is also worth noting that when a more naturalistic dyadic interaction similar to the present procedure was used (Experiment 1; Kensinger et al., 2016) no differences were observed in false alarms for emotional and nonemotional information, a finding that is in line with the present procedures and findings, and also with past reports where more naturalistic interactions have led to lower false memory than more controlled methods of collaboration (e.g., free flowing vs. turn-taking collaboration procedures, respectively; Thorley & Dewhurst, 2007). Together, these findings show that both emotional and nonemotional information are susceptible to social contagion errors, and that such transmission of errors and the confidence exhibited in these memory errors are mediated by different group structures and not by emotional valence. Future work that explores different methodologies and memory materials can shed light on the conditions where these outcomes may vary.

## The Emergence of Collective Memory for Emotional Information

In the context of replicating past findings that collaboration increases overlapping memories among group members, that is, collective memory (Blumen & Rajaram, 2008; Congleton & Rajaram, 2014; Stone et al., 2010), the novel findings here demonstrate how the composition of collective memory is affected by social contagion and emotional valence. Past discussions in the literature have recognized a potentially important role of social contagion of false memories in the formation of collective memory (e.g., Cuc et al., 2006). The design of the present study, with the inclusion of partially shared and unshared study information, enabled a test of this possibility through an examination of the quantity of collective contagion errors (i.e., collective recollection of information that is nonstudied but produced by collaborative partners). The results were striking in the present data; about 25% of collective recollection in the identical groups (collapsed across valence) was composed of information that at least one group member initially did not study, demonstrating a significant impact of social contagion of memory errors in what people collectively remember. In other words, this finding shows that memories for events experienced by only some group members can be nonetheless integrated into a group's, or a community's collective memory to a considerable degree through social interactions, and this is especially the case when such social interactions repeatedly occur within an insular network.

In considering true collective memory, our findings indicate that while emotion might not have a significant effect on memories that are collectively remembered, it does have a significant effect on the amount of information that is collectively forgotten. As a general process, collaboration can lead to collective forgetting through a group pruning process for recall outputs that are not shared by more than one group member (Rajaram & Pereira-Pasarin, 2010) as well as through forgetting that occurs at the individual level because listening to what other group members recall during collaboration can lead to forgetting of related but not remembered information (*socially shared retrieval-induced forgetting*; Cuc, Koppel, & Hirst, 2007; see Coman & Hirst, 2012 for propagation of this effect; see Stone, Coman, Brown, Koppel, & Hirst, 2012 for relevant reviews; and see Barber, Harris, & Rajaram, 2015 for evidence on the role of *retrieval inhibition*). As a more specific process for emotional valence, in the present study when people repeatedly recalled with the same partners, the amount of negative memories that were collectively forgotten among them was not noticeably different from what individuals recalling alone would likely forget, but there was a tendency for them to collectively forget more positive and neutral information. Given that these patterns suggest a potentially unfortunate consequence of collaboration in the formation of collective memory, it would be useful to explore its generality. In brief, the overall patterns of the finding converged on the conclusion.

## Conclusion

The current study investigates the extent to which emotional memory is shaped and transmitted via social interactions across two varied-sized networks. Weaving together the results from a variety of measures, the current findings identified the circumstances under which the transmission of emotional memories is reinforced or attenuated through more than a single interaction. When repeated social interactions occurred with the same group of people within a smaller, insular network, negative memories were solidified and transmitted farther compared with positive memories. Further, the interaction within an insular network not only reinforced true negative memories, but it also increased confidence in false memories and it increased the extent to which false memories became a part of the group's collective memory. In contrast, when people were exposed to a larger, diverse network that consisted of people who possess a greater variety of information, they came to possess a greater quantity of false memories but the transmission of true negative memories and false memories was limited. Lastly, both forms of collaboration revealed a key condition where true memories, especially negative memories, are reinforced and transmitted: when people initially had common experiences. Together, these findings shed light on the understanding of how an individual's and a group's memory for emotional events can be shaped and transmitted. Further, the negativity bias in collaborative remembering may have important implications for assessing why negative information is often passed at high rates in the Internet culture, or why the spread of gossip also tends to be more negative in nature. It will be important for futures studies to use the platform provided by these findings and explore the generality of the current findings, perhaps with other types of materials (e.g., emotional information with high self-relevance) and other network structures, to provide further insights on understanding of emotional social memories and individual's emotional well-being as a result of their sociality.

## References


Barber, S. J., Castrellon, J. J., Opitz, P., & Mather, M. (2017). Younger and older adults' collaborative recall of shared and unshared emotional pictures. *Memory & Cognition*. Advance online publication. http://dx.doi.org/10.3758/s13421-017-0694-3

Barber, S. J., Harris, C. B., & Rajaram, S. (2015). Why two heads apart are better than two heads together: Multiple mechanisms underlie the collaborative inhibition effect in memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 41,* 559–566. http://dx.doi.org/10.1037/xlm0000037

Bartlett, F. C. (1932). *Remembering: A study in experimental and social psychology*. Cambridge, UK: Cambridge University Press.

Basden, B. H., Basden, D. R., Bryner, S., & Thomas, R. L., III. (1997). A comparison of group and individual remembering: Does collaboration disrupt retrieval strategies? *Journal of Experimental Psychology: Learning, Memory, and Cognition, 23,* 1176–1189. http://dx.doi.org/10.1037/0278-7393.23.5.1176

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

Basden, B. H., Reysen, M. B., & Basden, D. R. (2002). Transmitting false memories in social groups. *The American Journal of Psychology, 115,* 211–231. http://dx.doi.org/10.2307/1423436

Baumeister, R. F., Bratslavsky, E., Finkenauer, C., & Vohs, K. D. (2001). Bad is stronger than good. *Review of General Psychology, 5,* 323–370. http://dx.doi.org/10.1037/1089-2680.5.4.323

Bennion, K. A., Ford, J. H., Murray, B. D., & Kensinger, E. A. (2013). Oversimplification in the study of emotional memory. *Journal of the International Neuropsychological Society, 19,* 953–961. http://dx.doi.org/10.1017/S1355617713000945

Berger, J. (2011). Arousal increases social transmission of information. *Psychological Science, 22,* 891–893. http://dx.doi.org/10.1177/0956797611413294

Berger, J., & Milkman, K. (2012). What Makes Online Content Viral? *Journal of Marketing Research, 49,* 192–205. http://dx.doi.org/10.1509/jmr.10.0353

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

Brainerd, C. J., Stein, L. M., Silveira, R. A., Rohenkohl, G., & Reyna, V. F. (2008). How does negative emotion cause false memories? *Psychological Science, 19,* 919–925. http://dx.doi.org/10.1111/j.1467-9280.2008.02177.x

Bruchey, A. K., Jones, C. E., & Monfils, M. H. (2010). Fear conditioning by-proxy: Social transmission of fear during memory retrieval. *Behavioural Brain Research, 214,* 80–84. http://dx.doi.org/10.1016/j.bbr.2010.04.047

Buchanan, T. W. (2007). Retrieval of emotional memories. *Psychological Bulletin, 133,* 761–779. http://dx.doi.org/10.1037/0033-2909.133.5.761

Choi, H.-Y., Blumen, H. M., Congleton, A. R., & Rajaram, S. (2014). The role of group configuration in the social transmission of memory: Evidence from identical and reconfigured groups. *Journal of Cognitive Psychology, 26,* 65–80. http://dx.doi.org/10.1080/20445911.2013.862536

Choi, H.-Y., Kensinger, E. A., & Rajaram, S. (2013). Emotional content enhances true but not false memory for categorized stimuli. *Memory & Cognition, 41,* 403–415. http://dx.doi.org/10.3758/s13421-012-0269-2

Clark, S. E., Hori, A., Putnam, A., & Martin, T. P. (2000). Group collaboration in recognition memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 26,* 1578–1588. http://dx.doi.org/10.1037/0278-7393.26.6.1578

Coman, A., & Hirst, W. (2012). Cognition through a social network: The propagation of induced forgetting and practice effects. *Journal of Experimental Psychology: General, 141,* 321–336. http://dx.doi.org/10.1037/a0025247

Congleton, A. R., & Rajaram, S. (2011). The influence of learning methods on collaboration: Prior repeated retrieval enhances retrieval organization, abolishes collaborative inhibition, and promotes post-collaborative memory. *Journal of Experimental Psychology: General, 140,* 535–551. http://dx.doi.org/10.1037/a0024308

Congleton, A. R., & Rajaram, S. (2014). Collaboration changes both the content and the structure of memory: Building the architecture of shared representations. *Journal of Experimental Psychology: General, 143,* 1570–1584. http://dx.doi.org/10.1037/a0035974

Cuc, A., Koppel, J., & Hirst, W. (2007). Silence is not golden: A case for socially shared retrieval-induced forgetting. *Psychological Science, 18,* 727–733. http://dx.doi.org/10.1111/j.1467-9280.2007.01967.x

Cuc, A., Ozuru, Y., Manier, D., & Hirst, W. (2006). On the formation of collective memories: The role of a dominant narrator. *Memory & Cognition, 34,* 752–762. http://dx.doi.org/10.3758/BF03193423

Emery, L., & Hess, T. M. (2008). Viewing instructions impact emotional memory differently in older and young adults. *Psychology and Aging, 23,* 2–12. http://dx.doi.org/10.1037/0882-7974.23.1.2

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

Fivush, R., & Wang, Q. (2005). Emotion talk in mother-child conversations of the shared past: The effects of culture, gender, and event valence. *Journal of Cognition and Development, 6,* 489–506. http://dx.doi.org/10.1207/s15327647jcd0604_3

Gallo, D. A., Foster, K. T., & Johnson, E. L. (2009). Elevated false recollection of emotional pictures in young and older adults. *Psychology and Aging, 24,* 981–988. http://dx.doi.org/10.1037/a0017545

Hamann, S. (2001). Cognitive and neural mechanisms of emotional memory. *Trends in Cognitive Sciences, 5,* 394–400. http://dx.doi.org/10.1016/S1364-6613(00)01707-1

Heath, C. (1996). Do people prefer to pass along good news or bad news? Valence and relevance of news as a predictor of transmission propensity. *Organizational Behavior and Human Decision Processes, 68,* 79–94. http://dx.doi.org/10.1006/obhd.1996.0091

Hirst, W., & Echterhoff, G. (2012). Remembering in conversations: The social sharing and reshaping of memories. *Annual Review of Psychology, 63,* 55–79. http://dx.doi.org/10.1146/annurev-psych-120710-100340

Hirst, W., & Manier, D. (2008). Towards a psychology of collective memory. *Memory, 16,* 183–200. http://dx.doi.org/10.1080/09658210701811912

Jiang, T., Hou, Y., & Wang, Q. (2016). Does micro-blogging make us "shallow"? Sharing information online interferes with information comprehension. *Computers in Human Behavior, 59,* 210–214. http://dx.doi.org/10.1016/j.chb.2016.02.008

Kensinger, E. A. (2004). Remembering emotional experiences: The contribution of valence and arousal, *Reviews in the Neurosciences, 15,* 214–253. http://dx.doi.org/10.1515/REVNEURO.2004.15.4.241

Kensinger, E. A. (2007). Negative emotion enhances memory accuracy: Behavioral and neuroimaging evidence. *Current Directions in Psychological Science, 16,* 213–218. http://dx.doi.org/10.1111/j.1467-8721.2007.00506.x

Kensinger, E. A. (2009). Remembering the details: Effects of emotion. *Emotion Review, 1,* 99–113. http://dx.doi.org/10.1177/1754073908100432

Kensinger, E. A., Choi, H.-Y., Murray, B. D., & Rajaram, S. (2016). How social interactions affect emotional memory accuracy: Evidence from collaborative retrieval and social contagion paradigms. *Memory & Cognition, 44,* 706–716. http://dx.doi.org/10.3758/s13421-016-0597-8

Kensinger, E. A., & Corkin, S. (2004). The effects of emotional content and aging on false memories. *Cognitive, Affective & Behavioral Neuroscience, 4,* 1–9. http://dx.doi.org/10.3758/CABN.4.1.1

Kensinger, E. A., & Schacter, D. L. (2008). Neural processes supporting young and older adults' emotional memories. *Journal of Cognitive Neuroscience, 20,* 1161–1173. http://dx.doi.org/10.1162/jocn.2008.20080

Luhmann, C. C., & Rajaram, S. (2015). Memory transmission in small groups and large networks: An agent-based model. *Psychological Science, 26,* 1909–1917. http://dx.doi.org/10.1177/0956797615605798

Luminet, O., IV, Bouts, P., Delie, F., Manstead, A. S. R., & Rimé, B. (2000). Social sharing of emotion following exposure to a negatively valenced situation. *Cognition and Emotion, 14,* 661–688. http://dx.doi.org/10.1080/02699930050117666

Meade, M. L., & Gigone, D. (2011). The effect of information distribution on collaborative inhibition. *Memory, 19,* 417–428. http://dx.doi.org/10.1080/09658211.2011.583928

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

Meade, M. L., & Roediger, H. L., III. (2002). Explorations in the social contagion of memory. *Memory & Cognition, 30,* 995–1009. http://dx.doi.org/10.3758/BF03194318

Meudell, P. R., Hitch, G. J., & Boyle, M. M. (1995). Collaboration in recall: Do pairs of people cross-cue each other to produce new memories? *Quarterly Journal of Experimental Psychology Section A: Human Experimental Psychology, 48,* 141–152. http://dx.doi.org/10.1080/14640749508401381

Muller, F., & Hirst, W. (2014). Remembering stories together: Social contagion and the moderating influence of disagreements in conversations. *Journal of Applied Research in Memory & Cognition, 3,* 7–11. http://dx.doi.org/10.1016/j.jarmac.2013.12.002

Ochsner, K. N. (2000). Are affective events richly recollected or simply familiar? The experience and process of recognizing feelings past. *Journal of Experimental Psychology: General, 129,* 242–261. http://dx.doi.org/10.1037/0096-3445.129.2.242

Payne, D. G. (1987). Hypermnesia and reminiscence in recall: A historical and empirical review. *Psychological Bulletin, 101,* 5–27. http://dx.doi.org/10.1037/0033-2909.101.1.5

Pereira-Pasarin, L. P., & Rajaram, S. (2011). Study repetition and divided attention: Effects of encoding manipulations on collaborative inhibition in group recall. *Memory & Cognition, 39,* 968–976. http://dx.doi.org/10.3758/s13421-011-0087-y

Pesta, B. J., Murphy, M. D., & Sanders, R. E. (2001). Are emotionally charged lures immune to false memory? *Journal of Experimental Psychology: Learning, Memory, and Cognition, 27,* 328–338. http://dx.doi.org/10.1037/0278-7393.27.2.328

Rajaram, S., & Maswood, R. (2017). Collaborative memory: A selective review of data and theory. In J. H. Byrne (Ed.), *Learning and Memory: A Comprehensive Reference* (2nd ed., Vol. 2, pp. 53–70). Oxford, UK: Academic Press. http://dx.doi.org/10.1016/B978-0-12-809324-5.21050-X

Rajaram, S., & Pereira-Pasarin, L. P. (2010). Collaborative memory: Cognitive research and theory. *Perspectives on Psychological Science, 5,* 649–663. http://dx.doi.org/10.1177/1745691610388763

Rimé, B. (2007). Interpersonal emotion regulation. In J. J. Gross (Ed.), *Handbook of emotion regulation* (pp. 466–485). New York, NY: Guilford Press.

Rimé, B. (2009). Emotion elicits the social sharing of emotion: Theory and empirical review. *Emotion Review, 1,* 60–85. http://dx.doi.org/10.1177/1754073908097189

Roediger, H. L., III, Meade, M. L., & Bergman, E. T. (2001). Social contagion of memory. *Psychonomic Bulletin & Review, 8,* 365–371. http://dx.doi.org/10.3758/BF03196174

Roediger, H. L., Zaromb, F. M., & Butler, A. C. (2009). The role of repeated retrieval in shaping collective memory. In P. Boyer & J. V. Wertsch (Eds.), *Memory in mind and culture* (pp. 29–58). Cambridge, UK: Cambridge University Press. http://dx.doi.org/10.1017/CBO9780511626999.009

Stewart, D. D., & Stasser, G. (1995). Expert role assignment and information sampling during collective recall and decision making. *Journal of Personality and Social Psychology, 69,* 619–628. http://dx.doi.org/10.1037/0022-3514.69.4.619

Stewart, D. D., Stewart, C. B., Tyson, C., Vinci, G., & Fioti, T. (2004). Serial position effects and the picture-superiority effect in the group recall of unshared information. *Group Dynamics, 8,* 166–181. http://dx.doi.org/10.1037/1089-2699.8.3.166

Stone, C. B., Barnier, A. J., Sutton, J., & Hirst, W. (2010). Building consensus about the past: Schema consistency and convergence in socially shared retrieval-induced forgetting. *Memory, 18,* 170–184. http://dx.doi.org/10.1080/09658210903159003

Stone, C. B., Coman, A., Brown, A. D., Koppel, J., & Hirst, W. (2012). Toward a science of silence: The consequences of leaving a memory unsaid. *Perspectives on Psychological Science, 7,* 39–53. http://dx.doi.org/10.1177/1745691611427303

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

Talmi, D., Luk, B. T. C., McGarry, L. M., & Moscovitch, M. (2007). The contribution of relatedness and distinctiveness on emotionally enhanced memory. *Journal of Memory and Language, 56,* 555–574. http://dx.doi.org/10.1016/j.jml.2007.01.002

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

Wang, B., & Fu, X. (2011). Time course of effects of emotion on item memory and source memory for Chinese words. *Neurobiology of Learning and Memory, 95,* 415–424. http://dx.doi.org/10.1016/j.nlm.2011.02.001

Wang, Q., & Fivush, R. (2005). Mother-child conversations of emotionally salient events: Exploring the functions of emotional reminiscing in European American and Chinese Families. *Social Development, 14,* 473–495. http://dx.doi.org/10.1111/j.1467-9507.2005.00312.x

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

Wertsch, J. V., & Roediger, H. L., III. (2008). Collective memory: Conceptual foundations and theoretical approaches. *Memory, 16,* 318–326. http://dx.doi.org/10.1080/09658210701801434

Wessel, I., Zandstra, A. R., Hengeveld, H. M., & Moulds, M. L. (2015). Collaborative recall of details of an emotional film. *Memory, 23,* 437–444. http://dx.doi.org/10.1080/09658211.2014.895384

Wright, D. B., Self, G., & Justice, C. (2000). Memory conformity: Exploring misinformation effects when presented by another person. *British Journal of Psychology, 91,* 189–202. http://dx.doi.org/10.1348/000712600161781

Yaron-Antar, A., & Nachson, I. (2006). Collaborative remembering of emotional events: The case of Rabin's assassination. *Memory, 14,* 46–56. http://dx.doi.org/10.1080/09658210444000502

Yonelinas, A. P., & Ritchey, M. (2015). The slow forgetting of emotional episodic memories: An emotional binding account. *Trends in Cognitive Sciences, 19,* 259–267. http://dx.doi.org/10.1016/j.tics.2015.02.009

# Appendix

## Collaborative Inhibition

Both in the **C**CI and the **C**RI conditions, respective ANOVAs revealed straightforward replications of the collaborative inhibition effect: the nominal group recall (i.e., the pooled recall of nonredundant items) in the **I**II condition (for negative items, $M$ = .47, $SE$ = .02; for neutral items, $M$ = .43, $SE$ = .02; and for positive items, $M$ = .42, $SE$ = .02) was significantly greater than the collaborative group recall in the **C**CI condition (for negative items, $M$ = .38, $SE$ = .02; for neutral items, $M$ = .32, $SE$ = .02; and for positive items, $M$ = .31, $SE$ = .02), $F$ (1, 46) = 36.11, $MS$e = .01, $p < .001$, $\eta_p^2 = .44$. The nominal recall was also greater than the collaborative recall in the **C**RI condition, (for negative items, $M$ = .37, $SE$ = .02; for neutral items, $M$ = .35, $SE$ = .02; for positive items, $M$ = .34, $SE$ = .02), $F$ (1, 46) = 17.80, $MS$e = .02, $p < .001$, $\eta_p^2 = .28$. There was no interaction between valence and collaborative inhibition in both comparisons, $F$s $< 1$, indicating that equivalent magnitudes of disruption occurred during collaboration across emotional valence (also see Barber, Castrellon, Opitz, & Mather, 2017). These findings provide a replication of the collaborative inhibition effect and also show that the disruptive effect does not readily vary as a function of emotionality of information in a systematic comparison of emotional valence.

Received November 29, 2016
Revision received April 17, 2017
Accepted April 17, 2017 ■