Social Transmission of Emotional Memory

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Abstract of the Dissertation

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People frequently reminisce about emotional occurrences with others in social settings. Past research has shown the benefits and costs of emotional or social influences on individual memory, but less is known about the interactive effects of these two factors. This dissertation research aimed to investigate the retrieval and transmission of emotional and nonemotional information by examining 1) how social interaction via group collaboration shapes one's and a group's memory for emotional information, 2) how shared or the absence of shared experiences among group members differentially affects the transmission of emotional memory. In Experiment 1, participants studied emotional (negative or positive) and nonemotional (neutral) pictures with words. Next, they completed three consecutive recall sessions either individually or in groups of three in one of three conditions: Individual-Individual-Individual (Control), Individual-Collaborative-Individual, and Collaborative-Collaborative-Individual. The results showed that the memory enhancement effects of emotional information observed in individual memory carries into group memory as well as into post-collaborative individual memory. It was also found that collaboration boosted post-collaborative individual recall of negative information to a greater extent than it did for positive information. In Experiment 2, participants completed three consecutive recall sessions in one of three conditions: Individual–Individual–Individual (Control), Collaborative–Collaborative (Identical group)–Individual, and Collaborative–Collaborative (Reconfigured group)–Individual. When individuals recalled the stimuli alone repeatedly, the memory enhancement effect of emotion was attenuated, illustrating the contributions of a more exhaustive retrieval effort. However, when people repeatedly retrieved emotional memory with others in groups, the memory enhancement effect of emotion was reinforced and boosted, especially for negative information. Finally, people remembered more negative information than positive information mainly when the information was shared with other group members, and did so more when they were asked to recall information with the same group of people, compared to a different group of people. Together, these findings converge to show that the retrieval and spread of emotional memory largely depends on whether the remembering of emotional experiences occurs in social or non-social context, as well as on whether such experiences are shared or unshared.

Table of Contents

List of Tables vi
List of Figures vii

I. Introduction 1

Spread of Good and Bad 2
Emotion and Memory 3
Collaboration and Memory 4
Spread of Information across Social Networks 9
The Present Study 11

II. Experiment 1 13

Method… 15
Results.. 16

Recall Performance 16
Collaborative Inhibition 17
Re-exposure Effects 18
Collective Memory 19

III. Experiment 2 23

Method.. 23
Results.. 27

Collaborative Inhibition for Shared, Partially Shared, and Unshared Information 28
Influences of Emotion on Recall 29
Transmission of Memory: Influence of Shared Experiences on Group Recall of Emotional Information 33
Transmission of Memory: Post-Collaborative Individual Memory 36
Collective Memory 42

IV. General Discussion 46

V. Conclusion 56

Tables and Figures 57
References 73

List of Tables

Table 1 Proportions of correct recall and standard errors (in parentheses)………57

Table 2 Mean proportion of shared, partially shared, and unshared items correctly recalled as a function of retrieval condition. Standard errors are shown in parentheses. For the III condition, the measure represents nominal group recall……………………………………………………………………..58

List of Figures

Figure 1 Group configuration in identical (CCI) and reconfigured (CRI) groups. Each different shape or filled pattern denotes an individual within a group……...59

Figure 2 Sample pictorial stimuli and verbal labels for each valence………………...60

Figure 3 [Experiment 1] Recall performance during Recall 1………………………..61

Figure 4 [Experiment 1] Collaborative inhibition during Recall 1…………………...62

Figure 5 [Experiment 1] Post-collaborative recall in Recall 3………………………..63

Figure 6 [Experiment 1] Collective recollection in Recall 3......................................64

Figure 7 [Experiment 2] Overall correct (individual or group) recall performance for each retrieval condition…………………………………………………….…..65

Figure 8 [Experiment 2] Proportions of correct recall from the first and second collaborative sessions in the CCI condition as a function of shardness and emotional valence..66

Figure 9 [Experiment 2] Proportions of correct recall from the first and second collaborative sessions in the CRI condition as a function of sharedness and emotional valence…………………………………………………….......67

Figure 10 [Experiment 2] Proportions of correct recall from the post-collaborative individual recall in the CCI and CRI condition as a function of shardness and emotional valence…………………………………………………….…..68

Figure 11 [Experiment 2] Non-redundant recall on Post-collaborative individual recall……………………………………………………………………………69

Figure 12 [Experiment 2] Effects of proximal and distal partners on the recall of non-studied items on post-collaborative individual recall across the CCI and CRI conditions as a function of emotional valence………………………………70

Figure 13 [Experiment 2] Corrected Recognition and Contagion following collaborative recall……………………………………………………………………………71

Figure 14 [Experiment 2] Collective memory in the final individual recall…………...72

I. Introduction

Individuals constantly form and retrieve their memories about past events. Such memories are often emotionally charged, and people often retrieve their memories with others in a social context to produce a joint account of the events (i.e., collaboration), which promotes the spread of information. When people experience an emotional event, they like to talk about it with others for various reasons and regardless of their gender, education, or culture, to regulate their negative affect or to boost their own positive affect, or in order to enhance social bonds (reviewed by Rime, 2009). Two bodies of rapidly growing research have separately examined the influences of emotion on individual memory and the influences of social factors on small group and individual memory for nonemotional, or neutral, information, respectively. However, little is known about how the emotionality of the to-be-remembered information, compared to nonemotional information, interacts with social process such as collaboration and what impact it could have on memory as well as on the transmission of information.

The present research aims to bring together the literatures on emotional memory, individual memory, and collaborative group memory to examine the processes that underlie social transmission of emotional memory. To do so, this work focuses on three unexplored issues about social and emotional influences on memory. First, we aim to examine whether emotional content affects group and post-collaborative individual memory to the same extent as it does individual memory and how it shapes the formation of shared memories among group members. The second issue examines the propagation of memory across more than a single social interaction, and how emotional valence modulates the propagation. Lastly, we examine the propagation of memory when group members share or do not share some information, and how valence modulates the propagation of such information.

Spread of Good and Bad

Social transmission of information is a pervasive phenomenon in everyday life and it influences nearly everything from individuals' behaviors such as purchasing a product based on its online reviews, talking about last night's breaking news with friends, to broader human culture. The study of social transmission has been an interest in the fields of marketing research and social psychology. For example, identifying what types of information tends to spread faster or to easily go viral than other information, and why this difference emerges, is likely to have direct implications for marketing as well as for shaping of ideas in culture. Research on word-of-mouth (in the spread of news or urban legends) or on the communicability of social anecdotes (e.g., Heath, 1996; Peters, Kashima, Clark, 2009; Heath, Bell, & Sternberg, 2001) have suggested a link between experienced emotion and social transmission. Berger and Milkman (2012) conducted an investigation on a data set of New York Times' most emailed list for articles published over a three-month period, and found that individual-level psychological processes such as experiencing emotion have an impact on one's selection of information to be passed along to others, what news to spread faster, and what news is more frequently shared (i.e., social transmission). Contrary to the lay belief that people might prefer to pass along negative news more than positive news, their analyses showed that positively valenced news articles are more likely to be shared. While these findings speak to the preferences for what people like to share, it does not tell us whether memories for positive and negative information differ through the process of transmission. That is, what types of information, negative or positive, do people eventually remember and transmit?

In a recent experimental investigation on social transmission (Berger, 2011), participants watched emotion-evoking (either negatively or positively valenced; also either high or low in arousal) movie clips and then rated how willing they would be to share the clips with other people. The results revealed an effect of arousal but not of the valence, which led the author to conclude that social sharing of emotional content is driven by physiological arousal rather than emotional valence. However, the findings of the study were limited to the intention to transmit information and did not measure actual transmission. Further, to our knowledge, the communicability of emotional information has never been tested from a cognitive perspective, especially in terms of memory that presumably has an impact on determining communicability of information.

Emotion and Memory

Emotion can shape memory (reviewed by Levine & Pizarro, 2004). It has been also well established that emotionally charged information is typically remembered better than nonemotional information (reviewed by Buchanan, 2007; Hamann, 2001). The underlying mechanisms for such mnemonic benefits of emotional information are complex, as various factors such as distinctiveness (e.g., Ochsner, 2000; Dewhurst & Parry, 2000; Kensinger & Corkin, 2003; Schmidt, 2007), semantic or conceptual relatedness (e.g., Talmi & Moscovitch, 2004; Talmi, Luk, McGarry, & Moscovitch, 2007), arousal (reviewed by LaBar & Cabeza, 2006), attention (e.g., Ohman, Flykt, & Esteves, 2001), or fluency in processing (e.g., Kityama, 1990) contribute to facilitating prioritized processing of emotional information (reviewed by Bennion, Ford, Murray, & Kensinger, 2013).

However, such benefits for facilitating the prioritized processing of emotion do not necessarily ensure memory accuracy because increases in both accurate and erroneous memories for emotional information have been reported. It is not yet clear from the studies on individual memory how emotion modulates memory errors. Past research on this question has reported divergent findings such that emotion facilitates either increased (Gallo, Foster, & Johnson, 2009), decreased (Pesta, Murphy, & Sanders, 2001; Kensinger & Corkin, 2004), or little changes (Choi, Kensinger, & Rajaram, 2013) in memory errors, depending on the types of study materials employed or the aspects of materials that become salient during encoding.

Of interest in the present study is the extent to which the broad and key findings in the individual emotional memory literature - i.e., the emotional enhancement effect for true memory and mixed findings for false memory – might be observed in and generalized to social contexts in which people share their emotional memories with others as they retrieve past events together. That is, what would be the retrieval product when people retrieve their memories together and produce a joint account of the emotional information that they experienced before? What would be the consequences of sharing emotional memories on post-collaborative retention of each collaborating individual? As discussed in the previous section, past empirical research on social sharing of emotion has focused on the principles that govern the act of talking about emotional events (e.g., intentions to pass along emotional content, frequency to talk about experienced emotional episode with others; Rime, 2007). However, little is known about how such behaviors would shape individuals' memory or how the recall of such information would influence transmission of information for emotional content compared to that of nonemotional content.

Collaboration and Memory

Collaborative Inhibition and Re-exposure Effects. Individuals recall less than their potential when engaging in a recall task in groups, a robust phenomenon known as *collaborative inhibition* (Weldon and Bellinger, 1997; B.H. Basden, Basden, Bryner, & Thomas, 1997; reviewed by Rajaram & Pereira-Pasarin, 2010). The underlying cognitive process for this phenomenon has been most successfully explained by the retrieval disruption account (B.H.

Basden et al., 1997). According to this account, each individual's idiosyncratic organization of information that is developed while encoding the information is later disrupted during collaboration while listening to the outputs of other group members' recall. This disruption in turn reduces each group member's recall performance during collaborative recall and, as a consequence, that of the group. Recent evidence shows that collaborative inhibition in group recall also occurs for negatively valenced information (Yaron-Antar & Nachson, 2006; Wessel, Zandstra, Hengeveld, & Moulds, 2015). However, as these studies focused only on negative valence, it is not yet known whether negative valence disrupts propagation of memories to a greater or lesser extent compared to nonemotional information or positively valenced information.

Although collaborative inhibition is a robust phenomenon, research has identified certain circumstances where the disruptive effects of collaboration can be reduced or eliminated, for example, when having a chance to strengthen one's retrieval organization through repeated study (Pereira-Pasarin & Rajaram, 2011) or repeated testing (Blumen & Rajaram, 2008; Congleton & Rajaram, 2011) prior to collaboration, or when engaging in collaborative recall multiple times but with different group of people each time (Choi, Blumen, Congleton, & Rajaram, 2014). Such reduction or the elimination of the collaboration inhibition effect in memory can boost post-collaborative individual memory through a process known as the *re-exposure effect* (Blumen & Rajaram, 2008).

The re-exposure effect refers to a mechanism that operates during collaboration and manifests its effects in post-collaborative recall, wherein the process of collaborative recall provides a second-learning opportunity for the items recalled by other group members that a given group member might have failed to recall had she worked alone (Weldon & Bellinger, 1997; Basden, Basden, & Henry, 2000; Thorley & Dewhurst, 2007; Blumen & Rajaram, 2008; Congleton & Rajaram, 2011; but see Finlay, Hitch, & Meudell, 2000). The process of re-exposure not only improves post-collaborative individual memory by increasing the quantity of information that is accurately and additionally remembered, it also plays an important role in gluing the group members' memories together and thus shaping the formation of shared memories, or *collective memory* (Congleton & Rajaram, 2014).

Collective Memory. The formation of shared memories or collective memory is often said to be tied to a group's identity (Hirst & Manier, 2008). In experimental paradigms, collective memory has been operationally defined as the number of overlapping items that the group members collectively share (also collectively forget, in some cases) in their post-collaborative individual recall (Choi et al., 2014; Congleton & Rajaram, 2014; Cuc, Ozuru, Manier, & Hirst, 2006; Stone, Barnier, Sutton, & Hirst, 2010). We follow the same experimental practice to measure collective memory in the present study. Empirical research on collective memory using the collaborative memory paradigm has shown that repeated collaboration triggers the formation of collective memory by increasing overlapping memory among group members (e.g., Blumen & Rajaram, 2008; Choi et al., 2014; Congleton & Rajaram, 2014) and has also examined how various factors such as the role of retrieval (Barber, Rajaram, & Fox, 2012), organization of memory structure (Congleton & Rajaram, 2014), or normal aging (Henkel & Rajaram, 2011) affect collective memory formation. However, little is known about how collective memory formation for emotional memories compares with that for nonemotional memories. The formation of collective memory is determined by the various processes that occur *during* collaboration (e.g., collaborative inhibition, re-exposure, error-pruning, blocking, etc.; reviewed by Rajaram & Pereira-Pasarin, 2010). Thus, if the extent to which emotion modulates the collaborative recall process is not significantly large, the amount of information that is collectively remembered or collectively forgotten in post-collaborative memory would not differ across emotional and nonemotional information. But, if collaboration poses a differential effect on collaborative recall of emotional and nonemotional information (either through more social sharing of emotion or, conversely, more information pruning during collaboration, depending on the emotional valence), the formation of collective memory would be either greater or lesser for emotional information compared to nonemotional information. We examined these possibilities in the present study, together with the extent to which non-studied information can be incorporated into collective memory through social contagion.

Social Contagion of Memory. Social contagion is another mechanism involved in the process of collaboration during or after collaboration, and refers to the spread of memory from one person to another by means of interpersonal interactions (Roediger, Meade, & Bergman, 2001; reviewed by Rajaram & Pereira-Pasarin, 2010 and Hirst & Echterhoff, 2012). One obvious consequence of such social contagion of memory would be the spread of non-studied information or false memory. In a typical social contagion paradigm that was developed to investigate social contagion of errors (Roediger et al, 2001; Meade & Roediger, 2002), participants first study target materials and engage in a collaborative memory task with a confederate who produced misinformation during the collaboration. Studies employing the social contagion or similar paradigms (i.e., memory conformity paradigm; Wright, Self, & Justice, 2000) consistently show the susceptibility of memory to misinformation introduced during collaborative recall (e.g., Roediger et al., 2001; Meade & Roediger, 2002; B. H. Basden, Reysen, & Basden, 2002). Our question is then, is emotional information more susceptible to social contagion than nonemotional information because people are more likely to pay attention to information that has emotional content, or is it less susceptible because people have higher accuracy in recall of emotional than nonemotional information and therefore would be better able to disregard non-studied emotional information compared to non-studied nonemotional information? To our knowledge, the patterns of social contagion of errors during collaboration for emotional information have not yet been investigated.

Social Transmission of Shared versus Unshared information. A situation where social contagion of errors can spontaneously occur during collaboration is when group members contribute information which other group members were not exposed to initially. Research in the group decision making and problem solving literature first utilized such cases in experimental paradigms to investigate ways in which groups can reach optimal group decision making when the distribution of information is non-equivalent among group members (reviewed by Stasser & Titus, 2003; Wittenbaum & Park, 20001; Ohtsubo, 2005). Such paradigms have extended to group recall research as well (Stewart & Stasser, 1995; Stewart & Stewart, 2001, Stewart, Stewart, Tyson, Vinci, & Fioti, 2004; Meade & Gione, 2011; Barber, Harris, & Rajaram, 2015). The general finding across the literatures is that shared information is more likely to be mentioned and remembered than unshared information during group discussion, consistently revealing groups' preference for shared information. However, the extent to which the unshared information (unknown to some group members) or partially shared information (known to some but not all group members) becomes a part of a group member's post-collaborative memory via social contagion has been overlooked since previous group recall research with this paradigm did not include post-collaborative memory measures (Stewart & Stewart, 2001, Stewart et al., 2004; Meade & Gione, 2011) or this question was not assessed as a main focus of the study (Barber, Harris, & Rajaram, 2015).

We found this shared/unshared paradigm particularly instrumental for examining our research questions about the social transmission of true emotional memories and social contagion of emotional memory errors. Specifically, by employing this paradigm we were able to examine the cascade of emotional memory for shared, partially shared, and unshared information. Would the shared emotional information spread more than partially shared or unshared nonemotional information because people have richer memory for emotional information (Ochsner, 2000) and it may trigger more discussion of emotional memories during social interaction (Rime, 2009)? Or, would the groups' tendency to focus on shared information appear equivalently regardless of emotionality of the information? If more social sharing of emotional information occurs during collaboration, then how would it affect the extent to which the unshared emotional information spreads to one's post-collaborative memory? On the one hand, unshared emotional information would have a higher chance of being incorporated into one's post-collaborative memory if a greater amount of unshared emotional information is mentioned during collaboration than is unshared nonemotional information. On the other hand, it is also possible that unshared emotional information would be more easily discarded because of its distinctive nature (Schacter, Gallo, & Kensinger, 2007). We aimed to test these questions by manipulating the shared, partially shared, and unshared status of information across repeated social interactions that varied in group configuration, which discussed next.

Spread of Information across Social Networks

A group of people might read reviews of a restaurant, talk to friends about the review, and the friends in turn talk to their friends about the review again. In this way, the memory of people within that social network can be shaped and reshaped not only by their direct friends but also by their friends' friends. It is only recently that researchers have started to consider simulating such cases in the laboratory where memory can be transmitted beyond small groups (typically dyads to tetrads) to larger chains (Kashima & Yeung, 2010) or networks of people. Coman and Hirst (2012) recently showed how a conversation between two people on an issue, and the consequence of the conversation on their memories, could be influenced by listening to an input from a third person's take on the issue. Their results indicated that the third person's influences can be propagated to the two conversational partners' final individual memory.

In our previous work, we have examined the transmission of information across two different group configurations such that a given individual's memory is affected not just by two partners in a collaborative triad but potentially by as many as eight other individuals in that network (Choi et al., 2014). Participants completed repeated collaborative recall sessions in groups of three, either with the same or a different group of collaborating partners. Figure 1 illustrates the group configuration used in that study. With this design, we were able to assess and measure the extent to which a given group member's post-collaborative individual memory is shaped not only by her immediate group partners (i.e., proximal partners) with whom she had direct interactions across two iterations of collaborative recall, but also by the partners of these partners (i.e., distal partners) with whom she had not interacted but whose memory could potentially affect her memory through their influence on her proximal partners. Thus, the design allowed any given individual participant in the reconfigured group condition to have four proximal partners and four distal partners. We observed not only the transmission of memory picked up from proximal partners but also detectable transmission of memory passed on from distal partners. The use of unrelated words in that study, and the resulting low rates of memory errors, precluded a test of the distal partner effects on the transmission of false memory. But, the success of the reconfigured group paradigm in capturing transmission of true memory opens up the avenue to explore both accurate and false memory transmission with more memorable materials, such as emotionally charged information.

The Present Study

The key interests in the present study were three-fold. First, we aimed to empirically test how emotional information transmits in small groups (three members) and across a larger network (nine members) in comparison to the key finding reported in the individual memory literature (i.e., the emotional memory advantage for true memories). Second, we aimed to examine this question both for transmission of memories for shared, partially shared, and unshared information, creating a situation where not all group members shared the same information. Third, we aimed to test how multiple cognitive processes that are known to operate during collaborative recall of nonemotional information are affected by the emotionality of information. As described at the outset of this Introduction, all aforementioned investigations have examined the influences of emotion on individual memory or the influences of collaboration on nonemotional information. Since the data available in the literature on the interactive effects of these two – emotional and social – factors on memory are sparse, we first conducted a foundational experiment (Experiment 1) to set the stage for examining the social transmission of emotional memory in the present research.

Selection of Stimuli. The stimuli used in the current study were identical to those used in Choi et al., (2013). The normative stimuli consisted of 360 categorized photo objects and corresponding word labels in each valence of negative, positive, and neutral (see Figure 2 for an example of each type). There were 15 categories per valence. Based on prior norming studies, 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. The items across the three valences did not differ in frequency, familiarity, imageability (norms from the MRC database, all $p > 0.15$) or in visual complexity (Fs < 1.5, ps > .25, based on normative data from 20 young adults). There were also equivalent numbers of sets that included people, inanimate objects, animals, or landscapes across valence and categories.

II. Experiment 1

In this experiment, we had two aims. One, we aimed to implement the collaborative memory paradigm that includes both emotional and neutral information and replicate the well-established phenomena of 1) emotional memory advantage in individual memory, 2) collaborative inhibition in group recall, and 3) post-collaborative recall benefits for neutral information. Two, we aimed to examine three novel issues that would help set the stage for examining social transmission of emotional information and false memory in Experiment 2. These three novel issues were: 1) when people collaborate to recall emotional and neutral information in groups, would the effects of collaboration on group memory be different for emotional versus neutral information? 2) what are the consequences of collaboration on post-collaborative individual memory for emotional versus neutral information? Specifically, we aimed to focus on how emotional content and two key cognitive mechanisms that operate during collaboration – retrieval disruption and re-exposure benefits –interactively influence collaborative group memory and post-collaborative individual memory, and 3) how collaboration influences the formation of collective memory for emotional and neutral information.

First, we examined whether the emotional memory enhancement for emotional information would be observed during collaborative recall as well as during individual recall. Past research shows that collaborative recall can behave just like individual recall in response to several well-known variables. For example, Weldon & Bellinger (1997) showed that collaborative recall exhibited the same effects as individual recall on some of the basic memory principles such as a level-of-processing effect (better memory for deeply processed – that is, information processed for meaning - as compared to shallowly processed information- that is, information processed for surface-level features; Craik & Lockhart, 1972), a picture-superiority effect (better memory for pictures than for words; Nelson, Reed, & Walling, 1976), and hypermnesia (memory enhancement as a function of repeated retrieval attempts without an additional study opportunity; Payne, 1987; Roediger & Payne, 1982). Based on these findings, we predicted that the emotional memory enhancement effects would occur with collaborative recall as well.

Second, we examined whether retrieval disruption (i.e., collaborative inhibition) would be observed in the recall of emotional information when both negatively and positively charged emotional information is intermixed with neutral information within a study list. Previous studies showed the presence of collaborative inhibition in the recall of negatively charged emotional material when only negative materials were presented (Yaron-Antar & Nachson, 2006; Wessel, et al., 2015). A possibility in our experiment is that we might see less collaborative inhibition for emotional information because emotional information is more distinctive than neutral information especially when they are co-presented, and thus people might discuss more emotional events during collaboration. This process could lead to more cross-cuing effects for emotional information compared to neutral information. That is, hearing additional items could serve to cue other as-yet-unrecalled items. However, if disruption is also greater for emotional information because the retrieval sequence of these items is organized more idiosyncratically (due to personal preferences) than the retrieval organization of neutral information, then this disruption would cancel out the cross-cuing effects, and would produce equivalent collaborative inhibition between emotional and neutral information or even greater inhibition for emotional information than for neutral information.

Third, we examined whether the magnitude of re-exposure effects in post-collaborative individual memory (Blumen & Rajaram, 2008) would differ or be equivalent for emotional and neutral information as a function of previous collaboration. Lastly, we examined how the collaborative inhibition and re-exposure processes occurring for emotional versus neutral information would modulate the formation of collective memory.

Method

Participants and Design

The experiment consisted of a 3x3 mixed design with retrieval sequence (III - Individual-Individual-Individual, ICI -Individual-Collaborative-Individual, and CCI - Collaborative-Collaborative-Individual) as a between-subjects factor and emotional valence (negative, positive, and neutral) as a within-subject factor. A total of 144 Stony Brook University students were tested, with 16 triads (48 participants) per condition across the three between-subject conditions. The triads were formed such that all members were strangers. The method was adapted from a combination of Choi et al. papers (2013, 2014) and Blumen and Rajaram (2008).

Materials

Since the purpose of this experiment was to provide an initial test of the comparison between individual memory and collaborative memory, we selected a subset of the stimuli from the stimulus set described earlier. In this selected subset, there were 6 categories per valence with 8 items per each category, resulting in 48 items per valence and for a total 144 items. Eight study lists were created for counterbalancing purposes, and each study list consisted of 5 to-be-studied and 3 not-to-be-studied items from each category, resulting in 30 studied and 18 non-studied items associated with each valence for a given participant.

Procedure

In the study phase, participants were presented with pictorial stimuli with corresponding word labels and each such pair randomly intermixed within the list with respect to valence, and were 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, including no mention of collaboration or non-collaboration possibilities during the memory test.

After the study phase, participants performed a distractor task (playing a game of computerized solitaire) for 8 minutes, followed by participation in three consecutive free-recall sessions. Participants in the III condition completed all three recall sessions individually. Participants in the ICI condition completed the first recall session individually, the second recall session collaboratively in three-person groups, and the last recall session individually again. Participants in the CCI condition completed the first two recall sessions in three-person groups (staying with the same group in both sessions) and the last recall session individually. Regardless of the retrieval condition, all participants were given 9 minutes to complete the recall task in each session, with 2-minute recesses between each recall session.

Results

The proportions of correctly recalled items for each condition across three recall sessions are shown in Table 1.

Recall Performance

With respect to the first aim of this experiment, that is, to investigate the effects of emotion on recall, we compared recall performance for each valence during the first recall session that serves as the baseline recall (Figure 3). Repeated measures of ANOVAs revealed significant effects of emotion across all three conditions, F (2, 94) = 55.62, MSe = .007, p <.001, η^2 = .54, in III, F (2, 94) = 26.33, MSe = .008, p < .001, η^2 = .36 in ICI, and F (2, 30) = 17.71, MSe = .009, p < .001, η^2 = .54 in CCI. Subsequent t-tests revealed that negative and positive items were recalled better than neutral items in all three conditions (*p*s < .001), with no difference between negative and positive items (*p*s > .09). These patterns are consistent with the past findings in individual memory literature that emotional content is remembered better than nonemotional content (e.g., Buchanan, 2007) as well as with the findings that the basic phenomena observed in individual recall are often carried into group recall (e.g., Weldon & Bellinger, 1997).

Collaborative Inhibition. In order to assess retrieval disruption that was expected to occur during collaboration (i.e., collaborative inhibition), we compared the nominal recall in the **I**II and the collaborative recall in the **C**CI during the first recall session (Figure 4). The collaborative group recall refers to the number of items recalled by groups, and the nominal group recall refers to the number of non-redundant items retrieved by an equal number of individual who have worked individually. The nominal group recall indexes the potential for a group's recall against which collaborative recall is measured, and thus any reduction in collaborative group recall compared to the nominal group recall indexes collaborative inhibition.

Collaborative inhibition in group recall occurred regardless of emotional valence such that nominal group recall was always greater than collaborative group recall across valence; t (30) = 2.60, SEM = .04, p = .01, d = .95 for negative, t (30) = 4.47, SEM = .04, p < .001, d = 1.60 for positive, and t (30) = 2.18, SEM = .05, p = .04, d = .77 for neutral items. These results replicated collaborative inhibition for neutral information (Rajaram & Pereira-Pasarin, 2010) and provided a novel finding that collaborative inhibition also occurs with both negatively and positively charged information. With respect to the question on whether the magnitude of collaborative inhibition would vary across valence, the magnitude of disruption was numerically greater for positive items (.17) than neutral (.10) or negative items (.12). However, the interaction between valence and collaborative inhibition did not reach significance, *F* < 1.

Consistent with previous findings (Blumen & Rajaram, 2008; Choi et al., 2014), collaborative inhibition persisted during the second collaborative session in the C**C**I compared to the control condition I**I**I, *t* (30) = 2.45, *SEM* = .04, *p* = .02, *d* = .83 for negative, *t* (30) = 2.75, *SEM* = .04, *p* = .01, *d* = 1.00 for neutral, and *t* (30) = 3.54, *SEM* = .04, *p* < .001, *d* = 1.30 for positive items, and the magnitude of this effect did not differ across valence (no interaction), *F* < 1. Also consistent with previous findings (Blumen & Rajaram, 2008; Choi et al., 2014), the magnitude of collaborative inhibition numerically reduced after repeated collaboration (a 2% reduction for negative, a 1% reduction for neutral, and a 5% reduction for positive items).

Re-exposure Effects. The possible re-exposure benefits of collaboration on post-collaborative individual recall were first assessed by comparing final individual recall in the II**I** and IC**I** conditions (Figure 5). A 3 (emotional valence: Negative vs. Positive vs. Neutral) x 2 (collaboration: III vs. ICI) ANOVA revealed a significant benefits from collaboration, *F* (1, 94) = 11.47, *MSe* = .001, *p* = .001, η^2 = .11, indicating final individual recall was better after collaboration than working alone. A main effect of valence was also observed, *F* (2, 188) = 63.54, *MSe* = .01, *p* < .001, η^2 = .40, with higher recall scores for negative and positive than for neutral items. There was a marginal interaction, *F* (2, 188) = 2.69, *MSe* = 01, *p* = .07, revealing a pattern that the re-exposure benefits of collaboration on post-collaborative recall were numerically greater for negative (.09) and neutral items (.11) than for positive items (.05). The comparison between the II**I** and CC**I** conditions revealed the same pattern. There was a significant benefit from collaboration, *F* (1, 94) = 9.66, *MSe* = .04, *p* = .002, η^2 = .09, as well as a significant effect of valence, F (2, 188) = 81.27, MSe = .01, p < .001, η^2 = .46, but no interaction, F < 1.

Collective Memory. The formation of collective memory was examined with the calculation of collective recollection scores (i.e., the proportions of items that all group members remembered in their post-collaborative individual recall; Figure 6) Collective recollection scores in both the ICI and CCI conditions were greater than in the III condition, *p*s < .02. Overall, the collective recollection scores for emotional items (both negative and positive) were consistently higher than the scores for neutral items, regardless of retrieval conditions. In the baseline III condition, the collective recollection scores for negative (.12) and positive (.14) items were higher than for the neutral (.03) items, t (15) = 7.39, SEM = .01, p < .001, d = 1.99, t (15) = 5.82, SEM = .02, p < .001, d = 1.73, with no difference between negative and positive items. The exact same patterns were found both in the ICI and the CCI. In the ICI condition, collective recollection scores for negative (.26) and positive (.25) items were higher than for the neutral (.18) items, t (15) = 3.28, SEM = .02, p = .01, d = .88, t (15) = 3.32, SEM = .02, p = .01, d = .73, with no difference between negative and positive items, p = .88. Also in the CCI condition, collective recollection scores for negative (.27) and positive (.26) items were higher than for the neutral (.15) items, t (15) = 3.73, SEM = .03, p = .002, d = 1.18, t (15) = 5.53, SEM = .02, p < .001, d = 1.21, with no difference between negative and positive items, p = .73. The collective recollection scores for negative and positive items did not differ both in the ICI and the CCI condition (*p*s > .70)

The results indicate that there was greater overlap in memory (collective memory) for emotional than neutral information and it was not affected by whether the emotional valence was negative or positive. In other words, the extent of overlap in post-collaborative recall of the group members was greater for emotional items than for neutral items, and this was true both in the baseline III condition (where only the study phase provided the bases for overlapping memories) and for the ICI and CCI conditions (where the collaborative recall phase provided additional bases for overlapping memories). The overall patterns were in line with recall level patterns, such that higher recall in individual memory for emotional items compared to neutral items in individual recall (III) produced higher overlapping memories for emotional information. Similarly, higher recall following collaboration (ICI and CCI) also produced greater overlap in post-collaborative memories compared to no collaboration (III). There was no interaction between collaboration and valence for the magnitude of collective memories, *F*s < 1.

However, an additional analysis based on non-overlaps in post-collaborative recall revealed the way in which the memory for items with negative versus positive valence can diverge. The non-overlaps in post-collaborative recall are measured through nominal group recall (i.e., non-redundancy in recall) and thus it indexes the variety of items held in post-collaborative individual memory of a group of individuals who had previously collaborated. When the nominal recall from the pre-collaboration session (Recall 1) and the post-collaboration (Recall 3) in the **I**C**I** condition was compared, collaboration significantly increased variety in recall for negative items (.66 to .74, t [15] = 3.63, *SEM* = .02, p = .002, d = .82) and for neutral items (.53 to .59, t [15] = 3.24, *SEM* = .02, p = .006, d = .44), but such patterns were not observed with positive items (.69 vs. .70, p = .65), suggesting more redundancy in memory for positive than negative and neutral items in post-collaborative recall.

There is another hint in our data that suggests that negative and positive information might have been processed differently during and following collaboration. When we examined the nominal group recall scores from the first recall in the ICI condition (.66 for negative, .53 for neutral, and .69 for positive) and the collaborative recall scores from the second recall (.66 for negative, .54 for neutral, and .65 for positive; see Table 1), the collaborative recall outputs during Recall 2 for negative and neutral items are almost identical as the sum of the individual outputs during Recall 1, while there was a drop only for the positive items. Although this difference (.69 vs. .65) did not reach significance, p = .18, it suggests that participants experienced slightly more disruption for positive items as they switched from individual to collaborative recall. This possibility is consistent with the finding we reported above that the recall of positive items showed less variety in memories following collaborative recall for positive items compared to negative or neutral items. In other words, it is possible that the greater disruption experienced during collaboration led to forgetting one's own items and settling on the group's output to a greater extent for positive items compared to the negative and neutral items.

The key findings from Experiment 1 have informed us that 1) the memory enhancement effects of emotional information observed in individual memory carries over into collaboration, 2) retrieval disruption occurs both for neutral and emotional information and produces collaborative inhibition in group recall for not only neutral memories but also emotionally valenced memories, and the degree of disruption does not differ as indexed by this measure, but 3) the re-exposure benefits of collaboration are numerically greater for negative and neutral items than for positive items, and 4) there is a possibility of negative and positive information might be processed differently during and following collaboration, as the data suggest that more disruptions might have occurred for positive information during collaboration (i.e., numerically greater magnitude of collaborative inhibition for positive information) that resulted in smaller post-collaborative benefits for positive items as well as less variety in memory for positive items in the post-collaborative recall. In Experiment 2, we examined these possible differential effects of negative and positive valence on memory using a larger set of stimuli while also investigating a new set of questions outlined in the next section.

III. Experiment 2

Experiment 2 was designed to test, 1) how emotional information transmits in small groups (three members) and across a larger network (nine members) in comparison to the key finding reported in the individual memory literature (i.e., the emotional memory advantage for true memories), 2) how transmission of emotional memory is modulated by shared or absence of shared experiences among group members, 3) how emotional valence and social interaction influence the transmission of memory for non-studied information, 4) how the emotional valence, sharedness of experience, and transmission of memory for studied and non-studied information modulate the formation of collective memory, and 4) whether differential effects of negative and positive valence would be revealed across these measures.

Method

Participants and Design

The experiment consisted of a 3x3x3 mixed design with retrieval condition (III: Individual-Individual-Individual, CCI: Collaborative-Identical Collaborative-Individual, and CRI: Collaborative-Reconfigured Collaborative – Individual) as a between-subjects factor and emotional valence (negative, positive, and neutral) as a within-subject factor. Distribution of information among group members (shared, partially shared, unshared) was also manipulated as a within-subject factor. A total of 216 Stony Brook University students participated for course credit, with 72 participants per retrieval condition. Once again, collaborating groups consisted of strangers.

Materials

The stimuli consisted of 360 categorized pictures and corresponding word labels in each valence of negative, positive, and neutral, as described at the outset. In other words, the stimulus set was expanded in Experiment 2 relative to Experiment 1 in order to test the effects of the added variable, that is, shared, partially shared, and unshared memories. There were 15 categories per valence with 8 items per each category, resulting in 120 items per valence. Four versions of study lists were created; each study list consisted of 3 to-be-studied and 5 not-to-be-studied items from each category, resulting in 135 (45 per valence) studied and 225 non-studied items associated with each list presented to a given participant. Six different sub-versions 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 135 randomly intermixed stimuli, and 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.

Additionally, in each 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 group members studied 90 identical items (*shared*), two groups members studied additional 30 identical items (*partially shared*), and one group member studied additional 30 items that were not studied by the other two group members (*unshared*). The participants were not informed about the unequal distribution of information among group members for the following reasons: first, the main reason for one to consider informing the participants about the unequal distribution of information would be to minimize the possibility of them finding the collaborative process unnatural (when listening to other group members producing items that she has never seen). However, in our study, the overall number of to-be-unshared items was small (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 reduced in magnitude when compared to 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 minutes.

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, complete the second recall session with the same group of people, and then complete 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 with a different group of people. This means nine participants were tested at the same time to ensure reconfiguration in any given experimental sessions. They completed the third recall session individually like the participants in the other two conditions.

Immediately after the completion of the final individual recall session, the participants in the CCI and CRI conditions were given their recall protocol back and asked to indicate whether the each item they produced during the final individual recall session was recalled by a) themselves, b) another group member, c) themselves and another group member, and d) no one, during the previous collaborative recall sessions. To ensure constant testing modality between the collaborative conditions and the individual condition, participants in the III condition were asked to indicate whether the each item they produced during the final recall session was recalled in previous recall sessions or not.

Recognition phase. All participants were shown 360 items (135 studied, 225 non-studied; these 225 non-studied items were unshared items that potentially could have been introduced during collaboration from 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.

Exit Questionnaires. At the end of the experiment, all participants were given the state version of STAI and PANAS to assess the level of anxiety. They were also asked about their subjective experiences about the collaborative tasks (e.g., "How did you feel while you were working with your group partners?" adapted from Henkel & Rajaram, 2011; Pociask & Rajaram 2014).

Results

The analyses included comparisons among the three retrieval conditions for, 1) the proportions of overall recall outputs for each valence (negative, positive, neutral), collapsed across sharedness, to examine the extent to which emotion influences group memory output and post-collaborative individual memory, 2) the proportions of correct recall of studied information that was shared, partially shared, and unshared during the study phase, 3) the proportions of recall of items that are not studied by a given member but were studied by other group members and were introduced by them during collaboration (social contagion), and 4) quantity of collective memory, to examine whether the post-collaborative memories overlap across participants, and whether the magnitude of overlap varies for people who collaborated in the identical versus reconfigured group, for emotional versus neutral information.

Prior to computing the influences of emotional valence on transmission of memory, we first assessed the overall recall performance by collapsing across valence in order to examine the standard findings on collaborative memory literature (collaborative inhibition). Since the findings from Experiment 1 established that collaborative inhibition occurred for both neutral memories and emotionally valence memories to a comparable degree, we collapsed across the valence feature in the current analyses and focused on the novel variables of the shared/unshared status of studied information.

Collaborative Inhibition for Shared, Partially Shared, and Unshared Information

The overall recall performance for shared, partially shared, and unshared items is shown in Table 2. In order to assess collaborative inhibition in Recall 1[1], we conducted two separate ANOVAs, one for the comparison between the III and CCI, and one for the comparison between the III and CRI. A 2 (III or CCI) x 3 (shared or partially shared or unshared) mixed-factor ANOVA revealed significant collaborative inhibition, F (1, 46) = 33.45, MSe = .01, $p < .001$, $\eta^2 = .42$, as well as the main effect of information distribution, F (2, 92) = 136.08, MSe = .01, $p < .001$, $\eta^2 = .75$, with the highest recall rates for the shared items and the lowest recall rates for the unshared items in both conditions. The interaction between the two factors was marginally significant, F (2, 92) = 2.58, MSe = .01, p = .08, $\eta^2 = .05$, suggesting the magnitude of collaborative inhibition varied as a function of sharedness; there was a trend for numerically larger collaborative inhibition for shared (M = .13) and partially shared items (M = .11) than for unshared items (M = .06).

The same analysis conducted for the comparison between the III and CRI revealed identical patterns, as it should, because the CCI and CRI are essentially identical at this point in time in the experiment; there was significant collaborative inhibition, F (1, 46) = 16.29, MSe = .02, $p < .001$, $\eta^2 = .26$, main effect of information distribution, F (1, 46) = 129.25, MSe = .008, $p < .001$, $\eta^2 = .74$, as well as a significant interaction, F (2, 92) = 3.28, MSe = .008, p = .04, η^2 =

[1] A test of collaborative inhibition patterns was conducted only on Recall 1 performance because this stage of recall included all "accurate" shared, partially shared, unshared recall. While the patterns were similar during Recall 2, these recall levels were not examined statistically for assessing collaborative inhibition because the recall outputs on Recall 2 included both accurate recall as well as "contagion" recall arising from the exposure to unshared (non-studied) items during the Recall 1 session in the CRI condition.

.07. Consistent with the trends shown in the CCI condition, follow-up pair-wise comparisons indicated that collaborative inhibition was significant for shared (M = .11) and partially shared items (M = .11), t (46) = 4.13, SEM = .03, p < .001, d = 1.16, t (46) = 3.37, SEM = .03, p = .002, d = .90, but was absent for unshared items (M = .03), p = .26. The CCI and CRI conditions did not differ, Fs < 1. These results indicate that collaborative inhibition occurs both for shared and partially shared information, but the effect was smaller or absent for unshared information. We will return to the discussion of these patterns in the General Discussion.

Influences of Emotion on Recall

Findings are reported for collaborative recall, post-collaborative individual recall and recognition (i.e., transmission of memory), and collective memory for each retrieval condition. The recall proportions for each retrieval condition and emotional valence are shown in Figure 7.

Individual Recall. The effect of emotional valence was tested for the III condition to set the baseline recall level when working alone. During the first recall session (Recall 1), a repeated measures of ANOVA revealed a significant effect of valence, F (2, 142) = 4.76, MSe = .006, p = .01, η^2 = .06. The effect was directional, in which the recall rates were highest for negative (M = .27), intermediate for neutral (M = .25), and lowest for positive items (M = .23). Subsequent t-tests indicated a significant difference between the recall rates for negative and positive items, t (71) = 3.20, SEM = .01, p = .002, d = .42, with no difference between negative and neutral, nor between neutral and positive items. Better memory for negatively valenced information especially among young adults is a standard finding in the literature (e.g., Ochsner, 2000), and such a directional effect of valence (negative > neutral > positive) on memory performance also has been reported (Brainerd, Stein, Silveira, Rohenkohl, & Reyna, 2008, with a recognition test). However, this finding is somewhat different from that obtained in Experiment 1 where we found enhanced memory for both negative and positive items than for neutral items. This is most likely due to the different composition of the study lists used in each experiment. Compared to the study list used in Experiment 1, the current study lists was much longer (135 items vs. 90 items) and the category size per each valence was reduced in the current experiment as well (3 items per each of 45 categories in the current experiment; 5 items per each of 18 categories in Experiment 1). When the newly added categories were excluded from the current analyses to match the study lists more closely between the two experiments, the same patterns that we found in Experiment 1 were observed: both negative (M = .29, SE = .02) and positive (M = .29, SE = .02) items were recalled significantly better than neutral items (M = .20, SE = .01), ps < .001. In other words, the emotional memory effect observed in Experiment 2 was in line with past findings and when participants had many more memories to recall (Experiment 2), an advantage for negative items (henceforth, a negativity effect) emerged in initial recall.

This directional effect of valence observed during Recall 1 disappeared in the subsequent individual recall sessions, ps > .30. We tested the *hypermnesia* effect (i.e., improved recall over time as a function of repeated recall attempts without additional study) to examine the disappearance of the valence effect. Recall rates across Recall 1 to Recall 2 were significantly increased, indicating the hypermensia effect, F (1, 71) = 101.89, MSe = .001, p < .001, η^2 = .59. The interaction between valence and recall sequence was also significant, F (2, 142) = 3.73, MSe = .001, p = .03, η^2 = .05, as the magnitude of the hypermnesia effect varied for each valence (2.5% for negative, 3.5% for neutral, and 4.7% for positive). The hypermnesia effect across Recall 2 to Recall 3 was also significant, F (1, 71) = 56.42, MSe = .002, p < .001, η^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), but the interaction was not significant, p = .12.

Overall, the results from the III condition indicated that when people have a large set of memories to recall and thus need to engage in a more exhaustive retrieval effort, they are more prone to recalling negative memories at first. Had the study list been shorter (with fewer possible items to recall, as in Experiment 1), an equivalent valence effect would have emerged for both negative and positive items. But when participants have a lot more memories from which to draw (as made possible by the longer study list in Experiment 2) the repeated attempts at recall enabled the recall of more positive items than observed in Recall 1 of the presented experiment.

Group Recall. The effect of emotional valence on group recall when individuals engaged in repeated collaborative recall sessions with the same group of partners was tested. During the first collaborative recall session in the CCI condition, the same directional effect of valence (negative > neutral > positive) that was observed in the III condition (Recall 1) was observed. A repeated measures ANOVA indicated a significant effect of emotional valence, F (2, 46) = 4.73, MSe = .01, p = .01, η^2 = .17, with higher recall rates for negative items (M = .50) than for neutral (M = .42) and positive (M = .41) items. Pair-wise comparisons indicated that only the difference between negative and positive items was significant, t (23) = 2.82, SEM = .03, p = .01, d = .75.

Both individuals working alone (**I**II) and collaborative groups (**C**CI) remembered negative information better than positive information during the first recall session, but the magnitude of the effect was larger for the CCI groups (9%), compared to the III (4%). Importantly, while the emotional valence effect disappeared when individuals continued to work alone (second and third recalls in III), the effect remained significant during the second collaborative recall session in the CCI condition, F (2, 46) = 3.66, MSe = .01, p = .03, η^2 = .14, with higher recall rates for negative items (M = .56) than for neutral (M = .49) and positive (M = .47) items. The numerical patterns showed the same directional effect observed in Recall 1, and pair-wise comparisons indicated that the difference between negative and positive was marginally significant, t (23) = 2.39, SEM = .03, p = .03, d = .74.

Next, as a manipulation check, the first recall session of CRI condition was compared to the first recall session of CCI condition, as these two conditions should not differ since these are essentially identical conditions at this time point in the experiment. As expected, a 2 (retrieval condition; CCI, CRI) x 3 (valence; negative, neutral, positive) mixed-factor ANOVA on Recall 1 revealed no effect of retrieval condition nor interaction, ps > .30. The first recall session in the CRI condition also showed the same directional effect of valence (negative>neutral>positive), although the differences did not reach significance, p = .39.

During the second collaborative recall session of the CRI condition, it was predicted that the CRI group would recall more than the CCI group as the participants in the CRI condition would bring more variety of items to the second collaborative recall session because new partners get together and bring their unique memories (not recalled by others) to the collaboration (Choi, et al. 2014). As expected, the difference between C**C**I and C**R**I condition emerged during the second collaborative recall session. A 2 (retrieval condition; CCI, CRI) x 3 (valence; negative, neutral, positive) mixed-factor ANOVA on Recall 2 indicated a significant effect of retrieval condition, F (1, 46) = 20.38, MSe = .03, p < .001, η^2 = .31, a significant effect of valence, F (2, 92) = 7.52, MSe = .01, p = .001, η^2 =.14, with no interaction, F < 1. The CRI group performed better than the CCI group across all valences, with the same directional effect of valence in both conditions (negative > neutral > positive). In this second recall session, this directional effect of valence was significant in CRI, F (2, 46) = 4.79, MSe = .01, p = .01, η^2 = .17, and similar to the CCI condition, only the difference between negative and positive items was significant, t (23) = 3.05, SEM = .02, p = .01, d = .56.

In brief, the results from the collaboration conditions indicated that collaboration boosted the recall of negative information to a greater extent than the recall of positive information, especially compared to when individuals worked alone to recall the studied information. The analyses thus far were conducted on the overall amount of recall outputs to get a broad view of recall performance as a function of valence. We now turn to analyses that make distinctions among shared, partially shared, or unshared items, as well as between studied and non-studied items.

Transmission of Memory: Influence of Shared Experiences on Group Recall of Emotional Information

The second question in this study was how emotional valence would affect group recall during collaboration and post-collaborative individual recall when not all group members have been initially exposed to the same information. There were three categories for studied items: 1) items that all three group members studied initially (*shared*), 2) items that two of the three group members studied initially (*partially-shared*), and 3) items that only one of the three group members studied initially and thus this item was unshared (*unshared*).

Repeated Collaboration with Identical Partners (CCI). Proportions of correct recall from the CCI condition as a function of sharing and emotional valence are shown in Figure 8. A 3 (Sharedness; Shared, Partially shared, Unshared) X 3 (Valence; Negative, Neutral, Positive) repeated ANOVA was conducted on Recall 1 from the **C**CI condition. There was a significant effect of sharedness, F (2, 46) = 76.86, MSe = .01, $p < .001$, η^2 = .77, as the shared items (M = .42) were recalled more frequently than the partially-shared items (M = .31), t (23) = 6.51, SEM = .02, $p < .001$, d = 1.46, and the partially shared items were recalled frequently more than the unshared items (M = .18), t (23) = 5.51, $p < .001$, SEM = .02, d = 1.63. The effect of valence was also significant, F (2, 46) = 4.49, MSe = .02, p = .02, η^2 = .16, which was driven by higher recall rates for negative items (collapsed across sharedness, M = .35) than positive items (collapsed across sharedness, M = .28). The interaction between valence and sharedness was not significant, p = .33. These results indicate that, even though collaboration boosted the recall of negative information, emotional valence did not have a differential effect on recall of shared/partially shared/unshared information during the first collaborative recall attempt. However, a numerical pattern emerged where the contrasts between recall rates for negative and positive items was smaller for unshared items (.02) than for shared (.08) and partially shared (.11) items.

During the second recall session in the C**C**I condition, both the effect of sharedness and valence continued to be significant, F (2, 46) = 75.31, MSe = .02, p < .001, η^2 = .77, F (2, 46) = 3.31, MSe = .02, p = .045, η^2 = .13, respectively. Interestingly, the interaction between the two factors was marginally significant, F (4, 92) = 2.22, MSe = .02, p = .07, η^2 = .09. The marginal interaction was driven by an increase in the recall of unshared positive items as negative items were recalled more than positive items when those are shared and partially shared. These results suggest that when people continue to collaborate with the same group of people, if the information was fully or partially shared with other group members, they go on to remember more negative information than positive information. But, when the information is unshared, such a negativity effect of valence is attenuated.

Repeated Collaboration with Reconfigured Partners (CRI). Proportions of correct recall from the CRI condition as a function of sharing and emotional valence are shown in Figure 9. The first recall of the CRI condition revealed a significant effect of sharedness F (2, 46) = 67. 47, MSe = .02, p < .001, η^2 = .75 with no effect of valence or interaction, p = .57, p = .11, respectively. Although the valence effect was absent, the overall patterns were numerically consistent with the Recall 1 of the CCI condition such that the negative items were remembered better than positive information when they were shared (.04) or partially shared (.05), but such an effect was numerically reversed (.03) when those items were unshared. For the analyses on Recall 2, each category of sharedness (shared, partially shared, and unshared) was assessed separately[2]. For shared items, there was a significant effect of valence, *F* (2, 46) = 4.92, *MSe* = .01, *p* = .01, η^2 = .18. Negative items were recalled significantly better than positive items, *t* (23) = 2.64, *SEM* = .03, *p* = .015, *d* = .54, with no difference between negative and neutral, nor between neutral and positive, *p* = .10, *p* = .07, respectively. For partially shared items, there was also a significant effect of valence, *F* (2, 30) = 5.25, *MSe* = .004, *p* = .01, η^2 = .26. Negative items were recalled significantly better than positive items, *t* (15) = 3.30, *SEM* = .02, *p* = .01, *d* = .87, with no difference between negative and neutral, nor between neutral and positive, *p* = .37, *p* = .04, respectively. The differences across valence were not significant for the unshared items, *p* = .13, although the numerical patterns were consistent with what was found in the CCI (positive>neutral>=negative for the unshared items) and in Recall 1 in CRI. These results 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 other group members. However, when information was unshared, the propensity to recall more negative than positive memories disappears.

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[2] No direct comparison between the CCI and CRI conditions was made for the analyses on Recall 2 because the variable of sharedness (shared, partially shared, unshared) was by design different across the two conditions during Recall 2. While all triads in the CCI condition continued to have the same shared/partially shared/unshared variables in Recall 2 as in Recall 1, in the CRI condition, two thirds of the triads always had only shared or partially shared items whereas one third of the triads always had only shared and unshared items. Such distributions make it impossible to create comparison terms for these variables across the two conditions in Recall 2.

In summary, across both same group (CCI) and reconfigured group (CRI) conditions, there was a consistent pattern of 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. These patterns in group recall are different from the patterns observed across Recall 1 and Recall 2 in individual performance where the initial negativity effect disappeared in Recall 2. Together, these patterns show that group recall enhances recall of negative memories.

Transmission of Memory: Post-Collaborative Individual Memory

Final Individual Recall. We first examined the effect of collaboration on post-collaborative individual recall. Recall 3 from all conditions was analyzed with a 3 (retrieval condition; III, CCI, CRI) x 3 (valence; negative, neutral, positive) mixed- factor ANOVA. The main effect of valence was significant, F (2, 426) = 13.99, MSe = .01, $p < .001$, η^2 = .06. The main effect of retrieval condition was also significant, F (2, 213) = 10.10, MSe = .03, $p < .001$, η^2 = .09. These main effects were qualified by a significant interaction between valence and retrieval condition, F (4, 426) = 3.68, MSe = .01, p = .01, η^2 = .03. When the III and CCI groups were compared, there was a main effect of valence, F (2, 284) = 10.85, MSe = .01, $p < .001$, η^2 = .07, and main effect of collaboration, F (1, 142) = 14.80, MSe = .03, $p < .001$, η^2 = .09 as well as a significant interaction, F (2, 284) = 5.83, MSe = .01, p = .003, η^2 = .04. Follow-up comparisons indicated that, the effect of collaboration was significant only for negative items, t (142) = 5.25, SEM = .02, $p < .001$, d = .87, while it was not for neutral (p = .03) and positive (p = .12) items. When the III and CRI were compared, there was a main effect of valence, F (2, 284)

= 3.12, *MSe* = .01, p = .045, η^2 = .02, as well as a main effect of collaboration, F (1, 142) = 14.32, *MSe* = .04, p < .001, η^2 = .09. However, there was no interaction between the two factors, p = .31. The absence of interaction here indicates that the post-collaborative individual recall of the CRI condition was greater than that of the III condition regardless of valence. Next, when the CCI and CRI were compared, there was a main effect of valence, F (2, 284) = 16.67, *MSe* = .01, p < .001, η^2 = .11 but no effect of collaboration type, F < 1. However the interaction between the two factors was significant, F (2, 284) = 3.37, *MSe* = .01, p = .03, η^2 = .02, indicating that the final individual memory from the two collaborative conditions differed across valence. The examinations of the differential valence effect are presented in next.

The impact of sharedness. The effects of sharedness on post-collaborative individual recall for the CCI and CRI conditions were examined (see Figure 10). First in the CCI condition, significant effects of valence were found both for the shared and partially shared items, F (2, 142) = 11.34, *MSe* = .01, p < .001, η^2 = .14, F (2, 94) = 7.10, p < .001, *MSe* = .01, η^2 = .13. Both for shared and partially shared items, the effect of valence was directional (negative > neutral > positive). For shared items, recall rates were higher for negative valence than both neutral and positive valence, t (71) = 2.84, *SEM* = .02, p = .006, d = .48, t (71) = 4.65, *SEM* = .02, p < .001, d = .75, with no difference between neutral and positive valence, p = .09. For partially shared items, recall rates for both negative and neutral valence were higher than positive valence, t (47) = 3.19, *SEM* = .03, p = .003, d = .61, t (47) = 3.27, *SEM* = .02, p = .002, d = .58, with no difference between negative and neutral valence, t < 1. Lastly, there was no effect of valence for unshared items, p = .30.

Next, in the CRI condition, the effect of valence was also significant for shared items, F (2, 142) = 4.77, *MSe* = .01, p = .01, η^2 = .06. Pair-wise comparisons indicated that this effect was driven by a significant difference between negative and neutral valence, t (71) = .02, SEM = .02, p = .005, d = .42. The difference between negative and positive valence, which was significant in the CCI condition, was marginal (p = .04). For partially shared items, the effect of valence was significant, F (2, 94) = 3.37, MSe = .01, p = .04, η^2 = .07, which was driven by a marginally significant difference between neutral and positive items, t (47) = 2.46, SEM = .02, p = .02, d = .38. Again, pair-wise 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. Lastly, as it was in the CCI condition, there was no effect of valence for unshared items, F < 1.

In brief, as with the patterns observed during group recall in Recall 1 and Recall 2, prior collaboration led individuals to preferentially recall negative memories when later working alone compared to those individuals who had not collaborated earlier, and this outcome was particularly evident if prior collaborative recall involved working with the same group members repeatedly. Consistent with this outcome, when people continued to collaborate with the same partners (CCI) their post-collaborative memories also exhibited preponderance of negative items when those items were shared and partially shared. Such negativity effects were also observed when people switched into new groups and collaborate with new partners (CRI), but it was robust only for shared information and less so for partially shared information. These patterns indicate that repeated collaboration with the same group of people reinforced the memory for negative information more so than it does for positive information, while working with a different group of people attenuates such a reinforcing effect for negative memories.

Social Contagion in Recall. Social contagion in recall (final individual recall for initially non-studied items) was analyzed in two ways. First, the non-redundant recall in Recall 3 for both studied and non-studied items were calculated and compared across the two collaboration conditions (see Figure 11). In this analysis, the non-redundancy for nonstudied items indexes social contagion, it provides an overview of the extent to which non-studied information made its way into one's post-collaborative individual memory, and it also enables us to make a comparison between the two collaboration conditions.

Second, we examined the extent to which memory for non-studied information was erroneously implanted in one's memory as a function of social interaction by examining the influences of proximal and distal partners on one's post-collaborative individual recall (see Figure 12). There were four categories for non-studied items to which a given participant (called the "target participant" in this analysis) could be exposed during collaboration: 1) items that were studied and could be produced by the target participant's both proximal partners who shared the items between themselves (*majority-proximal*), 2) items that one of the proximal partners had studied and could have produced during collaboration and did not share with anyone (*minority-proximal*), 3) items that were studied and could be produced by distal partners who between them shared those items (*majority-distal*), and 4) items that were studied and could be produced by one distal partner who did not share the items with anyone (*minority-distal*). The target participants in both CCI and CRI groups had proximal partners, but the distal partners existed only for the target participants only in the CRI groups. Thus, this analysis is conducted separately on the CCI and CRI conditions.

For the non-redundancy scores for non-studied items, as expected, there was greater non-redundancy (social contagion) in CRI than CCI, F (1, 46) = 33.40, MSe = .003, p < .001, η^2 = .42, with no effect of valence or interaction, Fs < 1. This result indicates that the absolute amount of social contagion is much greater when people are exposed to more of new information as they change partners across recall attempts than when collaborating with the same partners, and that the patterns are not affected by emotional valence.

For the effects of proximal and distal partners, collapsed across valence, the CCI condition showed 13% effect of majority-proximal partner and 8% effect of minority-proximal partner. The CRI condition showed 4.4% effect of majority-proximal partner, 3.8 % effect of minority-proximal partner, 1.4% effect of majority-distal partner, and 0.8% of minority-distal partners. As expected, the influences of proximal partners were greater on one's memory when people continue to have the same proximal partners (CCI) than different proximal partners for each collaborative recall session (CRI), t (142) = 5.53, SEM = .01, p < .001, d = 1.05 (collapsed across proximal partner types and valence).

The next critical question was then whether emotional or neutral content would be more vulnerable to social contagion. In the CCI condition, there was no effect of valence across all categories of items that index the influences of proximal partners, p = .33 for major proximal items, p = .17 for minor proximal items. Also in the CRI condition, there was no effect of valence across all categories of items that index the influences of proximal or distal partners, p = .36 for major-proximal items, Fs < 1 for minor proximal, minor distal, and major distal items. The rates were at floor and thus it is hard to interpret these data with respect to the effects of valence, yet the influences of proximal partners in the CCI condition (.22 for negative, .22 for neutral, .19 for positive, collapsed across proximal partner type) showed numerically higher social contagion for negative than positive information, while such pattern was absent in the CRI condition.

Final individual recognition. For the analyses on the post-collaborative individual recognition data, we calculated the Hits rates (the proportions of correct *Old* response for studied items) and overall False Alarm rates (the proportions of incorrect *Old* response for nonstudied items). The overall False Alarms included both True False Alarms (Old response to items that were neither studied nor produced by the partners during the previous collaborative recall sessions) and Contagion items (Old response for the items nonstudied but produced by partners during either of the previous collaborative recall sessions). Corrected recognition rates were calculated as Hits rates – overall False Alarm rates (true false alarms plus contagion items), and Contagion false alarm rates were calculated as the raw proportions of Contagion items taken out of the overall False Alarm rates for each individual participant (see Figure 13).

Corrected recognition. The effect of valence was observed both in the III and CCI, F (2, 142) = 9.55, MSe = .01, p < .001, η^2 = .12 for III, F (2,142) = 6.67, MSe = .01, p = .002, η^2 = .09 for CCI. Pair-wise comparisons indicated that, in both conditions, both negative and positive information was recognized with better accuracy than neutral information, ps < .01, with no difference between negative and positive valence, ps > .15. The pattern of effects for valence was similar though statistically marginal for the CRI condition, F (2, 142) = 2.85, MSe = .01, p = .06, η^2 = .04, and pair-wise comparisons revealed that the difference between negative and neutral items was marginally significant, p = .02, with no difference between neutral and positive, p = .06, or between negative and positive items, t < 1.

Overall, as expected, corrected recognition of negative items was the highest. Unlike the recall data, recognition of positive items was also better than for neutral items, which was also expected since recognition task would enable the effective use of the *distinctiveness heuristic strategy* (i.e., “I would have remembered it if I saw a picture of it”; Schacter, Israel, & Racine, 1999), which would have been less effective in the free recall task. In brief, the recognition memory findings show a replication of past findings for the valence effect (e.g., Ochsner, 2000, Choi et al., 2013). These patterns are similar to those observed for recall in Experiment 1 as recognition is an easier memory task than recall when the set of memories to be recalled are large (as in Experiment 2). As such, even a large set of stimuli in Experiment 2 produced equivalent advantage for negative and positive memories whereas the more difficult recall task revealed easier access to negative memories.

Social contagion in recognition. The analyses on the contagion ratio (the number of items nonstudied by the 'target' participant but studied and produced during collaboration by a partner/the total number of false alarms) revealed a significant effect of retrieval condition difference between CCI and CRI, F (1, 142) = 9.37, MSe = .08, p = .003, η^2 = .06, as the contagion ratio was much greater for CRI than CCI. There was no effect of valence, p = .11, or interaction, p = .14. These results are in line with the findings in our recall data (the analysis on non-redundancy in Recall 3), which showed the greater contagion in the CRI condition than in the CCI condition with no effect of valence.

Collective Memory

The formation of collective memory was examined for all the conditions with the calculation of collective recollection scores (i.e., the proportions of items that all group members remembered in their post-collaborative individual recall) and collective forgetting scores (i.e., the proportions of items that all group members failed to remember in their post-collaborative individual recall; see Figure 14).

Collapsed across valence, collective recollection scores were highest for the CCI condition (.15), intermediate for the CRI condition (.11), and lowest for the III condition (.05). Collective recollection scores in both the CCI and CRI conditions were greater than in the III condition, ps < .001. The comparison between CCI and CRI revealed a significant effect of collaboration condition, F (1, 46) = 16.90, MSe = .01, $p < .001$, η^2 = .27, such that collective recollection was higher in CCI than CRI, but there was no valence effect, p = .12, or interaction, p = .19. The collective recollection scores were then broken into two categories, one with collective recollection for studied items, and one with collective recollection for nonstudied items (that is, social contagion), and then the CCI and CRI conditions were compared for each category. For studied items, there was a significant effect of collaboration condition, F (1, 46) = 4.61, MSe = .004, p = .04, η^2 = .09, as collective recollection scores for the CCI condition were significantly higher than for the CRI condition. There was no effect of valence, p = .11, or interaction, p = .27. For non-studied items (collective contagion), there was also a significant effect of collaboration condition, such that collective contagion scores for the CCI condition were significantly higher than for the CRI condition, F (1, 46) = 28.59, MSe = .001, $p < .001$, η^2 = .38, with no effect of valence, $F < 1$, or interaction, p = .22.

Together, these results show that, regardless of emotional valence, collaborative retrieval with the same partners promotes collective recollection of studied information as well as collective contagion of non-studied information to a greater extent than does collaborative retrieval with different partners. The extent to which items overlapped or did not overlap in the post-collaborative recall of former group members was related to the *level* of sharedness of these items[3]. While the shared information was very likely to get repeatedly reinforced both in the CCI and CRI conditions across two collaborative recall sessions because all three members within a group (in CCI or CRI) had studied the information, the partially shared information was expected to be more strongly reinforced in CCI compared to CRI and, in turn, produce more overlap in memory for those items in CCI. The same mechanism would lead to more collective contagion of the partially shared items in the CCI condition as those items were studied by two out of three group members and would exert a stronger contagion effect on the third group member who did not study the item, whereas such repeated confluence from two members could not occur in the CRI condition.

Next, collapsed across valence, collective forgetting scores were highest for the CCI condition (.40), intermediate for the CRI condition (.32), and lowest for the III condition (.29). The CCI condition had more collective forgetting than the III condition, F (1, 46) = 16.38, MSe =

[3] In our design, the impact of level of sharedness manifested differently across groups that repeatedly worked together (CCI) versus groups that reconfigured (CRI) across recall attempts. This could be seen in a measure that provides the amount of variety (instead of overlap) in the post-collaborative individual recall of participants who were previously group members. While members in the CCI condition received repeated exposure to the same partially shared items, members in the CRI condition had exposure to a wider variety of partially shared items during Recall 2. This difference in exposure to a greater variety of partially shared items in the CRI condition but repeated exposure to the same set of partially shared items in the CCI condition raises the question as to which form of collaboration would preferentially affect the post-collaborative recall for partially shared information as well as the formation of collective memory. To address this question, a 3 (level of sharedness: shared, partially shared, unshared) x 3 (valence: negative, neutral, positive) x 2 (collaborative condition: CCI, CRI) mixed factor ANOVA was conducted on the non-redundant recall on Recall 3 for studied items. The results revealed a significant effect of level of sharedness, F (2, 92) = 224.98, MSe = .02, $p < .001$, η^2 = .83, a significant effect of valence, F (2, 92) = 8.55, MSe = .02, $p < .001$, η^2 = .16, but no effect of collaborative condition, $F < 1$. However, critically, there was a significant interaction between the level of sharedness and collaborative condition, F (2, 92) = 7.64, MSe = .02, p = .001, η^2 = .14. Follow-up tests indicated that there was more non-redundancy (i.e., variety in memory) in CRI than in CCI for shared items as a result of reconfigured collaboration, F (1, 46) = 13.84, MSe = .02, p = .001, η^2 = .23, but the non-redundancy scores were not greater for partially shared items, p = .18 or unshared items, p = .90 in CRI compared to CCI.

.03, $p < .001$, $\eta^2 = .26$, with a valence effect, F (2, 92) = 5.23, *MSe* = .01, $p = .01$, $\eta^2 = .10$, and marginal interaction, F (2, 92) = 3.12, *MSe* = .01, $p = .05$, $\eta^2 = .06$. Pair-wise comparisons revealed that collective forgetting was significantly greater in the CCI condition than in the III condition for positive and neutral information (*p*s < .001), but not for negative information, $p = .10$. Collective forgetting was greater for CCI than CRI, F (1, 46) = 7.27, *MSe* = .03, $p = .01$, $\eta^2 = .14$, and there was also a significant effect of valence, F (2, 92) = 12.85, *MSe* = .01, $p < .001$, $\eta^2 = .22$. In both conditions, collective forgetting was greater for positive than for negative items, *p*s < .001, with no interaction, $F < 1$. Lastly, the III and CRI conditions did not differ in collective forgetting, $p = .26$.

To summarize, these results on collective memory indicate that repeatedly collaborating with the same group partners promotes both collective recollection collective forgetting than collaborating with different group members. Also, collectively recollected memories are not affected by emotional valence but more positive than negative memories are collectively forgotten. Finally, both true and contagion memories overlap to a greater extent when people collaborate with the same partners than with different partners across recall opportunities.

IV. General Discussion

The main goals of the current study were to investigate how emotional valence (negative, positive, or neutral) and shared events (shared, partially shared, or unshared study items) modulate the propagation of memory via social interactions. To test these questions, we integrated two experimental paradigms where (1) the studied information consisted of picture-word label pairs of stimuli that were positive, negative, or neutral (or nonemotional) in emotional valence (Experiments 1 and 2), (2) 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, some other information was partially shared, and yet other information was unshared across their study lists (Experiment 2), and after the study phase, groups of three members collaborated with identical group partners (Experiments 1 and 2) or with different (reconfigured) partners (Experiment 2) across two recall opportunities. Yet another group of participants studied and recalled information twice individually to serve as the control group. Lastly, participants from all three conditions recalled the studied information individually.

Across two experiments, the results revealed that (1) collaborative inhibition occurs both for emotional and nonemotional information as well as both for shared and partially shared information, but the effect was reduced or absent for unshared information, (2) collaboration increases the retrieval of negative memories more than it does of neutral and positive memories, (3) such a facilitatory effect of collaboration on negative memories is especially prominent when the initial exposure to the information is shared among group members, and further, especially when people continue to collaborate with the same group partners rather than with different group members, (4) social contagion of non-studied information is greater when people are exposed to a greater variety of information through different group partners than when people are exposed to a relatively limited amount of information through identical group partners, (5) the influence of proximal partners is greater on one's final individual memory when people continue to have the same proximal partners than different proximal partners, (7) working with the same group partners promotes both collectively remembered and collectively forgotten memories more than does working with different partners, and (8) collaboration promotes collective forgetting of positive information.

Influences of Emotion on Collaborative Memory

The detrimental effect of collaboration on the magnitude of accurate recall, known as *collaborative inhibition*, is among the most robust phenomena reported in the collaborative memory literature. Yet, only a few studies have examined this phenomenon with emotionally charged information, and in those studies the comparisons between the nominal and collaborative recall were made only for negative information and with relatively less controlled materials (e.g., a historic event or a video clip; Yaron-Antar & Nachson, 2006; Wessel, et al., 2015). We assessed collaborative inhibition for the three dimensions of emotional valence (negative, positive, and neutral) and found that collaborative inhibition occurs for all types of valence, with a numerically greater magnitude of the inhibition for positive information than for negative information (Experiment 1). This finding indicates that collaboration impairs memory for emotional information regardless of its emotional valence, but more so for positive than negative information.

In addition to examining collaborative inhibition for emotional information, our study provides new empirical data for understanding the underlying mechanisms of the collaborative inhibition effect. As discussed earlier, collaborative inhibition has been thought to arise due to retrieval disruption (B. H. Basden, et al., 1997) that is, listening to what other group members produce during collaboration disrupts one's organizational strategy and lower the recall levels. However, growing evidence indicates that retrieval disruption may not be the sole mechanism underlying the phenomenon. According to the logic of the retrieval disruption account, collaborative inhibition should not occur if each group member has their own unique studied information since her subjective organization of such unshared information should not be disrupted by other group members' recall products. However, recent findings showed that collaborative inhibition persists, even with a greater magnitude, for such unshared information when group members shared some but not other information (Meade & Gione 2011) and even when each group member studied completely different information (Barber, Harris, & Rajaram, 2015).

Unlike the abovementioned studies, our results showed different patterns such that the magnitude of collaborative inhibition was smaller or statistically absent for unshared information compared to shared or partially shared information. It should be noted that the study stimuli in our experiment consisted of pairs of pictorial items with their verbal labels whereas previous studies using unshared items have used a list on only verbal words. It has been shown that under circumstances where unshared information is more distinctive - such as by being represented in pictorial form as compared to verbal form – the probability that the unshared information would be recalled during collaboration increases (Stewart & Stewart, 2001; Stewart, Stewart, Tyson, Vinci, & Fioti, 2004). Our findings are in line with this view because emotional, pictorial stimuli are considered to be distinctive in nature (Dewhurst & Parry, 2000; Ochsner, 2000) and this property likely increased the production of unshared items during collaboration, and thereby reduced the magnitude of collaborative inhibition for unshared information.

Next, we consider the influences of emotion on group recall. The general pattern of findings showed that collaboration increases retrieval of negative memories more than that of neutral or positive memories. The results from Experiment 1 showed that the recall was greater for both negative and positive information than neutral information both in the individual and group recall. But as noted earlier, these results were likely a function of the selected stimuli that consisted of a smaller number of items than in Experiment 2. When a larger set of normative stimuli was used such that there were many more memories from which to draw (Experiment 2), the valence effect clearly began to favor negative information over positive information both in the individual and group recall, and this effect persisted in collaborative recall whereas it became attenuated in the individual recall over repeated recall attempts (Recall 2). It should also be noted that it was not the case that positive information was simply less memorable in Experiment 2 because recognition memory, a task that is easier to perform than free recall, showed equivalently high recognition accuracy for both negative and positive information. Therefore, the enhancement of negative memories through collaboration shows that the process of collaboration facilitates recall of negative memories.

Why does collaboration facilitate recall of negative memories? Although the data from the Experiment 1 should be interpreted with caution due to the selection of a small set of stimuli, those data also revealed a numerical pattern suggesting positive memories were relatively less protected from disruption compared to negative memories. The magnitude of collaborative inhibition was consistently higher for positive information than for negative or neutral information in the comparisons between I**I**I and I**C**I, and between **II**I and **CC**I. Similarly, in a within-subject comparison in the **I**C**I** condition there was a 4% drop in the nominal recall between pre-collaborative individual nominal recall and collaborative recall only for the positive information whereas recall levels stayed at the same level for negative and neutral information. There is evidence in the emotional individual memory literature both at the behavioral and neural levels that suggests a link between negative emotion and sensory processing and a link between positive emotion and conceptual processing (reviewed by Kensinger, 2009). That is, negative information tends to be encoded with more vivid details whereas positive information tends to be encoded with increased familiarity. It is then possible that collaboration triggers discussion and retrieval of negative information that is encoded with vivid details and strengthens negative memories while such collaborative facilitation cannot occur when individual retrieving alone (Experiment 2). The more “social sharing” of negative information during collaboration is also in line with the report by Luminet, Bouts, Delie, Manstead, & Rime (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.

Importantly, such a facilitating effect of collaboration for retrieval of negative memories was prominent only when the initial exposure to the information was shared or at least partially shared among group members as no such effect was found for unshared information. The findings in Experiment 2 consistently showed a directional valence effect (negative >neutral > positive) for shared and partially shared items but not for unshared items. When participants repeatedly collaborated with the same partners to recall unshared items, the contrast between negative and positive information was numerically either very small (Recall 1) or absent (Recall 2). Yet, in the final recall where participants worked alone to recall the studied information, an interesting numerical trend emerged for the unshared items. When the influence of collaboration was no longer available, participants recalled more negative than positive information (7% increase in negative memories but 2% increase in positive memories across prior group recall and final individual recall of unshared items). In other words, memory for unshared negative information were somehow suppressed *during* collaboration with identical partners and rebounded later when people recalled information alone. Turning to the CRI condition, a similar numerical pattern as in the CCI condition was observed during group recall such that a numerically reversed pattern for valence (positive > negative) arose in the recall of unshared items. However, across the group recalls to the final individual recall the increase in the recall of negative items (about 4%) was not far greater than the increase in the recall of positive items (about 2%), and unshared positive information was remembered numerically even more than negative information. That is, when collaborative partners are changed, the unshared negative memories that were suppressed *during* collaboration did not rebound as much as they did when working repeatedly with the same collaborative partners (CCI). We emphasize that the patterns of recall described here are based on numerical changes but these patterns are worth noting because they are also consistent with the patterns observed for partially shared items across the same group (CCI) and reconfigured group (CRI) conditions. Specifically, negative items were recalled significant more than neutral or positive items when participants repeatedly collaborated with the same partners in Recall 2 (CCI) but this negativity effect reduced when participants worked with a different set of patterns during Recall 2 (CRI). Together, these patterns suggest a role of social validation such as verbal feedback from other group members during collaboration (Stewart & Stasser, 1995; Stewart et al., 2004; Meade & Gigone, 2011; Muller & Hirst, 2014) and how such factors could be varied by emotion. Specifically, when group members are less likely to acknowledge and reinforce the recalled items during collaboration, either because they did not encode the same items (partially shared or unshared) or because they worked with new partners with different memories (reconfigured group), this process reduces the retrieval of negative information.

Social Contagion of Emotional Memory

Two different forms of social contagion were examined in the current study: the spread of memory for information to which people had initial exposure (studied items) prior to collaboration, and the spread of memory for information to which people did not have initial exposure (nonstudied items) but that was introduced by other group members during collaboration. The latter form of social contagion is directly related to the social contagion of errors or misinformation (Roediger et al, 2001; Meade & Roediger, 2002). In considering the former form of contagion (studied items) first, our findings showed that the facilitating effects of collaboration for studied, negative memories that occurred during collaboration carried into post-collaborative individual memory. After people repeatedly collaborated with the same partners (CCI), they consistently remembered the negative items the best both when those items were shared and partially shared. Such negativity effects were also observed when people switched into new groups and formed a larger network (CRI), but this was the case only for shared information and not for partially shared information. These findings suggest that negative memories are more likely to be reinforced and propagated in a smaller network that consisted of individuals possessing less variety of information, compared to a larger network that consisted of individuals possessing more variety of information. Past investigations on non-memory based social transmission of emotionally charged information reported that people are more likely to pass along positively valenced newspaper articles than negatively valenced articles (Berger & Milkman, 2012), and people's intentions to transmit the information is modulated by emotional arousal, but not by valence (Berger, 2011). But, whether such transmission shaped the consequent memories have not reported. Our findings show that beyond transmission of emotional information, when memory via interpersonal interaction is examined, negative information is more likely to shape memories at least in networks of the size tested in the present experiments.

Turning next to social contagion for non-studied information, our findings show that social contagion was greater when people worked with more and different collaborative partners (CRI) than when 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 re-exposure benefits and enhanced post-collaborative 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, such that there is greater social contagion for non-studied information (that is, false memories) when working with different partners who possess a variety of new information. This pattern emerged in both recall and recognition memory, regardless of emotional valence. The absence of valence effect on social contagion for non-studied information indicate that, while true negative memories are reinforced and transmitted further through repeated collaboration, the negative valence does not affect the transmission of false memories. That is, even though social contagion of false memories does occur for emotional information, the magnitude of the contagion is not any greater or lesser than the contagion of nonemotional false memories.

Emotion and Social Contagion on the Formation of Collective Memory

To our knowledge, the current study is the first to examine the formation of collective memory for emotional information in an experimental setting. In the context of replicating past findings that collaboration increases overlapping memories among group members (Blumen & Rajaram, 2008; Stone et al., 2010; Congleton & Rajaram, 2014), our novel findings demonstrate how the composition of collective memory is affected by emotional valence and social contagion. Although there has been a discussion in the literature on the role of social contagion in the formation of collective memory (Cuc et al., 2006), this idea has not been directly tested. Our design enabled this test through the examination of the quantities of collective contagion (i.e., collective recollection of information that is non-studied but produced by collaborative partners) and revealed striking results. In our data, about 25% of collective recollection (collapsed across valence, in CCI in Experiment 2) was composed of information that people initially did not study, demonstrating a significant impact of social contagion of errors in what people collectively remember. In other words, this finding suggests that memories for never experienced events could be integrated into a group's, or a community's collective memory to a considerable degree through social interactions, especially when such social interactions repeatedly occur within a smaller network.

In considering the effect of emotion in the formation of collective memory, our findings indicate that emotion may not have a significant effect in shared memories that are collectively *remembered*, but it does have a significant effect on the amount of information that is collectively *forgotten*. When people repeatedly recalled with the same partners, the amount of negative memories that were collectively forgotten among them was not any different from what individuals recalling alone would forget. Yet, they collectively forgot more positive and neutral information than did individuals recalling alone, suggesting a potentially unfortunate consequence of collaboration in the formation of collective memory. 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 as 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). Together with the greater recall of negative memories consistently shown in our data (especially when people repeatedly collaborated with the same partners), our findings on more collective forgetting of positive memories suggests that such pruning process during collaboration operated more actively for positive than negative information. Thus, this finding supports the idea that repeatedly recalling the past with the same group of people leads to reduced sharing of positive memories while it strengthens negative memories.

V. Conclusion

The current study investigates the extent to which emotional memory is shaped and transmitted via social interaction 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 occur with the same group of people within a smaller network, true negative memories are solidified and transmitted farther compared to positive memories, resulted in more collective forgetting of positive memories. Further, the interaction within a smaller network not only reinforced true negative memories, but also reinforced social contagion of false memories to a greater extent than when the network was larger. Working with the same small group also increased the extent which the false memories become a part of group's collective memory. In contrast, when people were exposed to a larger 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 have had common experiences. Together, these findings shed light on the understanding of how one's and groups' memory for emotional events can be shaped and transmitted. It will be important for futures studies to explore the retention and the generality of the current findings, perhaps with other types of materials (e.g., emotional information with high self-relevancy), to provide further insights on understanding of emotional social memories and individual's emotional well-being as a result of their sociality.

Table 1

[Experiment 1] Proportions of correct recall and standard errors (in parentheses).

	Individual or Collaborative Recall			Nominal Recall		
	Negative	Neutral	Positive	Negative	Neutral	Positive
III						
Recall 1	.36 (.02)	.22 (.01)	.39 (.02)	.69 (.03)	.49 (.03)	.73 (.02)
Recall 2	.41 (.02)	.25 (.02)	.42 (.02)	.74 (.03)	.55 (.03)	.75 (.02)
Recall 3	.42 (.02)	.28 (.02)	.44 (.02)	.77 (.03)	.58 (.03)	.80 (.03)
ICI						
Recall 1	.35 (.02)	.24 (.02)	.36 (.02)	.66 (.02)	.53 (.03)	.69 (.03)
Recall 2	.66 (.02)	.54 (.03)	.65 (.03)	-	-	-
Recall 3	.51 (.02)	.39 (.02)	.49 (.02)	.74 (.02)	.59 (.03)	.70 (.02)
CCI						
Recall 1	.57 (.04)	.39 (.03)	.56 (.03)	-	-	-
Recall 2	.64 (.03)	.44 (.03)	.61 (.03)	-	-	-
Recall 3	.50 (.02)	.33(.02)	.49 (.02)	.69 (.04)	.48 (.04)	.67 (.03)

Table 2

[Experiment 2] Mean proportion of shared, partially shared, and unshared items correctly recalled as a function of retrieval condition. Standard errors are shown in parentheses. For the III condition, the measure represents nominal group recall.

	Shared	**Partially Shared**	**Unshared**
Recall 1			
III	.55 (.02)	.42 (.02)	.24 (.02)
CCI	.42 (.01)	.31 (.02)	.18 (.02)
CRI	.44 (.02)	.32 (.02)	.21 (.02)
Recall 2			
III	.61 (.02)	.46 (.02)	.29 (.02)
CCI	.47 (.01)	.37 (.02)	.20 (.02)
CRI	.52 (.03)	.22 (.02)	.23 (.02)

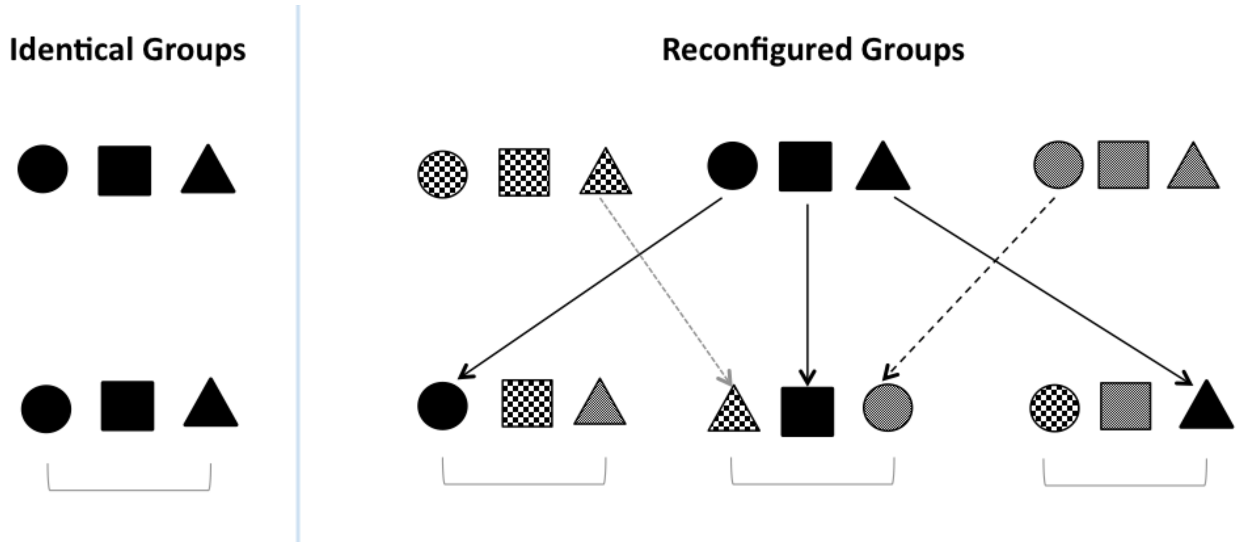


Figure 1. Group configuration in identical (CCI) and reconfigured (CRI) groups. Each different shape or filled pattern denotes an individual within a group.

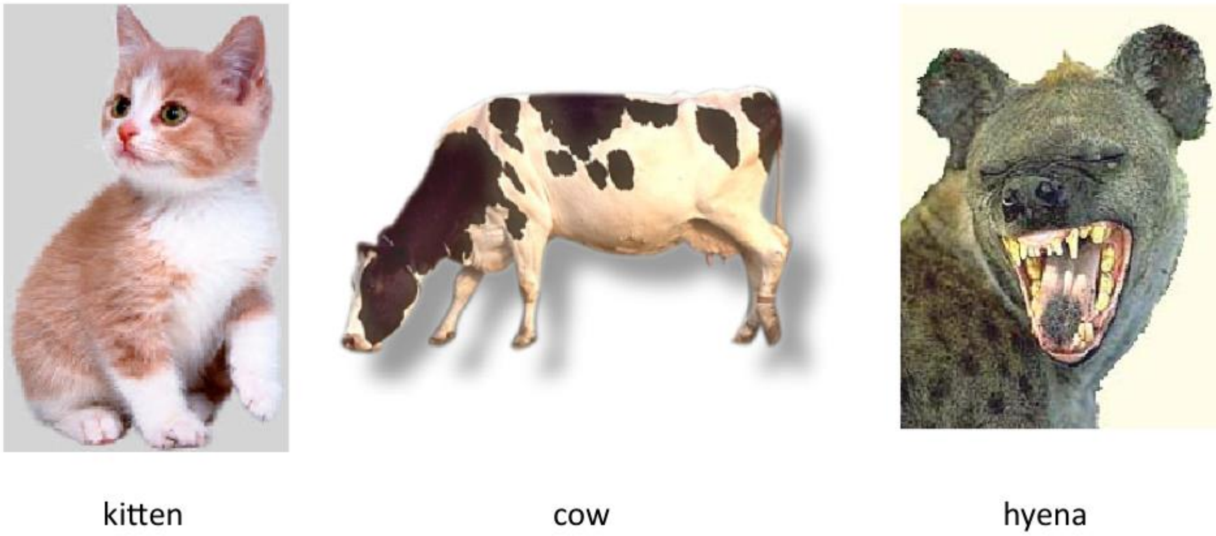


Figure 2. Sample pictorial stimuli and verbal labels for each valence (kitten: positive, cow: neutral, hyena: negative).

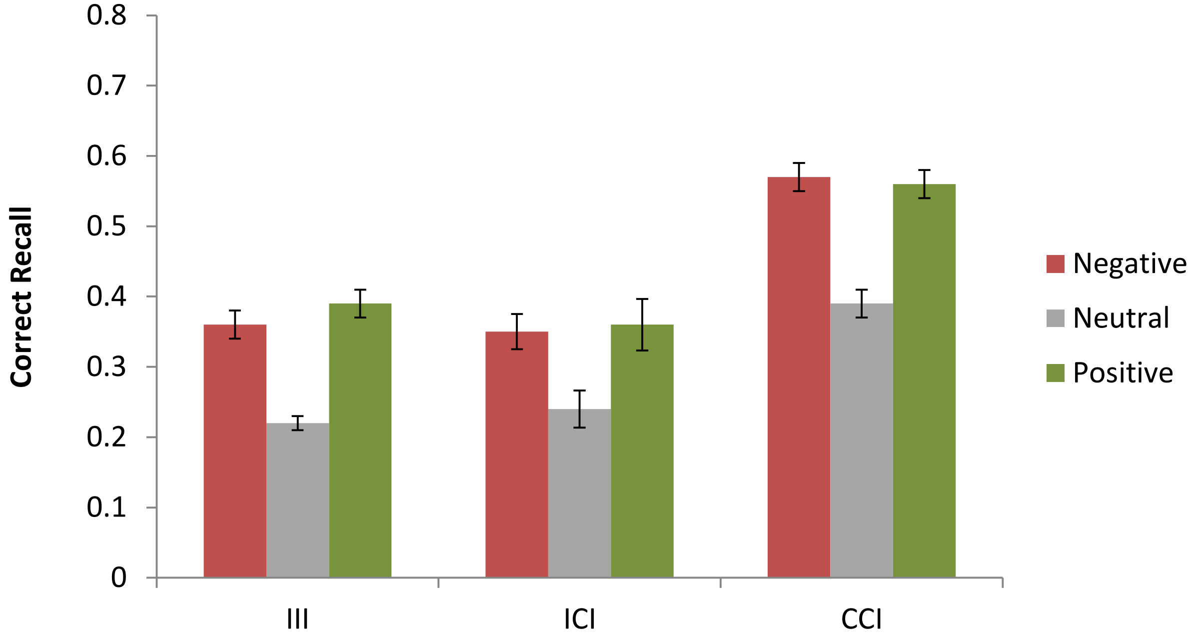


Figure 3. [Experiment 1] Recall performance during Recall 1.

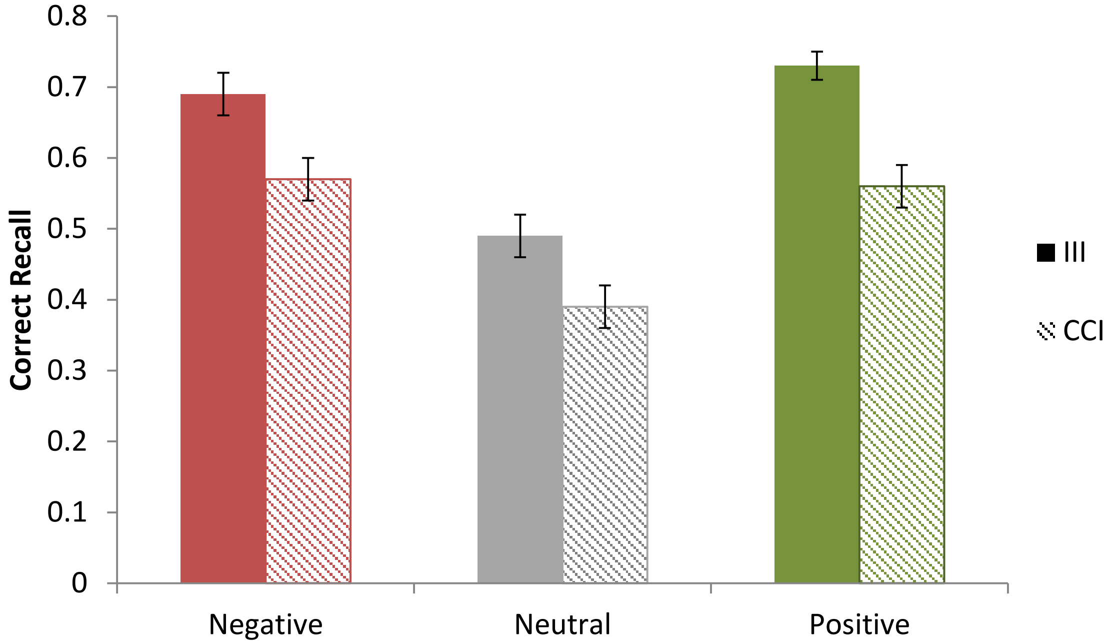


Figure 4. [Experiment 1] Collaborative inhibition during Recall 1.

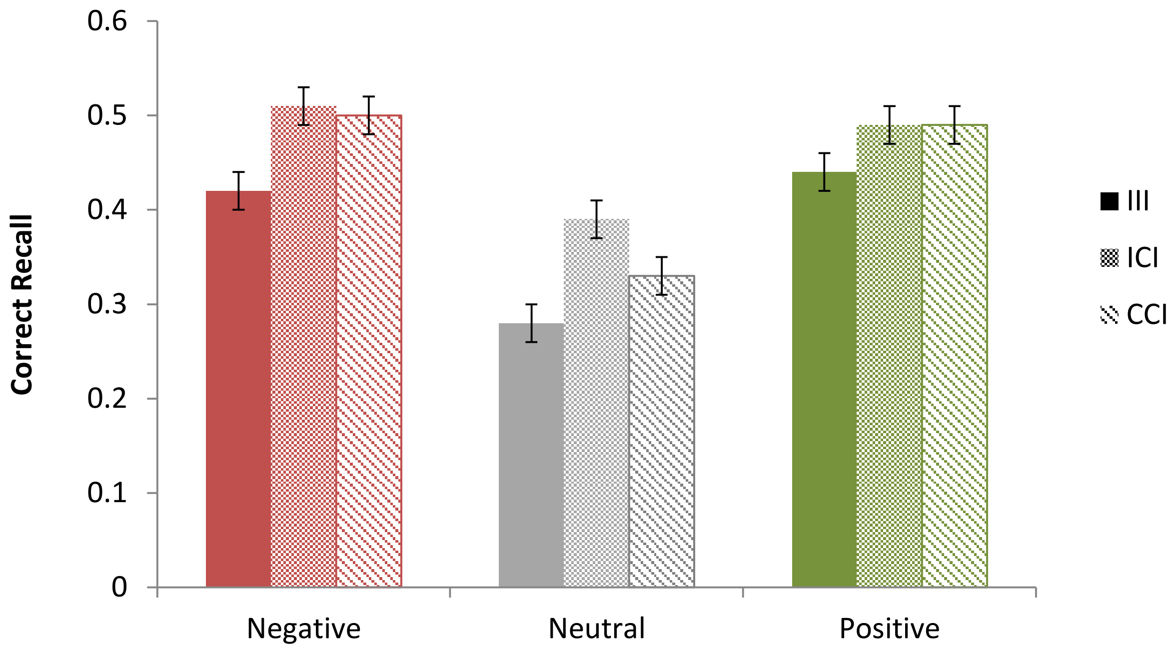


Figure 5. [Experiment 1] Post-collaborative recall in Recall 3.

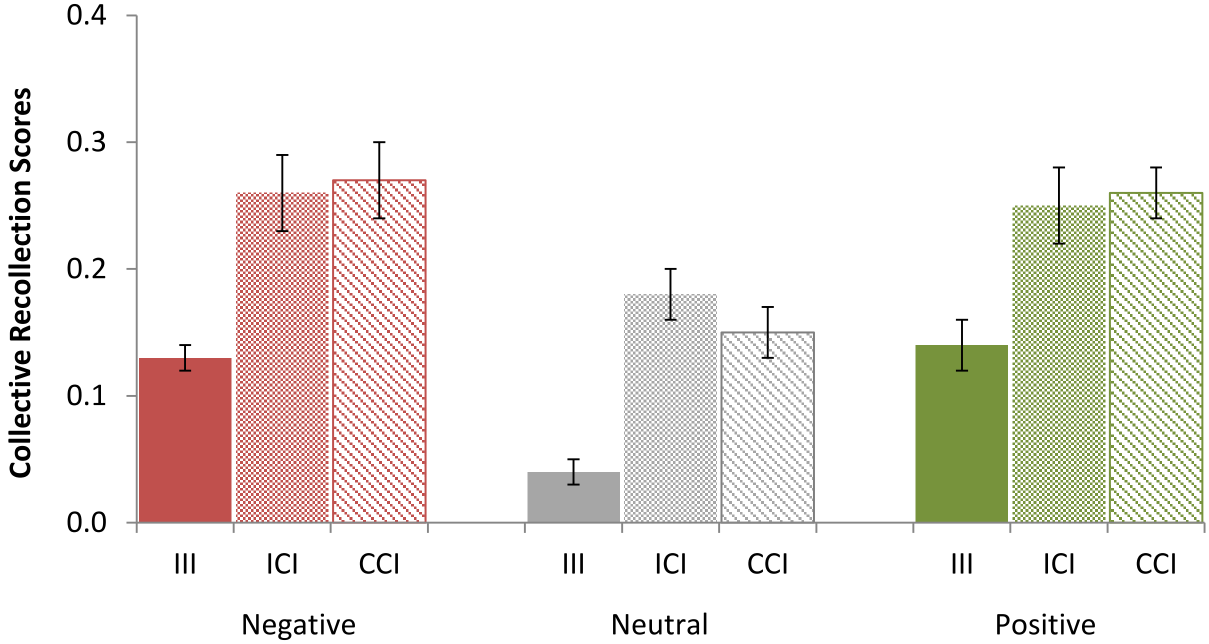


Figure 6. [Experiment 1] Collective recollection in Recall 3.

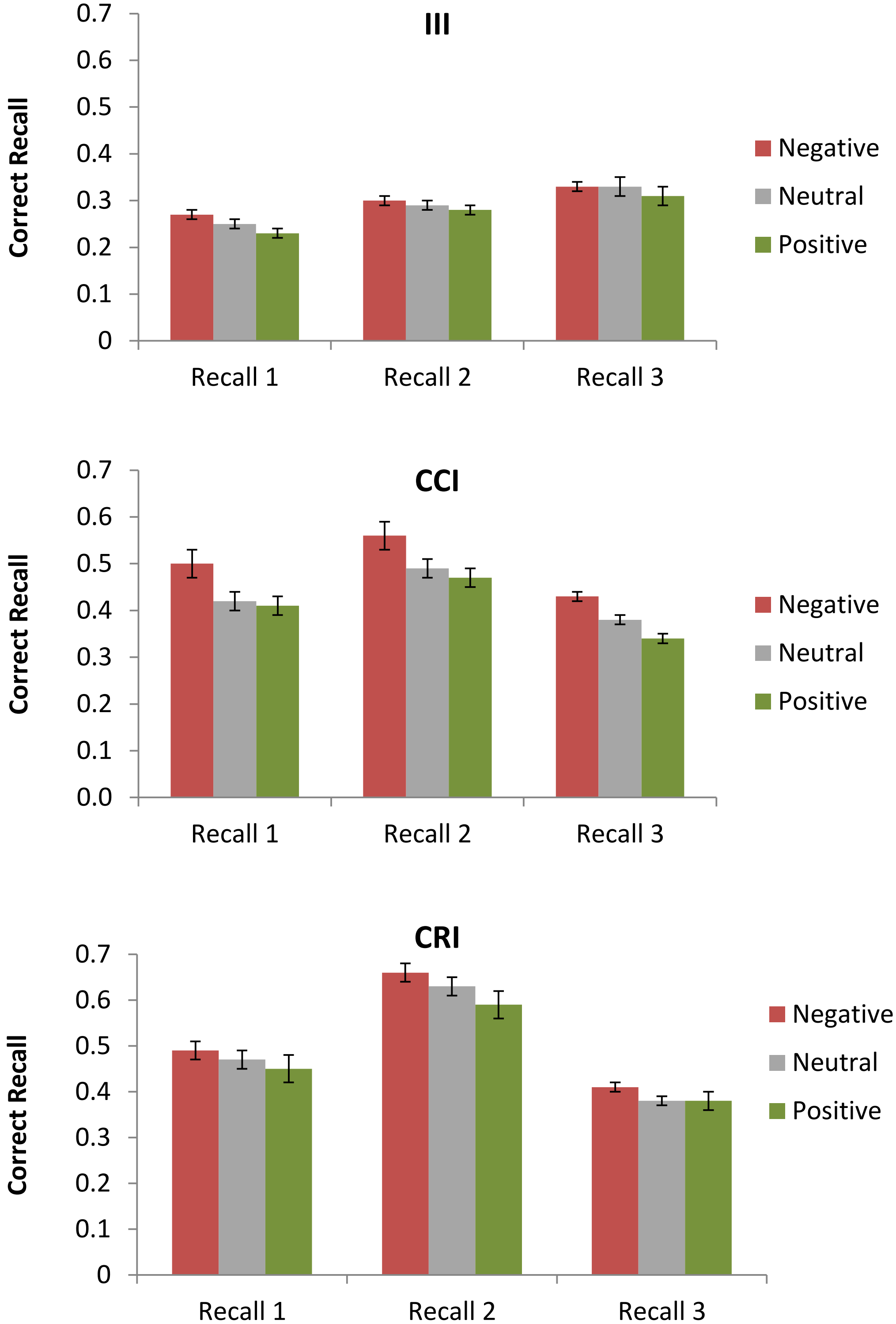
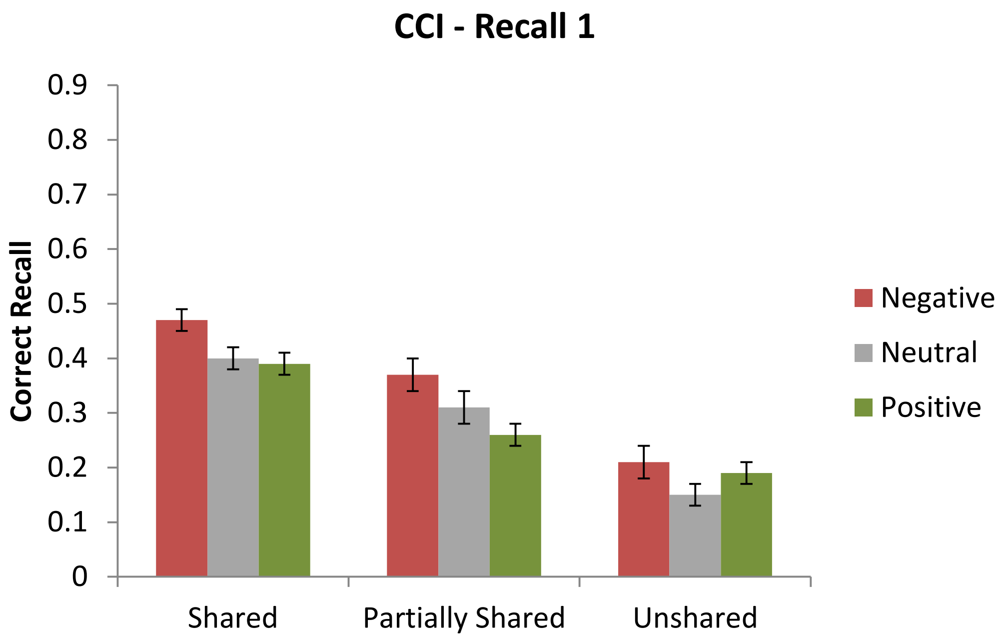


Figure 7. [Experiment 2] Overall correct (individual or group) recall performance for each retrieval condition.



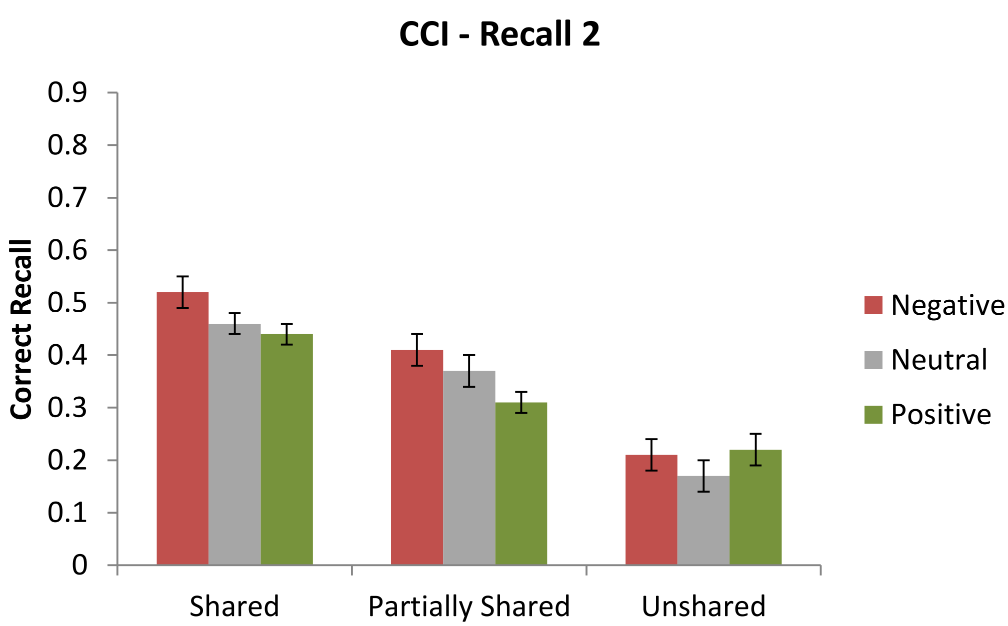


Figure 8. [Experiment 2] Proportions of correct recall from the first and second collaborative sessions in the CCI condition as a function of shardness and emotional valence.

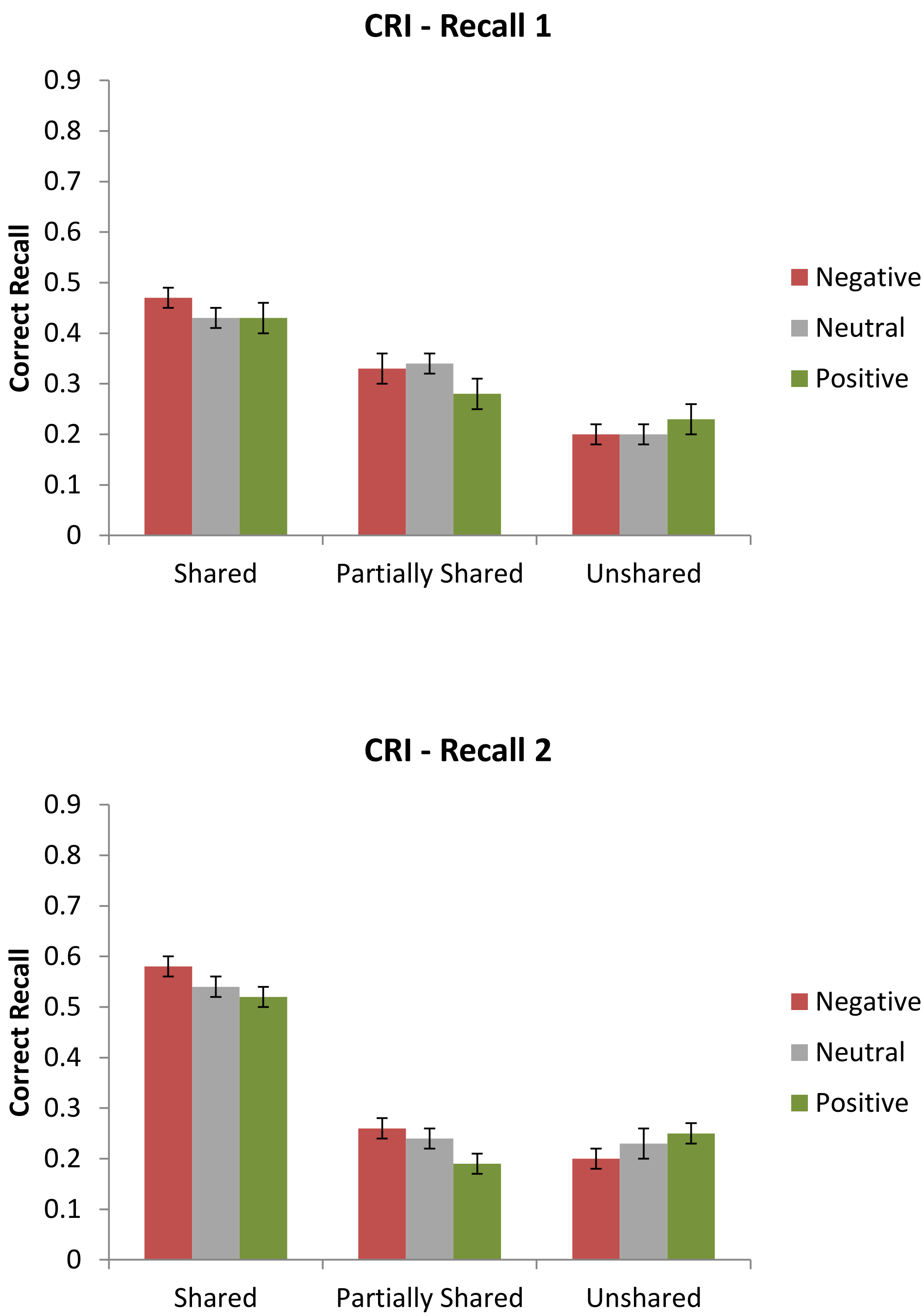
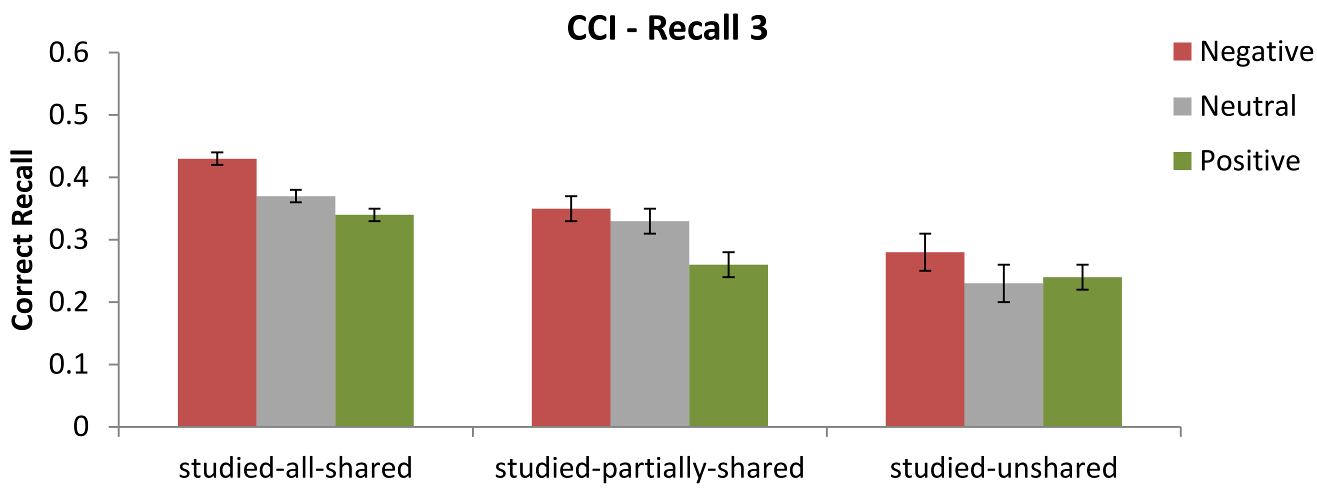


Figure 9. [Experiment 2] Proportions of correct recall from the first and second collaborative sessions in the CRI condition as a function of sharedness and emotional valence.



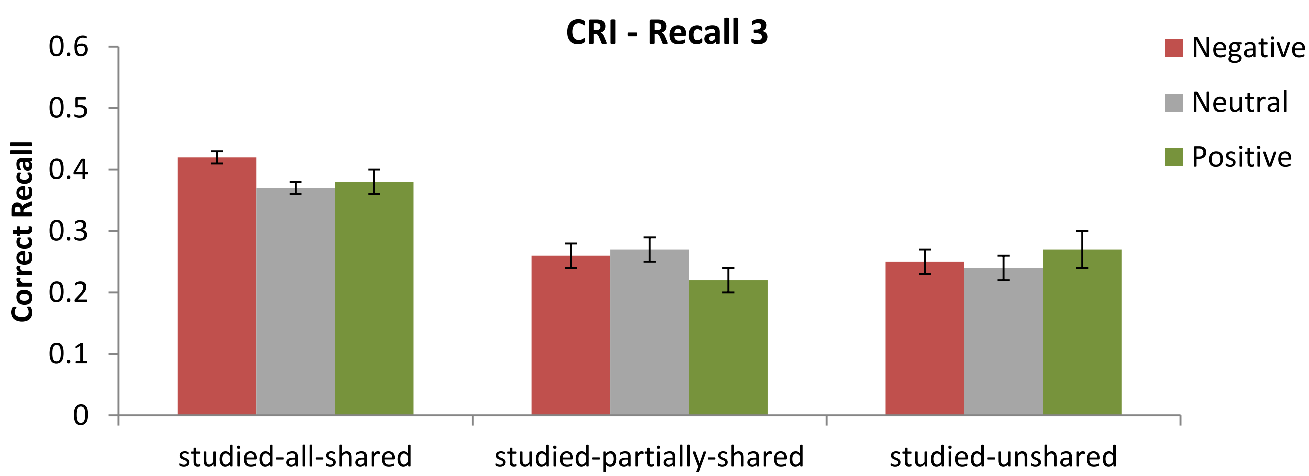


Figure 10. [Experiment 2] Proportions of correct recall from the post-collaborative individual recall in the CCI and CRI condition as a function of shardness and emotional valence.

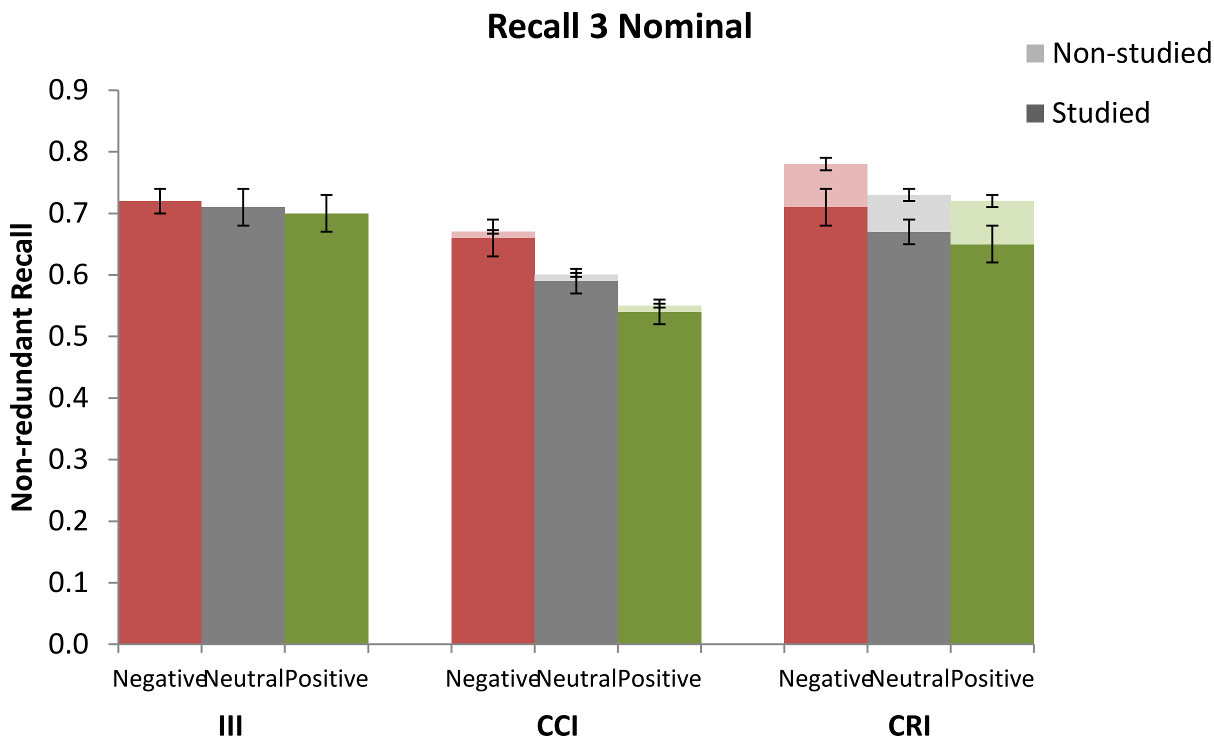
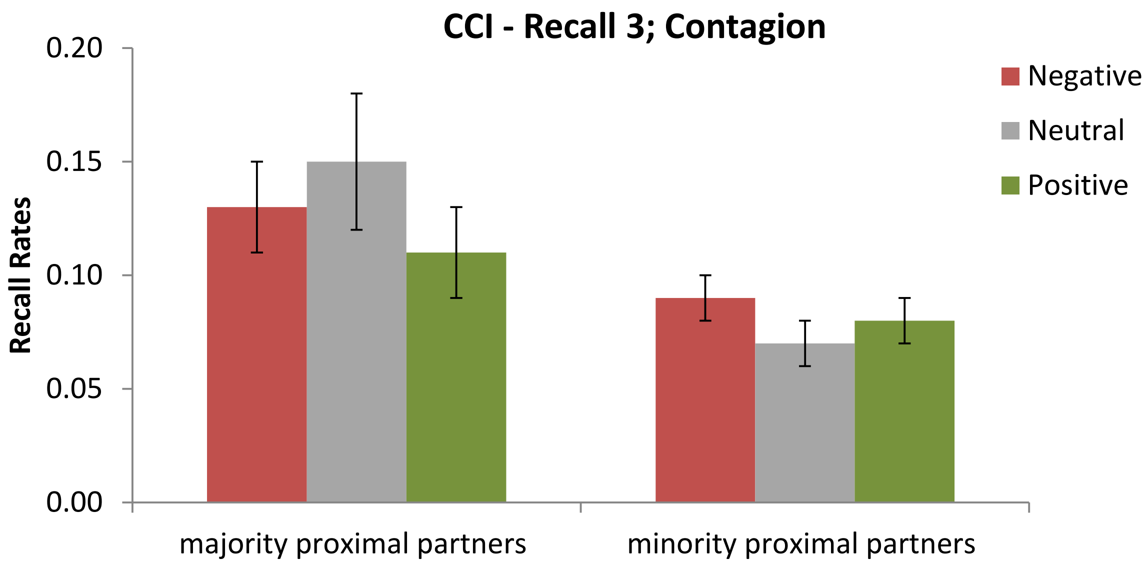


Figure 11. [Experiment 2] Non-redundant recall on Post-collaborative individual recall.



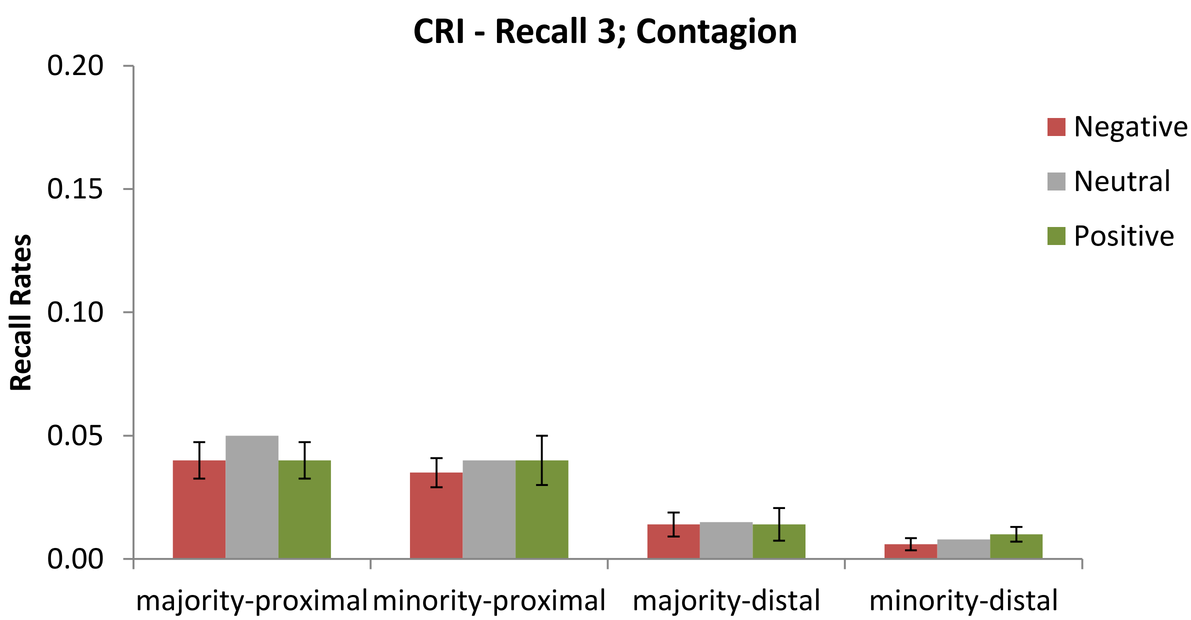
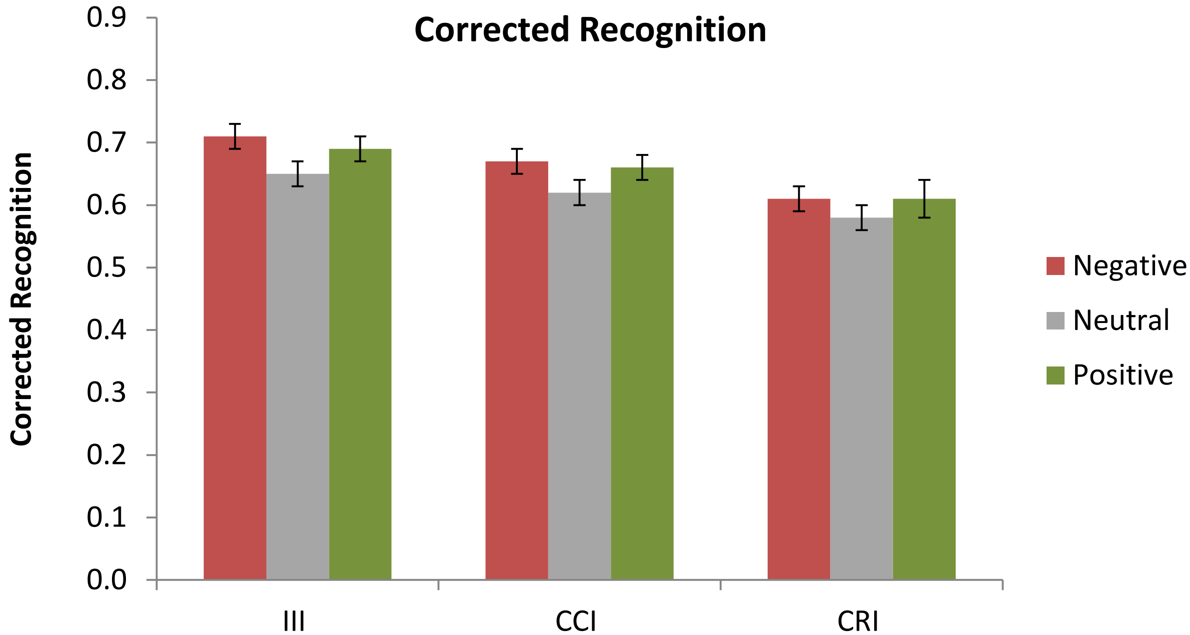


Figure 12. [Experiment 2] Effects of proximal and distal partners on the recall of non-studied items on post-collaborative individual recall across the CCI and CRI conditions as a function of emotional valence.



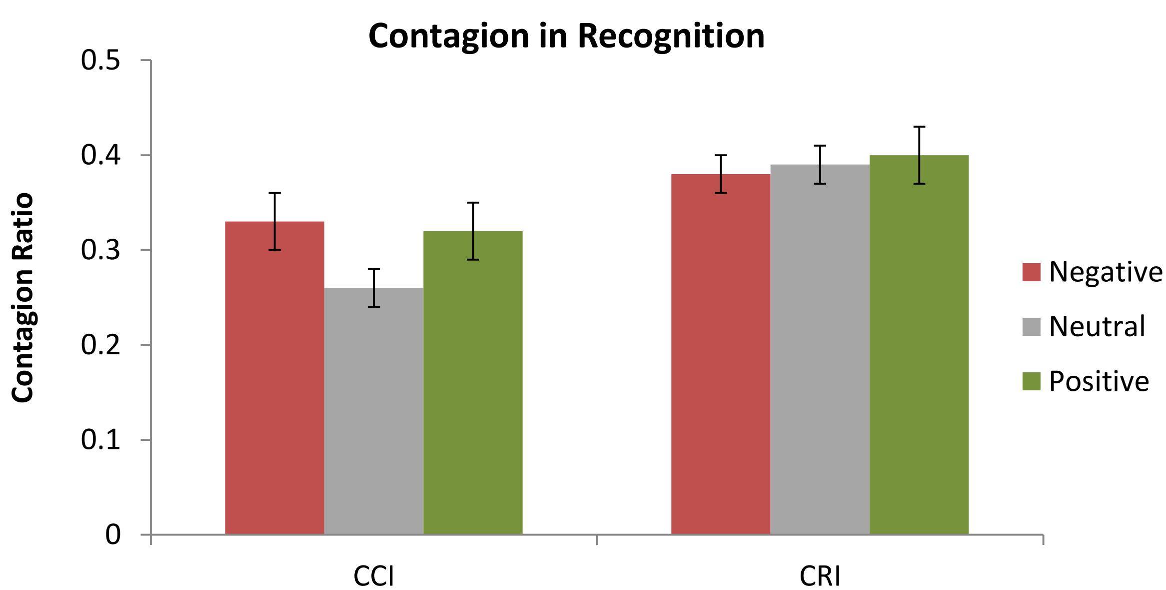


Figure 13. [Experiment 2] Corrected Recognition and Contagion following collaborative recall.

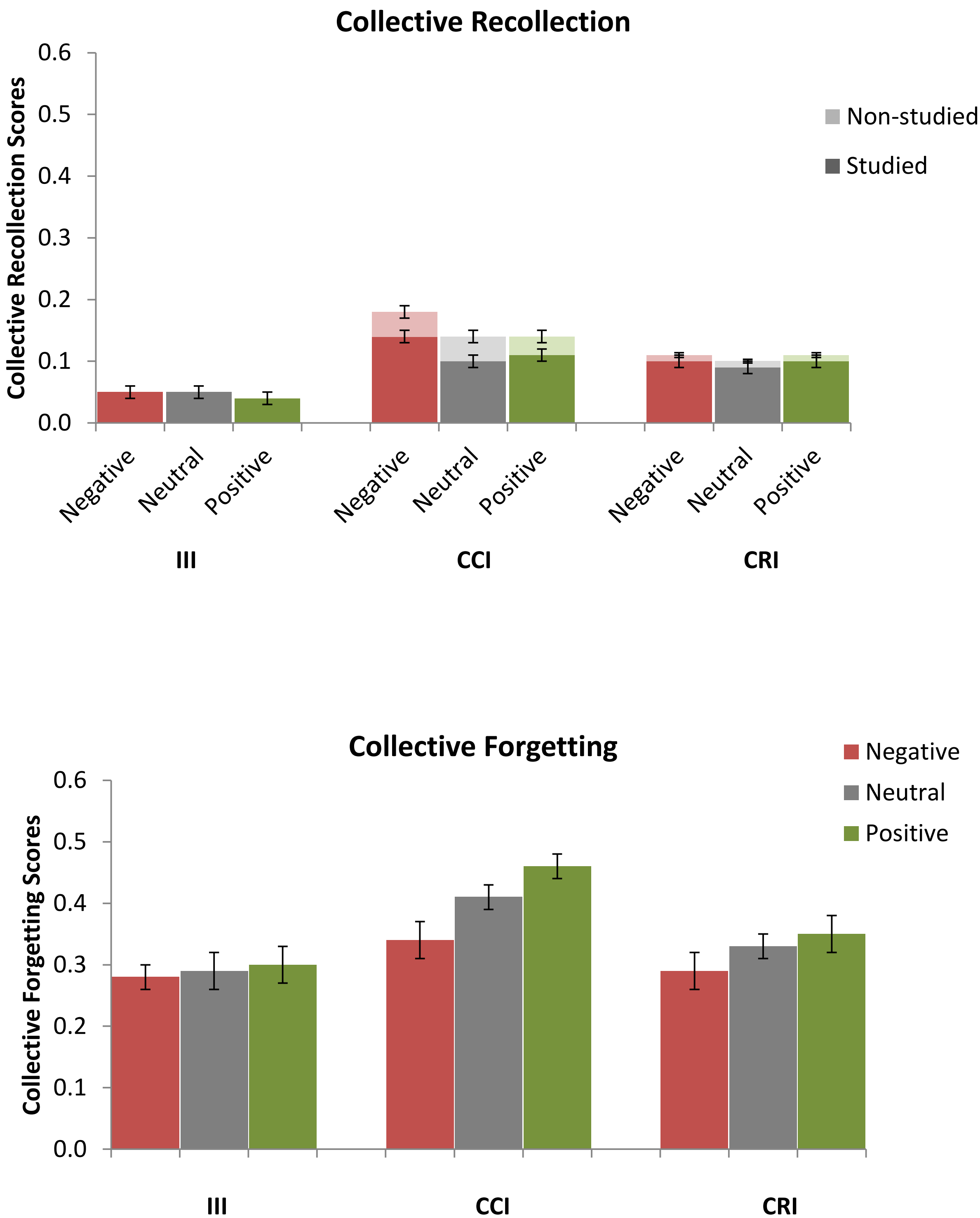


Figure 14. [Experiment 2] Collective memory in the final individual recall.

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