Persistence of False Memories and Emergence of Collective False Memory: Collaborative Recall of DRM Word Lists

Raeya Maswood

Christian C. Luhmann

Suparna Rajaram

Stony Brook University

Author Note: Correspondence concerning this article should be addressed to Raeya Maswood (Raeya.maswood@alumni.stonybrook.edu), Department of Psychology, Stony Brook University, Stony Brook, NY 11794-2500, USA. This work was supported by the National Science Foundation under Grant 1456928.

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Abstract

Information and misinformation are proliferating on social media. A rapid rise in the use of these platforms makes it important to identify psychological mechanisms that underlie the production, propagation, and convergence of false memories in groups. Websites and social media platforms vary in the extent of restrictions placed on interactive communication (e.g., group chats, threaded or disabled comments, direct messaging), prompting questions about the impact of different interaction styles on false memory production. We tested this question in a laboratory analog of interaction styles and compared two well-known procedures of collaboration, free-for-all and turn-taking. To expose participants to information known to promote recall of both true and false information, we used the Deese-Roediger-McDermott (DRM) word lists (Roediger & McDermott, 1995). Participants recalled these words using free-for-all collaboration, turn-taking collaboration, or individually. Next, all participants individually recalled the studied items. Turn-taking produced more false memories in group recall than did free-for-all collaboration, replicating past findings. Novel findings showed that former group members exhibited social contagion following both interaction styles, where they produced more false information in later individual recall and exhibited collective false memories. We discuss the implications for the emergence and convergence of true and false memories among users online.

Keywords: Collective Memory, False Memory, Collective False Memory, Memory Transmission, Error Correction, DRM Paradigm

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As social beings, much of what we learn and remember about news, world events, and others' personal lives comes from daily social interactions. The advent of social media has amplified such social influences, with people receiving frequent updates and alerts from a variety of sources and posting, sharing and transmitting their own news and information (e.g., Marsh & Rajaram, 2018; Perrin & Anderson, 2019). Research on social media usage and quality of information encountered shows that people are not only exposed to accurate information on social media but also to a good deal of inaccurate information (e.g., Smith et al., 2019). Constant exposure to information via the internet as well as proliferation of false information online introduce a host of questions about how such exposure alters memory.

In this article, we focus on the impact of interaction styles during information exchange on the persistence and convergence of false memories in groups. Styles of information exchange are of interest because the internet and social media platforms offer a range of interaction capabilities. Interactions in a group chat or comments sections introduce the possibility that inaccurate details are added during these discussions. Information on a social media feed introduces the possibility that fake news articles shared by a friend on social media feed can continue to be shared with friends of that friend, and so on. Beyond these everyday occurrences, more grandiose forms of false information can also originate in social contexts, for example, when individuals develop conspiracy theories on online forums (e.g., Bessi et al., 2015; Quattrociocchi et al., 2016). In brief, online social contexts abound with both everyday scenarios and more unusual and consequential scenarios where individuals may be exposed to false information and where people can produce false information when recalling and sharing

information with others. As a result of such information transmission and exchange, members in groups and communities can develop overlapping memories, also known as collective memories. Since online platforms vary in the extent of interaction they allow, with some involving free-flowing exchange and others involving relatively more restricted interaction, these variations may change the propagation of false information, with increases or reductions depending on the extent of interaction allowed. Laboratory research on the impact of interaction style is modest but extant findings suggest that restricted versus unrestricted collaboration during recall can influence false recall by groups (Basden et al., 1997b; Maki et al., 2008; Takahashi, 2007; Thorley & Dewhurst, 2007; Weigold et al., 2014). We aimed to test whether the extent of interaction influences false memory transmission such that false information persists and converges in later individual memory of former group members.

Emergence of False Memory in Individual Retrieval

A long history of memory research shows that people frequently report distorted and even false memories (e.g., Bartlett, 1932). Much of the work on this topic has tested the performance of individuals learning and remembering in isolation and has used a variety of experimental approaches to document the range of false memory phenomena people exhibit. For example, research on the well-documented misinformation effect demonstrates the influence post-event information can have on memory accuracy (Loftus et al., 1978; see Pickrell et al., 2016 for a review). Studies on rich memories show false memory production for complex and rich information such as autobiographical events, demonstrating the strength of suggestibility even for personally relevant memories (e.g., Bernstein et al., 2005; Hyman et al., 1995; Loftus, 1997, 2005). Furthermore, other studies have observed susceptibility to false retrieval when

people incorporate misinformation despite possessing accurate prior knowledge (see Marsh et al., 2016 for a review).

Another influential approach to studying false memory production is the Deese-Roediger-McDermott (DRM) paradigm (Deese, 1959; Roediger & McDermott, 1995). Here, instead of introducing misinformation that participants falsely remember later, the experimenter presents semantically associated word lists for study (e.g., *bed, rest, awake, tired, dream, wake, snooze, blanket, doze, slumber, snore, nap, peace, yawn, drowsy*). Participants report false memories when recalling these word lists theorized due to the activation of semantic associations (e.g., Roediger et al., 2001) and similarity and gist-based errors (e.g., Brainerd & Reyna, 2002), resulting in the recall of certain nonstudied words known as critical lures (e.g., *sleep*, for this study list) (Gallo, 2006; 2010; Roediger & Gallo, 2016).

Together, these examples represent a wide and impressive array of false memory phenomena that experimenters have documented in the laboratory and highlight different ways individuals can be susceptible to making false memory errors in everyday life. While this body of research has largely focused on false memory phenomena in individual remembering, it has also served as a springboard for asking questions about false remembering in social contexts (see Maswood & Rajaram, 2019 for a review). In our study, we drew upon this prior work to address how social interactions can influence false memory.

Social interactions comprise a unique source of influence on memory and its accuracy, yielding a variety of consequences beyond those observed in individual remembering. A recent surge in laboratory research on group recall shows that several factors come into play and influence memory when people recall and share information with others (Rajaram, in press). In the present study, we focus on one such factor, namely interaction dynamics, or the extent of

interaction among individuals who engage in information exchange. This variable provides a laboratory analog for the types of interactive information exchange that occur online. The differing features of various social media platforms and websites influence the level of interaction users can have with one another. Some online platforms allow more interaction and facilitate a free-flowing conversation (e.g., messaging on Whatsapp or Facebook Messenger) whereas other platforms allow less interaction and place more restrictions on communication (e.g., turn-taking on threaded comments on Youtube or Reddit, disabling of comments on posts). A test of the impact of the extent of interactions during recall thus has the potential to provide a relevant reference for the consequences that everyday interactions, including online interactions, have on memory accuracy.

Social Influences on False Memories

False memory in social contexts has been largely investigated in studies on social contagion and collaborative memory. Experiments on social contagion, using the social contagion paradigm (Roediger et al., 2001, Meade & Roediger, 2002) and the memory conformity paradigm (Gabbert et al., 2003; Wright et al., 2001), show that individuals are susceptible to incorporating false information introduced by social sources. In these studies, after being exposed to descriptions of events or everyday scenes as study information for later recall, naïve participants are exposed to post-event misinformation from a social source, e.g., a confederate, who presents misinformation while recalling the studied information together with the naïve participants. Participants reliably exhibit social contagion of memory whereby they incorporate this nonstudied, false information into their memory and later incorrectly remember it as studied information (e.g., Gabbert, Memon & Allan, 2003; Meade & Roediger, 2002; Roediger et al., 2001; Wright, Self & Justice, 2000). Social contagion has been observed in a

range of studies examining the influence of interpersonal and social factors as well as cognitive factors (e.g., Allan & Gabbert, 2008; Andrews & Rapp, 2014; Davis & Meade, 2013; French et al., 2008; Hope et al., 2008; Huff et al., 2013; Kensinger et al., 2016; Kwong et al., 2001; McNabb & Meade, 2014; Park et al., 2016; Skagerberg & Wright, 2009; see Maswood & Rajaram, 2019 for a review).

Collaborative memory research on false memories in social contexts has focused on a related question: Are individuals more likely to produce nonstudied information, that is, false memories, in social contexts than when recalling alone? In the typical procedure of the collaborative memory paradigm, false information is not planted by social sources such as a confederate but arises in the natural course of information exchange among group members. These studies have focused on how small groups recall information that they studied earlier in the experiment, and the effects of such group retrieval on the group members' individual memory later (Basden et al., 1997a; Rajaram & Pereira-Pasarin, 2010; Rajaram, 2017; Weldon & Bellinger, 1997). These experiments typically begin with a standard study phase where each participant is exposed to information such as a list of words, pictures, or narratives, and later performs one or a series of memory tests. A key comparison in the test phase involves participants recalling the studied information either once again working individually or working collaboratively in groups that typically consist of three strangers. To assess the effects of collaboration on group recall, information recalled by the collaborating groups is compared to the recall by nominal groups of equal size that are groups in name only. Nominal group recall is derived by nonredundantly pooling the study information that individuals recalled while working alone (Basden et al., 1997a; Weldon & Bellinger, 1997). A comparison of collaborative and nominal group recall reveals a counterintuitive but robust effect of group recall. While groups

predictably recall more than a person recalling alone, collaboration actually lowers group recall when compared to the recall of nominal groups, a phenomenon known as collaborative inhibition in recall (Basden et al., 1997a; Weldon & Bellinger, 1997; see Marion & Thorley, 2016 for a metanalysis).

Research on collaborative memory has generated an impressive array of findings on how groups retrieve accurate memories (Rajaram, in press). The focus on the production of false memories has been modest by comparison, but extant studies are directly pertinent to our questions about the role of interaction dynamics in influencing false memory. These studies show that groups are more likely to produce nonstudied false information during collaborative recall if communication is limited among group members. By contrast, unrestricted communication that allows back-and-forth feedback curtails false memory production in group recall. These findings come from the application of two methods of collaboration that are widely used during recall in collaborative memory studies, free-for-all (Weldon & Bellinger, 1997) and turn-taking (Basden et al., 1997a).

Interaction Dynamics during Collaborative Recall

In free-for-all collaboration, communication between group members is unrestricted. Group members receive minimal instructions regarding how to collaborate and are allowed to freely discuss and converse with one another. Furthermore, group members are not required to reach consensus and are free to resolve disagreements in any manner they decide amongst themselves. In turn-taking collaboration, communication is restricted. Group members are instructed to take turns and speak only during their turn to recall a previously studied item in a sequential fashion. As a result, group members cannot correct errors, validate a response, or otherwise provide feedback to one another. Taken together, free-for-all collaboration promotes

interaction and feedback, allowing for error correction, with group members detecting, discussing, and correcting false information that may be produced. In contrast, the features of turn-taking collaboration make it a more restrictive interaction.

While a few studies have reported that false recall rates of nonstudied information do not differ as a function of collaboration style, a majority of studies suggest that false memory rates are sensitive to collaboration style. Several studies have found evidence for free-for-all collaboration curtailing errors, whereby the recall of intrusions by groups using this interaction style is reduced compared to the control, nominal group condition (e.g., Congleton & Rajaram, 2011; Harris et al., 2012a, 2012b; Pereira-Pasarin & Rajaram, 2011; Ross et al., 2004; 2008; Takahashi & Saito, 2004, Experiment 1; Wessel et al., 2015; Yaron-Antar & Nachson, 2006; see Finlay et al., 2000; Experiments 2 and 3; Takahashi & Saito, 2004, Experiment 2; Weldon & Bellinger, 1997 for equivalent rates). While the study materials used in these experiments were word lists, which typically do not give rise to many false memories, these reports are nonetheless in line with evidence that errors introduced in a free-for-all collaboration environment are often detected and corrected by group members (Pritchard & Keenan, 2002; Ross et al., 2008; Weigold et al., 2014).

The free-for-all interaction style also appears to be effective for curtailing errors for study materials that do give rise to high rates of errors on later memory tasks, such as the DRM word lists (Deese, 1959; Roediger & McDermott, 1995). As noted earlier, the DRM paradigm has been widely used in memory research to examine the production of false memories in individual recall and recognition memory performance (e.g., Gallo, 2010; Maswood & Rajaram, 2019). Collaborative memory studies using the DRM stimuli have shown that free-for-all collaborative recall produces fewer critical lures than nominal groups (Maki et al., 2008, Experiment 1;

Takahashi, 2007, Experiment 2, 3; Thorley & Dewhurst, 2007; Weigold et al., 2014; see Takahashi, 2007, Experiment 1 for no difference), and sometimes comparable to that of single, individual participants (Maki et al., Experiment 2; Weigold et al., 2014).

Fewer studies have compared the turn-taking method of collaboration to the recall performance of nominal groups, but the pattern of results provides an interesting contrast to those found with free-for-all. In some cases, turn-taking collaboration does not reduce false recall compared to the nominal group conditions, and in other cases it even produces more false memories. This pattern has been reported both for study materials that are not designed to increase error rates in recall as well those that are, such as the DRM stimuli (Basden et al, 1997a; Basden et al., 1997b, Experiment 2; Thorley & Dewhurst, 2007; see Basden et al., 1997b, Experiment 1, Peker & Tekcan, 2009 for no difference). Even fewer are studies have directly compared the free-for-all collaboration with turn-taking collaboration in group recall. Evidence to date substantiates the patterns reported in studies that used only one of the two collaboration styles, with turn-taking collaboration leading to more false memories in group recall than free-for-all collaboration (Thorley & Dewhurst, 2007).

While growing evidence shows that different interaction styles during collaboration can change the propensity for false memory in group recall performance, less is known about the persistent effects of different interaction styles on false memory. The variety of interaction dynamics that characterize information exchange, along with increase in the proliferation of misinformation on online platforms (e.g., Smith et al., 2019), prompt questions about the post-interaction consequences of interaction styles. In other words, does interaction style produce changes in the accuracy of memory that persist even after collaboration has ceased?

Only a few studies have examined the retention of memory errors introduced during collaboration on later individual recall or recognition tasks, and the general patterns here suggest that turn-taking interaction style produces persisting reports of false memory in later individual performance (Basden et al., 2002; Peker & Tekcan, 2009; Thorley & Dewhurst, 2007, 2009). A direct comparison between the persisting effects of free-for-all versus turn-taking interaction has not been conducted, but in instances where earlier group memory is compared to later individual memory, findings suggest individuals from turn-taking groups retain similar levels of false memories but that free-for-all members recall fewer false memories individually than they earlier did collaboratively (Thorley & Dewhurst, 2007).

Together, the prevalence of different interaction styles on online platforms and websites and the patterns of experimental results for different interaction styles motivate a direct comparison of post-collaborative, individual performance for participants who earlier recalled in the free-for-all collaboration, turn-taking collaboration, or nominal group recall conditions. As noted earlier, a test of the interaction dynamics variable not only allows us to build on past research to test questions about persistence of false memories, it also provides a laboratory analog to draw implications for the interaction features of social media platforms and websites that vary and dictate the ways people interact online and the level of interaction they are allowed. For instance, interaction can sometimes involve continuous reach and contact (e.g., a free-flowing texting conversation on Whatsapp or Facebook Messenger), or less direct forms of communication that involve discrete turns (e.g., threaded comment sections on Reddit or Youtube, sequential revisions to Wikipedia articles), or be restricted altogether (e.g., disabling comments, replies or direct messages). As such, the interactions captured by the free-for-all or turn-taking styles represent the two ends of a continuum for the level of interaction among

people. These differences in the features of online interactions motivated our aim to directly compare the free-for-all and turn-taking collaboration styles and assess social contagion of false memories in post-collaborative recall.

Finally, past research shows that collaboration can influence post-collaborative memory of former group members not only at the individual level but also at the collective level, by increasing memory convergence across former group members (e.g., Brown et al., 2009; Choi et al., 2014; Choi et al., 2017; Coman et al., 2016; Congleton & Rajaram, 2014; Cuc et al., 2006; Cuc et al., 2007; Geana et al., 2019; Luhmann & Rajaram, 2015; Mommenejad et al., 2019; Rajaram et al., in press; Stone et al., 2010). This experimental research has largely focused on collective memory for accurate retrieval, providing little experimental insight into the formation of false collective memory as a function of collaboration styles. Therefore, our interest in the persistence of false memory production included a test of emergence of collective false memory as a function of different styles of collaborative recall.

Collective Memory

The notion of collective memory has received considerable attention in the social sciences including in anthropology, history, and sociology. A variety of definitions have been used to describe collective memory across these disciplines, but this phenomenon generally refers to shared memory representations or cultural knowledge of a people (e.g., Halbwachs, 1980; Olick, 2008; Olick & Robbins, 1998; Werstch, 2002; Werstch & Roediger, 2008). While other social sciences have tied the notion of collective memory to group identity, in experimental psychological research that focuses on understanding the psychological and cognitive mechanisms underlying memory convergence, collective memory has been operationalized mainly as overlapping information that a group of individuals remember or forget (e.g., Brown et

al., 2009; Choi et al., 2014; Choi et al., 2017; Coman et al., 2016; Congleton & Rajaram, 2014; Cuc et al., 2006; Cuc et al., 2007; Geana et al., 2019; Luhmann & Rajaram, 2015; Mommenejad et al., 2019; Rajaram et al., in press; Stone et al., 2010; see Roediger & Abel, 2015; Hirst et al., 2018 for reviews). In this experimental approach, collective memory is measured by calculating the overlap of information in the post-collaborative recall of those individuals who previously belonged to the same group or network. We follow this standard approach prevalent in cognitive-experimental studies and use this definition of collective memory to investigate the emergence of collective false memory as a function of prior collaboration.

Experimental research has mainly focused on emergence of collective memory for studied information, but some evidence suggests that people can also develop collective memory for nonstudied information following collaborative recall. In a recent study, participants initially studied a list of words working individually, where the three participants who would later form a collaborative group saw some overlapping and some unique words (Choi et al., 2017). Thus, some words were studied by one or two members of a triadic collaborative group but were not studied by the third member. In two consecutive sessions of collaborative recall that followed, participants recalled their own studied words using free-for-all collaboration either with the same partners in both sessions or with different partners across the sessions. In post-collaborative recall, where all participants now worked alone to recall the studied words, former collaborators exhibited collective memory for words they had not studied. Thus, information that was studied by some group members but not by others nonetheless became integrated into the group's collective memory through social exchange, particularly for those who repeatedly collaborated with the same partners in both sessions. This evidence raises two related questions. One, can collective false memories emerge for information that no member in the group previously

studied and that instead arose during the course of collaboration? Two, can interaction dynamics during collaborative recall, in the form of free-for-all versus turn-taking, influence the formation of such collective false memory? We tested these questions in the current laboratory study.

Past research shows that cognitive processes activated during collaborative retrieval are also associated with formation of collective memory (Rajaram, 2017; Rajaram & Maswood, 2019). Specifically, retrieval disruption during collaborative recall not only leads to collaborative inhibition in group recall, but is also associated with the magnitude of later collective memory observed for individuals who earlier collaborated (Congleton & Rajaram 2014). Furthermore, listening to group members during collaborative recall can lead to re-exposure to information (Blumen & Rajaram, 2008). This process not only improves post-collaborative recall accuracy in individual performance but can also promote memory convergence among collaborators (Choi et al., 2014). To the extent that restriction in recall production and correction can affect disruption and re-exposure, these processes can influence not only group recall but also post-collaborative memory, motivating our questions about the formation of collective false memories. To this end, we examined the impact of collaborative recall on later emergence of collective false memory for information that no group member saw prior to collaborative recall.

The Present Study

We compared the effects of recalling in an unrestricted, free-for-all environment for communication, a restricted, turn-taking environment for communication, and individually in a nonsocial environment (nominal group condition) that served as the baseline. As we noted earlier, the social contexts where people interact vary in the interaction dynamics involved and online platforms, including social networking sites, offer a variety of features that influence the dynamics of the interaction among users and the degree of communication allowed. These social

spaces online fall on a continuum of restricted and unrestricted communication, similar to the environments represented by turn-taking and free-for-all collaboration contexts in collaborative memory experiments. Understanding the consequences of interacting in environments such as these can provide reference points for the variety of social interactions people engage in, both on and offline. Our study provided a laboratory test of possible differences in the false memories produced in such environments. We used the DRM word lists to promote false memory production in our study. These word lists are particularly advantageous in the context of our questions because the DRM lists naturally give rise to large proportions of both true and false remembering, making this a reliable methodology to test our questions. A related advantage of this property of the DRM lists is that no confederate or other procedural arrangements are needed to implant false memories, thus making it feasible to implement different interaction styles for collaborative recall. The use of the collaborative recall paradigm confers further advantage by building on past empirical work on interaction styles during collaborative recall (Basden et al., 1997b; Maki et al., 2008; Thorley & Dewhurst, 2007; Weigold et al., 2014).

Method

Participants and Design

One hundred and eight volunteers at Stony Brook University (age, M = 19.59 years; 67% female) participated in the study for partial course credit, with 12 groups of three participants (36 individuals) each in the turn-taking, free-for-all, and nominal conditions. The sample size of 12 groups per condition is consistent with the range of groups (10-16) typically used in collaborative memory studies (e.g., B. H. Basden, et al. 1997; Finlay et al., 2000; Weldon & Bellinger, 1997; Weldon et al., 2000) as well as previous collaborative memory work on false recall using similar methodology (12 groups; Thorley & Dewhurst, 2007). This sample size used

was consistent with a power analysis using an alpha level of 0.05 and the effect size for false recall ($f = 0.73$; Thorley & Dewhurst, 2007) which suggests a sample of 10 groups per condition would be needed for a power of 0.9. All participants were fluent English speakers.

Materials

The study material consisted of 10 DRM word lists from Stadler et al. (1999) found to generate the highest levels of false recall of nonstudied critical lure words. Each list consisted of 15 related words and was associated with one of the following non-presented critical lures - *window, sleep, smell, doctor, sweet, chair, smoke, rough, needle,* and *anger*.

Procedure

The experiment consisted of the following sequence of phases: study, delay, initial recall (individual recall, turn-taking collaborative recall, or free-for-all collaborative recall), and final individual recall. During study, participants individually listened to audio recordings of the 10-word lists, one list at a time, presented to them in a male voice. The 10-word lists were presented in a random order across participants, with the number of the list being shown on the computer screen for the duration of that list's presentation. Participants were instructed not to talk or write anything down during this phase, and were informed of later, unspecified memory tests. A 2-3 minute delay followed the study phase when participants played the card game Solitaire individually on their computers.

In the test phase that followed, participants completed two sequential recall tasks. In the first recall, participants in the free-for-all and turn-taking collaborative groups recalled the words from the study list working in groups of three. In the baseline condition, participants worked individually to recall the studied words. In each condition, participants had 15 minutes to recall the study words and they entered their responses using a computer such that the typed words

remained on the monitor for the duration of the recall period. Participants were instructed to be accurate when recalling the study words and report the words they were sure they had heard earlier in the study phase. In the collaborative conditions, participants recalled in triads using one computer. For the turn-taking groups, collaboration involved participants taking turns in a sequence to recall. Participants were instructed not to assist or talk to one another, and not to repeat words that other group members had already recalled. During turns, each participant had 10 seconds to recall and type one word. Once a word was entered and submitted, or the 10 seconds elapsed, a sound signaled the end of the turn and the screen notified the next group member of their turn. For the free-for-all groups, collaboration involved participants freely discussing the study words to recall and one group member typing the recalled words into the computer. Participants were instructed to work together and discuss the study words to recall and to settle any disagreements as they like. All participants completed a second and final recall task to report the studied words for 15 minutes, this time working individually. The entire experiment took approximately 45 minutes.

Results

We first present results on false recall of groups during the first recall before turning to our key measures of post-collaborative recall where we report on both individual and collective false memories. Though our main interest in this study was on the production of false memories, we also present the results for accurate recall of studied information to provide replications of previously reported patterns. We examined recall performance using one-way ANOVAs on proportion of items recalled (non-presented critical lures; studied items), and where applicable, pairwise comparisons using Bonferroni corrections.

Recall 1 - Group Recall

We compared recall performance of the free-for-all collaboration groups, the turn-taking collaboration groups, and the baseline, nominal groups. As noted earlier, nominal group recall was derived by pooling the nonredundant items recalled by three individuals in the baseline condition. As predicted, false memory production of the non-presented critical lures varied across conditions, F (2, 33) = 10.24, $p < .001$, $\eta^2 = 0.383$ (Table 1). Replicating previous findings, free-for-all groups ($M = 0.53$, $SD = 0.19$) produced fewer false memories in group recall compared to both the turn-taking groups ($M = 0.72$, $SD = 0.14$, $p = .015$, $d = 1.14$), and the baseline, nominal groups ($M = 0.81$, $SD = 0.13$, $p <.001$, $d = 1.73$). False recall did not differ between the turn-taking and the nominal groups ($p = .482$, $d = 0.67$).

Patterns of accurate recall were consistent with past work on the collaborative inhibition effect, F (2, 33) = 3.39, $p = .046$, $\eta^2 = 0.171$, where nominal groups ($M = 0.40$, $SD = 0.05$) recalled more studied items than the collaborative groups (Table 2). This effect was significant for the free-for-all groups ($M = 0.33$, $SD = 0.08$, $p = .048$, $d = 1.05$) and numerically present for turn-taking groups ($M = 0.35$, $SD = 0.07$, $p = .258$, $d = 0.82$), with large effect sizes observed for both collaboration conditions. Accurate recall did not differ between the collaborative groups ($p = 1.00$, $d = 0.28$).

Recall 2 - Post-collaborative Individual Recall

As noted, post-collaborative false recall measures were of main interest in this study. Recall of the non-presented critical lures differed by condition, F (2, 105) = 8.63, $p < .001$, $\eta^2 = 0.141$ (Table 1). False recall was significantly higher for those who had collaborated earlier in free-for-all groups ($M = 0.53$, $SD = 0.22$; $p = .051$, $d = 0.56$) and the turn-taking groups ($M = 0.61$, $SD = 0.19$; $p < .001$, $d = 1.03$) compared to those who did not collaborate ($M = 0.42$, $SD =$

0.19). Although false recall rates were numerically higher following turn-taking collaboration these rates did not differ statistically between the two collaboration groups ($p = .269$, $d = 0.39$).

Accurate recall in the post-collaborative individual performance replicated patterns reported in past studies: Those who had previously collaborated now exhibited greater accurate memory for the studied information, F (2, 105) = 9.38, $p < .001$, $\eta^2 = 0.152$, demonstrating re-exposure benefits (Blumen & Rajaram, 2008) (Table 2). Individuals from both free-for-all groups and turn-taking groups recalled more studied information than individuals who had previously recalled alone ($M = 0.17$, $SD = 0.07$; p's = .001, $d = 0.97$ (turn-taking), $d = 0.86$ (free-for-all)), and performance did not differ for individuals from free-for-all groups ($M = 0.24$, $SD = 0.09$) compared to the turn-taking groups ($M = 0.24$, $SD = 0.08$; $p = 1.00$, $d = 0.05$).

We assessed post-collaborative individual memory performance further to examine social contagion. We analyzed across conditions the proportion of items (studied, false) recalled by other group members during the initial group recall that were later retrieved in the individual recall. Items from the initial group recall were categorized as items recalled by *other group member* or by *self,* based on which participant in the group initially produced the item in the free-for-all or turn-taking groups, respectively. For nominal individuals, the *self* items consisted of all items from their initial recall, and *other group members'* items consisted of items recalled by their nominal group partners that they themselves did not recall.[1]

For false memory, we found that participants in both collaborative conditions (free-for-all: $M = 0.70$, $SD = 0.31$; $p < .001$, $d = 2.17$, turn-taking: $M = 0.67$, $SD = 0.30$; $p < .001$, $d = 2.05$) recalled a greater proportion of critical lures produced by their other group members in the final individual recall compared to the nominal condition ($M = 0.13$, $SD = 0.22$), F (2, 95) =

[1] The sample included in this set of analyses included nine out of 12 free-for-all groups for whom audio recordings were available to map items in the initial group recall to later recall by individual participants.

44.10, $p < .001$, $\eta^2 = 0.481$), with no difference between the two collaborative conditions ($p = 1.00$, $d = 0.08$). Participants in all three conditions (free-for-all: $M = 0.91$, $SD = 0.25$; turn-taking: $M = 0.87$, $SD = 0.24$; nominal: $M = 0.87$, $SD = 0.17$) exhibited equivalent recall of false information later that they themselves had produced in the initial recall, F (2, 83) = 0.32, $p = .725$, $\eta^2 = 0.008$.[2]

For accurate memory, we found similar patterns, with participants in both collaborative conditions (free-for-all: $M = 0.52$, $SD = 0.14$; $p < .001$, d =5.04, turn-taking: $M = 0.47$, $SD = 0.12$; $p < .001$, $d = 4.57$) recalling a greater proportion of studied items produced by their other group members in the final individual recall than the nominal condition ($M = 0.04$, $SD = 0.05$), F (2, 96) = 204.4, $p < .001$, $\eta^2 = 0.810$), with no difference between the two collaborative conditions ($p = .197$, $d = 0.40$). Once again, participants in all three conditions (free-for-all: $M = 0.85$, $SD = 0.15$; turn-taking: $M = 0.89$, $SD = 0.12$; nominal individual: $M = 0.85$, $SD = 0.10$) later recalled to equivalent levels the studied items they had themselves produced in the initial recall, F (2, 96) = 1.13, $p = .327$, $\eta^2 = 0.023$. Taken together, these results demonstrate the social contagion effect such that individuals in the group conditions incorporated more of the information recalled by other group members than in the nominal condition. This social contagion effect was evident for both false and accurate memory.

Recall 2 - Collective Memory

Collective memory was calculated based on the items participants recalled in the second, individual recall task, and consisted of the proportion of critical lures or studied items that were recalled by all three individuals who had been members of the same collaborative or nominal group during the first recall. Results showed the emergence of collective false memories, F (2,

[2] The sample did not include participants for whom proportions could not be calculated (no false items produced by themselves (13 out of 108 participants) or by other group members (1 out of 108 participants) in the initial recall).

33) = 10.71, $p < .001$, $\eta^2 = 0.394$ (Figure 1). After collaboration, individuals from both the free-for-all groups ($M = 0.32$, $SD = 0.19$; $p = .001$, $d = 1.70$) and turn-taking groups ($M = 0.32$, $SD = 0.17$; $p = .001$, $d = 1.90$) formed collective false memories by recalling a greater proportion of the same nonstudied critical lures compared to individuals from the baseline, nominal groups who had previously recalled alone ($M = 0.06$, $SD = 0.09$). Collective false memory did not differ between individuals who previously collaborated in free-for-all groups and turn-taking groups ($p = 1.00$, $d = 0.00$).

Our findings for accurate memory are, moreover, consistent with past reports on collective memory. Collective memory for studied items varied by condition (F (2, 33) = 12.65, $p < .001$, $\eta^2 = 0.434$), with greater overlap observed in groups that had previously collaborated compared to groups of participants placed in nominal groups (Table 2). This pattern of greater collective memory was true for the free-for-all groups ($M = 0.09$, $SD = 0.06$; $p < .001$, $d = 1.74$) as well as the turn-taking groups ($M = 0.08$, $SD = 0.03$; $p = .001$, $d = 2.66$) when compared to the nominal groups ($M = 0.01$, $SD = 0.01$). Collective memory did not differ for participants from the free-for-all and turn-taking groups ($p = 1.00$, $d = 0.19$).

These patterns for collective memory were also observed when including partial overlap in recall among group members. In this analysis, collective memory consisted of items that were recalled by two or three group members. Participants from both turn-taking groups ($M = 0.65$, $SD = 0.14$; $p = .002$, $d = 1.71$) and free-for-all groups ($M = 0.55$, $SD = 0.23$; $p = .053$, $d = 0.91$) once again had more collective false memories than the nominal group baseline ($M = 0.35$, $SD = 0.21$); this effect was numerically larger in the turn-taking condition but it was not statistical different from the free-for-all condition ($p = .662$, $d = 0.52$), F (2, 33) = 7.28, $p = .002$, $\eta^2 = 0.306$. Collective accurate memory also did not differ between the collaborative conditions (free-

for-all groups: $M = 0.23$, $SD = 0.09$; turn-taking groups: $M = 0.23$, $SD = 0.07$; $p = 1.00$, $d = 0.03$). Both collaborative conditions had greater collective memory than in the nominal condition ($M = 0.10$, $SD = 0.04$; $ps < .001$, $d = 1.83$ (free-for-all), $d = 2.36$ (turn-taking)); $F(2, 33) = 14.09$, $p < .001$, $\eta^2 = 0.461$.

In summary, our study produced several key results as well as replications about the role of interaction dynamics in how groups and individuals recall false and accurate information. In group recall, we observed differences in false recall as a function of the interaction style; groups who engaged in free-for-all style of collaboration produced fewer false memories compared to groups who used turn-taking collaboration. We also observed that participants from both collaborative groups continued to produce false recall even after they were no longer recalling in groups, compared to individuals who recalled alone during both first and second recall. Individuals from both collaborative conditions exhibited social contagion such that they incorporated more false memories into their later individual recall that were earlier produced by their other group members during group recall, compared to those in nominal condition. Finally, our study showed that following collaboration, group members developed collective false memories, and this outcome occurred regardless of the interaction style people used during collaborative recall. Thus, our study reveals the novel finding that both interactive and restricted forms of collaborative recall can lead to the formation of collective false memories.

Discussion

People encounter and share a wide variety of information during both face-to-face interactions and online interactions, including those that occur on social media platforms. Though these social exchanges usually feature the transmission of accurate information, they also abound with opportunities to transmit false information (e.g., Smith et al., 2019). As a

consequence, both true and false information discussed during these exchanges have the potential to shape the accuracy of people's memories after they leave these interactions (Marsh & Rajaram, 2019). With the widespread use of social media platforms where a rise in the transmission of misinformation has become a growing source of concern (e.g., Vosoughi, Roy, & Aral, 2018), questions about the persisting effects of exposure to false information on memory are of pressing interest. In the present study, we implemented a laboratory test to assess whether false memories persist after collaborative exchange of information and whether individuals exhibit collective false memory for such information in their post-collaborative recall.

We focused on the style of the collaborative exchange during recall to measure its consequences on later memory. Interaction style is of interest because social media platforms and websites come with a range of features that allow relatively restricted to relatively unrestricted communication. Past laboratory studies show that the extent to which group members are allowed to interact has an impact the magnitude of false memory production in group recall (Basden et al., 1997b; Maki et al., 2998; Takahashi, 2007; Thorley & Dewhurst, 2007; Weigold et al., 2014)), with more restrictive interactions, known as turn-taking, increasing false memories (Basden et al., 1997b; Thorley & Dewhurst, 2007). These findings motivate the question whether collaboration styles that vary in the extent of interaction can lead to persisting memory errors people make even after they are no longer recalling in groups. These findings can provide a reference for understanding the mnemonic consequences of the types of interactions in which people engage, both online and offline.

We implemented the collaborative memory paradigm to compare interaction styles across three conditions: unrestricted, free-for-all group collaboration; restricted, turn-taking group collaboration; and a nonsocial, nominal group condition that served as a baseline control. In

addition to testing the effects of interaction dynamics on group recall as a replication of past work, we compared two key, post-collaboration outcomes across these conditions. First, we compared the individual recall performance of those who had previously collaborated with those who had not. Second, we measured memory convergence in the recall of group members who had previously collaborated compared to those who had not collaborated (nominal group participants) to examine the emergence of collective false memory. We used the DRM word lists as study materials to facilitate the production of both accurate and false recall.

We observed several key replications of both accurate and false memory effects that provide the context for our novel questions. Focusing first on group recall, we found reduced recall in collaborative groups compared to the control, nominal groups for studied information. This pattern is consistent with the collaborative inhibition effect in group recall (Basden et al., 1997a; Weldon & Bellinger, 1997). This deficit was significant for free-for-all collaborative groups, with large effect sizes observed for both free-for-all and turn-taking collaborative groups. Furthermore, false memories during group recall were lower for the free-for-all collaboration groups compared to turn-taking (Thorley & Dewhurst, 2007) and nominal groups (Weldon & Bellinger, 1997). Free-for-all collaboration is an interactive environment that allows for the detection and correction of errors that are not possible in the turn-taking environment. Thus, these patterns of results are consistent with the error-correction benefits associated with the free-for-all style of collaboration, and also with prior reports of free-for-all groups producing fewer false memories than turn-taking and nominal groups (e.g., Maki et al., 2008; Takahashi, 2007; Thorley & Dewhurst, 2007; Weigold et al., 2014).

Our results for later individual memory are also consistent with past reports on the post-collaborative effects on memory. Individuals from both collaboration conditions later recalled

more accurate (i.e., studied) information than those who had previously recalled alone. These findings are consistent with the expected benefits of re-exposure to information during collaboration that a given group member might have otherwise forgotten (e.g., Blumen & Rajaram, 2008). Finally, our results on collective memory for studied information replicate past work showing that collaboration promotes gives rise to collective memories, as indexed by overlapping information in recall of individuals who previously collaborated in the same group (e.g., Choi et al., 2014; Congleton & Rajaram, 2014; Cuc et al., 2006).

False Memory Transmission and Collective False Memory

The novel questions of this study focused on the post-collaborative emergence of false memory. While prior research has investigated the production of false memories during collaborative recall, less is known about the persistence of false information in post-collaborative reports, especially as a function of different interaction styles used during collaborative recall. We examined two ways in which individuals' false memories may be influenced by collaboration – by examining the individual-level reporting of false memories after collaboration and assessing the formation of collective false memories.

When we examined false information in later individual recall, consistent with past findings (Thorley & Dewhurst, 2007) we found that those who had previously collaborated now reported more false memories than the individuals in the nominal group condition who had previously recalled alone. This rise in false recall occurred both for individuals from free-for-all as well as turn-taking collaboration groups, with a numerically larger difference for participants the turn-taking groups, indicating that susceptibility to false information persists after collaboration. Past research that compared recall performance across the first, group recall with the second, individual recall suggested that false memories persisted in individual recall for only

those participants who earlier collaborated using the turn-taking procedures (Thorley & Dewhurst, 2007). How the false reports in the second, individual recall compare between participants from the free-for-all groups and the turn-taking groups had not been addressed. A direct comparison between these two conditions in our study revealed free-for-all collaboration to also led to a persisting effect of false recall in later individual memory although this cascading effect was numerically higher following turn-taking collaboration. Furthermore, as mentioned earlier, research on the social contagion effect shows that people incorporate nonstudied, false information when such information planted or explicitly introduced through experimental methods (e.g., Gabbert et al., 2003; Roediger et al., 2001). The question still remains whether people spontaneously produce false information during collaboration during the course of the social exchange and whether people retain and report this false information when recalling alone afterwards. Our results show this effect of social contagion, whereby individuals exhibited a susceptibility to incorporating false information from social influences.

How do the persisting effects of collaborative recall on false memory in later individual recall shape collective false memory? As reviewed earlier, previous studies have shown that collaborative recall promotes memory convergence, with former group members exhibiting overlapping memories, or collective memory, in post-collaborative recall (e.g., Brown et al., 2009; Choi et al., 2014; Choi et al., 2017; Coman et al., 2016; Congleton & Rajaram, 2014; Cuc et al., 2006; Cuc et al., 2007; Geana et al., 2019; Luhmann & Rajaram, 2015; Mommenejad et al., 2019; Rajaram et al., (in press); Stone et al., 2010). However, collective memory research has almost exclusively focused on accurate memory by examining how individuals develop shared memories for the same studied information. Although sparse, available evidence suggests that individuals can incorporate into their own memories items they had not studied but their partners

had studied, and later report this information to falsely contribute to collective memory (Choi et al., 2017). In the present study, we asked two questions related to collective false memory: One, whether collective false memories can emerge for information that no member in the group had previously studied; and two, whether differences in the interaction dynamics during collaborative recall influence the formation of collective false memory. We observed collective false memory in our study for information that no group member had studied and found it to be statistically equivalent between the two types of interaction styles.

As we noted in the introduction, several cognitive mechanisms associated with collaborative recall have been implicated in the formation of collective memory. For example, others' recall during collaboration can disrupt the retrieval strategy for one's own recall and eliminate some items that a member might uniquely remember, thereby increasing the overlap in the items that all members remember after collaboration (Basden, et al., 1997a). Conversely, others' recall during collaboration can also provide re-exposure to items that one might not have thought of otherwise, and thus create overlapping memories for such items (Blumen & Rajaram 2008). Extant research has by and large implicated these mechanisms in the formation of collective memory for accurate information. The current findings suggest that these cognitive mechanisms, particularly re-exposure, can lead to the formation of collective memory for false information as well. For instance, re-exposure is essentially the same process as social contagion where the former process is usually associated with incorporating studied information and the latter process is typically associated with incorporating false (or nonstudied) information received from others into one's own memory. Similarly, disruption can increase when people might correct each other's errors in free-for-all collaboration, and also when others' recall can disrupt the recall of one's own erroneous items while waiting one's own turn during turn-taking.

With regard to the two collaboration styles we implemented, our results showed equivalent individual post-collaborative recall and collective false memory for those who earlier participated in restricted turn-taking collaboration versus in unrestricted free-for-all collaboration. Interestingly, this pattern differs from the higher levels of false recall observed during collaboration for turn-taking groups compared to the free-for-all groups. As we noted earlier, post-collaborative individual recall was numerically higher following turn-taking collaboration compared to free-for-all collaboration. We also observed numerically higher collective false memory following turn-taking collaboration in the analysis that included recall overlap for two as well as all three members of a collaborative group. One possibility for why these differences observed during collaboration were not reliable in the post-collaboration measures might be because of offsetting processes involved in the two types of collaboration. While free-for-all collaboration allows for correction of false memories produced during collaboration, it is possible that falsely produced information that goes uncorrected or is validated can endure in later recall and thereby persist to comparable levels of false memories that the turn-taking group members later report. In this vein, while the false memories produced by the turn-taking groups may be greater in number, these false responses do not endure to a greater extent because this information is not overtly evaluated by group members. These differences may explain why turn-taking groups collectively remember similar false information as the free-for-all groups, albeit, as noted, we did observe a numerical increase in post-collaborative individual recall and collective false memory (when we also took into account the memory overlap for two of three group members) following turn-taking collaboration. Future research that delves further into post-collaborative memory consequences we report here is needed to shed light on these patterns and possibilities.

Conclusions, Limitations and Directions for Future Research

In this study, we tested the consequences of recalling information in two different collaboration environments that varied in interaction dynamics, and compared it to a nonsocial, nominal group condition where individuals recalled alone. Our main focus was to examine the influence of two different collaboration styles on the reports of nonstudied or false information in recall. We also included tests of these effects on memory for the studied information in order to anchor our novel findings in the context of replicating the standard effects of collaborative recall. Our novel findings show that while interactive collaborative recall environments lead to production of less false information compared to more restricted settings, both collaborative contexts lead to higher false recall in later individual performance and to formation of collective false memory, compared to a condition where participants always recalled alone.

Findings from the present study have important implications for future investigations on the emergence of false memories in a variety of social contexts where people interact, recall, and share information. These results are especially relevant for online platforms that people use for social exchange of information, where different posting and editing features can lead to variations in the extent of interaction allowed among users. The landscape for everyday online interactions spans a continuum for the level of interactions involved, where platforms and websites frequently vary in features and in turn, the level of interaction that is possible among users. Our manipulation of free-for-all and turn-taking interactions represent largely opposite ends of the continuum, thus providing insights into the impact of interactions online. This investigation paves the way for future tests of other levels of interactions that are representative of online conversations on different platforms.

Our study also provides novel evidence on the formation of collective false memory, a phenomenon that has received considerable attention from the general public but has not yet been a subject of extensive scientific investigation. Reports of collective memory have ranged from relatively innocuous memory mistakes about book and movie titles to more serious collective misremembering about public events and death of influential figures. Reports of such extreme errors in shared memory, especially those that greatly deviate from reality, are colloquially referred to as the *Mandela effect* by the general public and by communities online and have gained attention from communities online. Our study represents an initial step towards building a body of experimental evidence that can explain how interaction dynamics may contribute to such false memory production and collective narratives that represent false memory.

Collective false memories can come in different forms, including those we observed in the present study, that is, memories for information or events that did not occur but are nonetheless recollected by a group of people. We used the DRM word lists as information that participants studied and recalled later to simulate such errors because these lists were suitable for several reasons. First, these word lists produce substantial accurate and false memory production (Roediger & McDermott, 1995; Gallo, 2006; 2010). Due to these properties, DRM lists do not require confederates to generate false recall and therefore facilitate the use of different interaction styles during collaboration. Second, the use of DRM word lists allowed us to build on past research where these materials were used in a collaborative recall paradigm (Basden et al., 1997b; Maki et al., 2008; Takahashi, 2007; Thorley & Dewhurst, 2007; Weigold et al., 2013). This enabled us to examine new questions about the persistence and convergence of false memory following information exchange in the context of replication.

Future work that examines other types of study-test information and other false memory paradigms can elucidate the impact of interaction styles on a variety of false memories that can arise in response to social influences. This would be an important future direction given that researchers have used a variety of paradigms to study false memory production, as noted in the introduction. Furthermore, past research also shows that false memory errors may not be all based on the same cognitive processes. For example, studies have demonstrated that susceptibility to DRM errors is different from susceptibility to other false memory errors such as those resulting from the misinformation effect paradigm (e.g., Patihis et al., 2018; Ost et al., 2013; Zhu et al., 2013). Interaction styles could produce a different cascading effect of false remembering with different materials and procedures, thereby demonstrating a wider range of false memory effects in response of group interactions. In addition, future work directed towards the use of ecologically relevant materials, including materials that resembles online information, also has the potential to provide direct applied understanding of propagation and convergence of false memories on social media. Finally, with studies on false memories in individual memory performance having also explored the positive impact false memories may have (e.g., Bernstein et al., 2005; Laney et al., 2008). This is an intriguing avenue for future research, to examine the positive and adaptive consequences of forming collective memories, including collective false memories in the service collective group goals.

In summary, we implemented a laboratory analog to examine the transmission of false memories and formation of collective false memories. The information a community of people collectively share, including both accurate and false information, can influence beliefs, decisions and behaviors. For these reasons, research on the persistence, social contagion, and emergence of false memories is relevant and timely, especially in the context online communities that attribute

collective false memories to supernatural or conspiratorial rather than cognitive factors and scientific evidence (e.g., Dagnall & Drinkwater, 2018; McPherson, 2016). The findings from this study contribute to research on these timely issues by elucidating the circumstances where social environments can lead to an increase or reduction of false information in recall and the formation of collective false memory.

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Disclosure of Interest

The authors report no conflict of interest.

Data Availability Statement

The data for this study are uploaded in OSF [pre-reserved DOI 10.17605/OSF.IO/T8VQK].

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Table 1

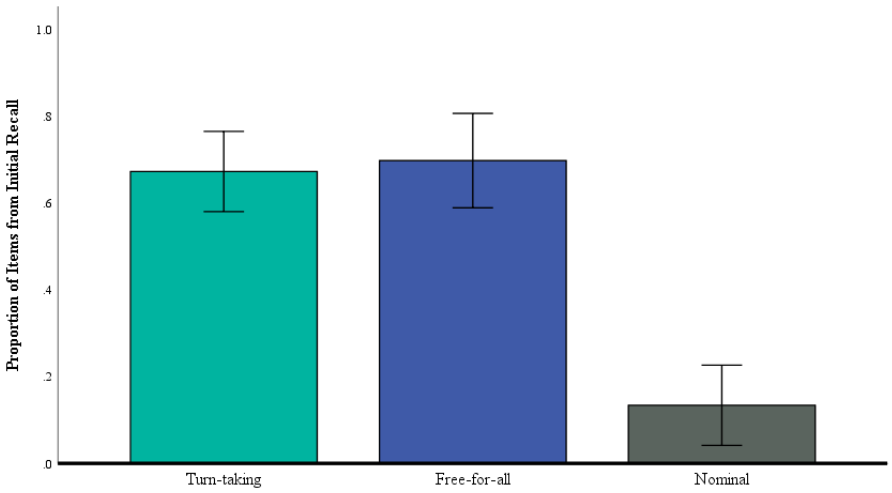
Mean proportion of false memories recalled. Standard deviations are shown in parentheses and 95% confidence intervals for the mean values are shown below the means.

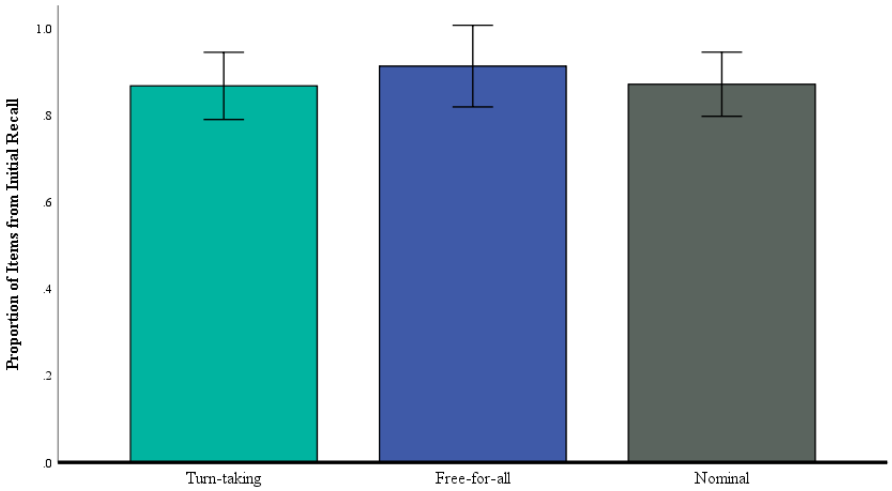
	Recall 1 – Group Memory	Recall 2 – Later Individual Memory
Free-for-all	0.53 (0.19)	0.53 (0.22)
	[0.42, 0.64]	[0.46, 0.60]
Turn-taking	0.72 (0.14)	0.61 (0.19)
	[0.64, 0.80]	[0.55, 0.67]
Nominal (Control)	0.81 (0.13)	0.42 (0.19)
	[0.74, 0.88]	[0.36, 0.48]

Table 2

Mean proportion of accurate memories recalled. Standard deviations are shown in parentheses and 95% confidence intervals for the mean values are shown below the means.

	Recall 1 – Group Memory	Recall 2 – Later Individual Memory	Recall 2 – Collective Memory
Free-for-all	0.33 (0.08)	0.24 (0.09)	0.09 (0.06)
	[0.28, 0.38]	[0.21, 0.27]	[0.06, 0.12]
Turn-taking	0.35 (0.07)	0.24 (0.08)	0.08 (0.03)
	[0.31, 0.39]	[0.21, 0.27]	[0.06, 0.10]
Nominal (Control)	0.40 (0.05)	0.17 (0.07)	0.01 (0.01)
	[0.37, 0.43]	[0.15, 0.19]	[0.00, 0.02]


Proportion of Items from Initial Recall
1.0
.8
.6
.4
.2
.0
Turn-taking
Free-for-all
Nominal


Proportion of Items from Initial Recall
1.0
.8
.6
.4
.2
.0
Turn-taking
Free-for-all
Nominal

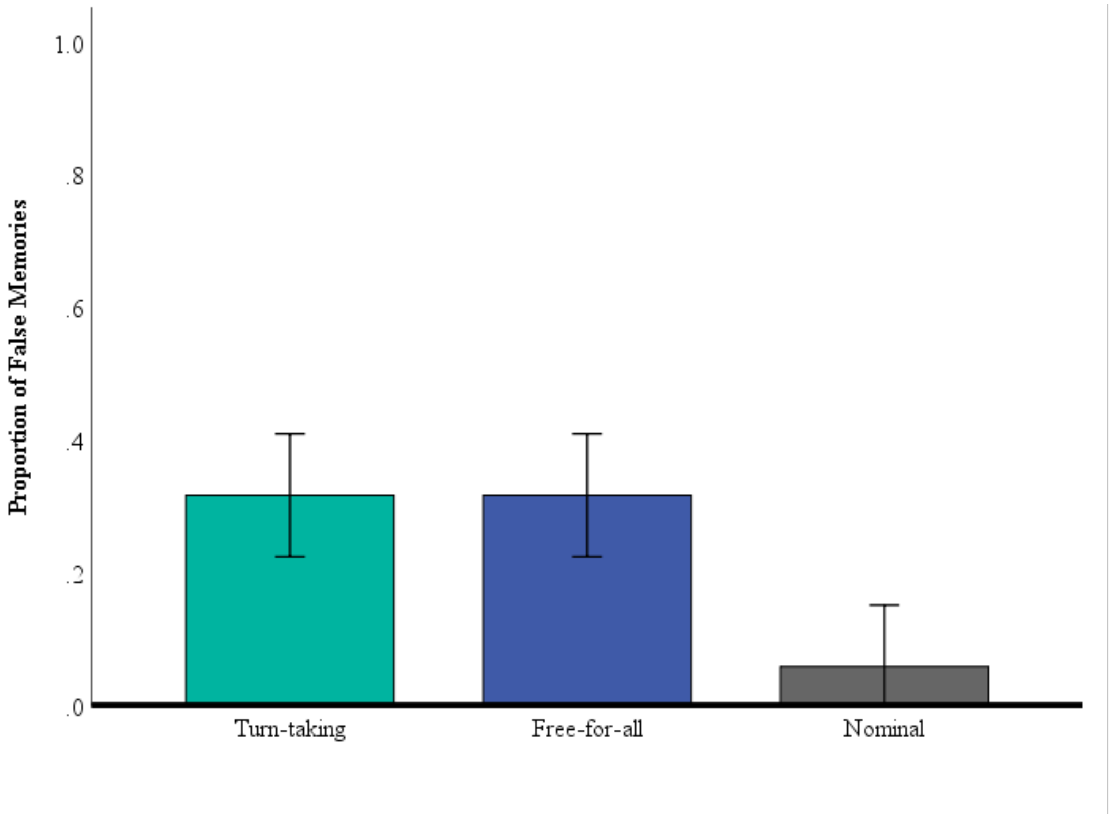

Proportion of False Memories
1.0
.8
.6
.4
.2
.0
Turn-taking
Free-for-all
Nominal

Figure 1. Items incorporated from initial recall in the turn-taking, free-for-all and nominal (control) recall conditions. After collaboration, individuals from both the free-for-all groups and turn-taking groups incorporated more false memories recalled by their other group members from the initial recall compared to nominal individuals (Top). Individuals from all three conditions retrieved equivalent number of false memories recalled by themselves from the initial recall (Bottom). Error bars represent 95% confidence intervals.

Figure 2. Collective false memories produced in the turn-taking, free-for-all and nominal (control) recall conditions. After collaboration, individuals from both the free-for-all groups and turn-taking groups exhibited collective false memories, by recalling more of the same critical lures compared to individuals from the control, nominal groups who had previously recalled alone. Error bars represent 95% confidence intervals.