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Collaborative Recall Changes the Global Organization of Memory: A Representational Similarity Analysis of Social Influences on Individual and Collective Memory Organization

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The last 25 years of research have revealed that recalling the past with others changes memory. A key finding is that former group members show increased memory overlap or collective memory. Beyond memory content, we ask whether collaborative recall changes the organization of memory. How we organize information has far-reaching consequences on learning and remembering, and research has produced sophisticated theories and measures of memory organization when people recall alone. However, research remains sparse on how social influences shape memory organization. Furthermore, studies document local changes only (small segments in recall), raising the question whether collaboration produces global changes (positional relations among all items) in memory organization that can inform how people construct memory narratives. It is also unclear whether collaboration affects memory organization differently for different emotional contents despite the well-established influence of emotion on memory. We address these questions by focusing on two important advances. Using representational similarity analysis, we seek a deeper understanding of collaborative recall on memory organization at the global level and how emotional valence influences memory organization. Comparing two collaborative recall sequences, collaborative–collaborative–individual and individual–collaborative–individual, with individual–individual–individual (baseline sequence), we replicated better memory for emotional than neutral content and collective memory for content. Novel to our aims, collaborative recall changed global memory organization, both at individual and collective levels and for neutral and emotional contents. These quantitative indices for holistic changes in memory organization reveal the depth of social influences in reshaping memory, with implications for remembering, beliefs, education, and national narratives.

Public Significance Statement

Social interactions can alter a person's memory and have a far-reaching impact. These changes have major implications for various aspects of human cognition, including learning, remembering, beliefs, education, and the construction of shared narratives. This research showcases a novel application of the quantitative approach known as representational similarity analysis to the study of memory organization. Our findings show that recalling the past with others, even just once, leads to holistic changes in the way we organize our memories, changing what we remember and forget as well as the way we organize the interrelationships among the details to construct memory narratives. The study also reveals that the influence of social interactions on memory organization extends to both neutral and emotional contents, further emphasizing the importance of understanding the role of emotion in shaping collective memory. These insights contribute to our understanding of memory processes and offer potential avenues for enhancing memory performance as well as fostering more accurate and cohesive collective recollections.

Keywords: collaborative recall, collective memory, retrieval similarity analysis, global memory organization, emotional valence

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continued

In psychological research, memory is often measured as how much information is recalled or recognized, and such performance is traditionally assessed at the individual level. However, remembering is also a profoundly social experience. The recognition for a need to study the impact of social systems on individual cognition has underscored the importance of studying social influences on cognition (Dubova et al., 2022; Rabb et al., 2019). In this context, building on over a century-long investigation focused on individual recall (see Crowder, 1976; Neath & Surprenant, 2009), a call to examine memory as a social process (Weldon, 2001) has given rise to cognitive–experimental studies of social remembering. These studies examine the consequences of collaboration, both during and following interpersonal interactions, and report one common theme—remembering with others changes our memory (Basden et al., 1997; Rajaram & Pereira-Pasarin, 2010; Weldon & Bellinger, 1997). A key aspect of social interactions is the sharing of emotional information, which individuals tend to share more readily than neutral information (Berger, 2011; Berger & Milkman, 2012), presumably because such sharing helps regulate negative affect and strengthen social bonds (Fivush & Wang, 2005; Rimé, 2009; Q. Wang & Fivush, 2005). As such, studies have started to expand the focus on the role of emotions in collaborative recall (Barber et al., 2015; Choi et al., 2017; Wessel et al., 2015; Yaron-Antar & Nachson, 2006).

In pursuing questions about social influences on memory, we draw a distinction between the specifics people recall, that is, the contents of recall, and the way people organize these specifics, that is, the organization of recall. It is not necessarily the case that when people recount the same experiences and events that they have organized these memories in an identical manner. This distinction can be observed in real-life examples such as in legal trials where multiple witnesses may have exposure to the same events and details about the case. Yet, each witness's account may be woven into different narratives, with witnesses emphasizing some details over another and weaving information clusters in different sequences and relationships, to convey their memory for the same events where overlapping content is organized in different ways.

Beyond specific examples, our daily life is filled with remembering some details while forgetting others. This process also entails weaving together the details to produce a coherent and integrated account, making retrieval organization a cornerstone of memory narrative construction. Among the key questions we investigated in this study, we ask how recalling with others shapes the retrieval organization for each person in the collaborating group and the extent to which collaboration synchronizes the retrieval organization of collaborating partners, thereby giving rise to collective retrieval organization. These questions have important and broad implications for how social remembering shapes memory narratives.

To the extent remembering with others alters how we organize memories, a change in retrieval organization has significant consequences for how others influence the way we remember our past and approach the future, shaping our knowledge, beliefs, and decisions that are based on what we remember. Crucially, research is increasingly demonstrating the influential role of emotional content of memories in shaping memory structures (e.g., Choi et al., 2017; Kensinger et al., 2016; Maswood et al., 2019) and the propensity people have for sharing emotional information (Berger, 2011; Berger & Milkman, 2012). It is thus timely to explore how emotion impacts the organization of collective memory.

We situate the present study by first reviewing the relevant past findings and the critical gaps in this literature that motivated the theoretical advances we sought. This background includes the importance of retrieval organization in individual memory, the need for assessing holistic or global retrieval organization to better understand memory narrative construction, the impact of collaboration on memory, and the role of emotion in shaping the effects of collaborative recall on memory organization. We then describe the collaborative memory paradigm we used to measure the impact of collaborative recall on individual and collective memory. Finally, we describe the application of the representational similarity analysis (RSA) to pursue the novel aims which is to capture the emergence of holistic memory organization at both individual and collective levels.

Retrieval Organization in Individual Memory

The nature of memory organization has long been of interest in the field of cognitive psychology, especially as it pertains to constructing and testing theories (Kahana, 2012). Far removed from the courtroom, basic experiments here leverage free-recall tasks, using word lists for study and recall. These experiments capture retrieval organization by considering how responses are sequenced,

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ordered, or clustered during the retrieval process (see Farrell, 2012; J. R. Manning & Kahana, 2012; also see Bair et al., 2023), allowing theoretical insights into real-life phenomena that motivate these questions. The specific operationalization of retrieval organization here depends on the goal of the research, and among the prevalent metrics, two are of note for current purposes. One is the pair frequency measure (Sternberg & Tulving, 1977) that takes into account the adjacent occurrence of pairs of remembered items in successive recalls. The second is the adjusted ratio of clustering measure that considers the clustering of categorically related information in recall (Roenker et al., 1971). More generally, these metrics share two defining characteristics: A focus on item-to-item transitions that account for small units of item clustering, thus providing what we will call "local" level measures, and the consideration of only remembered material, excluding forgotten materials.

Likewise, research has been directed almost exclusively at examining the nature of organization as people work alone to study and recall material. The body of research on memory organization at this level provides an important backdrop, as it has revealed relationships between recall, organization, and learning; organization guides not only our retrieval of the learned information (A. Congleton & Rajaram, 2012; Mulligan, 2005; Zaromb & Roediger, 2010) but may also influence our future learning by facilitating the grasp of related information (Chan, Manley, et al., 2018; Chan, Meissner, & Davis, 2018).

We build on this foundational work to advance our understanding of retrieval organization at a holistic level. In this approach, we aim to assess how each recalled element is positioned in relation to all other recalled elements, and how each forgotten element affects the positioning of detailed recalled material, thus undertaking what we will call a "global"-level analysis. This approach addresses the theoretical need to understand the construction of holistic memory representation of events and experiences.

Theoretical Importance of Studying a Holistic Organization of Memory: Global Retrieval Organization

The importance of examining contents of recall in a holistic manner can be traced back to classic examples of recall Bartlett (1977) reported in his seminal book. Particularly instructive are his reports of narrative recall of the North American Folk Tale "War of the Ghosts." This story, with its unfamiliar details and structure, is especially illustrative for considering the alternations people make when recalling a story. In their individual recall, British college students deleted, added, changed, and importantly, migrated the details from the original version of the story, including migration of details that appeared relatively early in the original story to later stages. Participants made alterations that ultimately transformed the story to fit their own cultural schema, a process Bartlett (1977) called "rationalization." Relevant to present considerations, while many clusters of details, what we call local clusters, from the original story appeared in recall, their relative positioning in the story often changed, suggesting shifts made to fit the narrative into the individual's preexisting cognitive tendencies. Similarly, deletions of certain details changed the positioning of many of the recalled elements in the story relative to the original positioning. Bartlett argued that the process of adding, deleting, and reordering details in memory report gives rise to schemas where people distill their memories into a coherent representation such that the holistically recalled version aligns with their existing cognitive structures and subject to sociocultural factors. Beyond Bartlett's (1977) examples of story recall, there has been a continued focus on the study of memory narrative development in adults (Conway et al., 1991; Conway & Rubin, 1993; Neisser, 1998) and across early development (e.g., J. M. Mandler & Johnson, 1977), underscoring the theoretical importance of understanding how past experiences become organized in memory.

In brief, a holistic analysis of both recalled and forgotten details is essential for understanding how an integrated narrative of the original experience emerges, and the extent to which the recalled version differs from the original. As Bartlett's (1977) examples suggest, this comparison is important for understanding the way shifts in the interrelationships among the recalled and forgotten details change the memory narrative relative to the original. As noted, we refer to such holistic quantitative analysis as *global retrieval organization*.

Social Influences on Memory

Beyond understanding global retrieval organization that emerges through repeated individual recall, it is just as important to understand this process in social recall. The importance Bartlett (1977) gave to social influences on recall is captured in the very title of his book, *Remembering: A Study in Experimental and Social Psychology*, emphasizing both experimental and social psychology. Bartlett (1977) examined social influence in a chain of information transmission, with one person's recall serving as study information for the next person, and so on. This social process substantially changed the memory narrative. With this historic antecedent in mind, we focused on how recalling with others influences global retrieval organization.

There has been a resurgence of interest in the social influences on memory in cognitive psychological research in recent years. Unlike Bartlett's (1977) approach, these studies typically use laboratory methodologies with study and test of materials consisting of words and pictures to facilitate statistical assessments. We focus on a widely used experimental approach that we describe in a later section, known as the collaborative memory paradigm, to study social influences on memory (Basden et al., 1997; Weldon & Bellinger, 1997). This body of work shows that recalling with others, known as collaborative recall, changes the contents of memory. For example, following collaborative recall, when former collaborators once again recall the studied information now working alone, contents of their postcollaborative recall show changes compared to those who never collaborated (e.g., Blumen & Rajaram, 2008; Choi et al., 2014; Weldon & Bellinger, 1997; Wissman & Rawson, 2015). Beyond changing what people remember, research, although in infancy, shows that collaborative recall also changes the way former collaborators organize the contents in their individual recall (A. R. Congleton & Rajaram, 2014).

Furthermore, former collaborators also develop collective memory—their recall shows convergence in what is remembered and forgotten, producing overlap in the contents of their recall (A. R. Congleton & Rajaram, 2014; Hirst & Manier, 2008; Wertsch & Roediger, 2008). The notion of collective memory has had a long history of interest in the humanities and social sciences, with anthropologists, historians, and sociologists having written extensively about the social and political pressures that shape the collective memory of groups, communities, and nations (e.g., Assmann & Czaplicka, 1995; Halbwachs, 1980; Roediger & Wertsch, 2022). In psychological science, empirical inquiry into collective memory is just coming out of its infancy (see Barnier & Sutton, 2008). Across disciplines, definitions of collective memory vary somewhat, but the core ideas overlap. In disciplines outside cognition, collective memory is typically associated with group identity (Hirst & Manier, 2008; Wertsch & Roediger, 2008), whereas in the cognitive–experimental approach we take here, collective memory is operationalized as the amount of overlapping content in the recall of members who belonged to a collaborative group (A. R. Congleton & Rajaram, 2014; Cuc et al., 2006; Stone et al., 2010; also see Umanath & Abel, 2022, for a national conception of "group"). This body of research shows that former group members report more of the same studied information when recalling alone later, compared to those who never collaborated (e.g., Barber et al., 2012; Choi et al., 2014, 2017; A. R. Congleton & Rajaram, 2014; Cuc et al., 2006; Greeley & Rajaram, 2023; Harris et al., 2008; Pepe et al., 2021; Stone et al., 2010; Yamashiro & Hirst, 2014). In other words, recalling with others changes the content of individual memory and produces an overlap in the contents of memories that former group members report afterward.

Central to our interests here, beyond giving rise to collective memory content, we investigate the influence of collaborative recall on giving rise to collective memory organization, that is, similarity in the way former collaborators organize their later individual recall. This research is still in its early stages and thus motivated the focus of our study. Here, people leave the social context with a synchronized representation of the past, both with respect to what they recall and how they reconstruct the original experience. Ultimately, advances made in our ability to assess such global narrative construction would provide insights into how groups, families, communities, and nations create converging or diverging accounts of the past.

Collaborative Recall of Emotional Information

Scientific understanding of how collective memory organization emerges is not only limited, but it is also restricted to the recall of emotionally neutral information. Yet, emerging research increasingly suggests the pivotal role that emotional information may play both in collaborative recall and in organizing memory structures. In the collaborative memory domain, research reveals that the memory advantage observed for the recall of emotional compared to neutral information in individual memory (Bookbinder & Brainerd, 2017; B. Wang et al., 2021; Xie & Zhang, 2017) is similarly evident for content in collaborative memory contexts (Barber et al., 2015; Bärthel et al., 2017; Choi et al., 2017; Kensinger et al., 2016; Maswood et al., 2019; Wessel et al., 2015; Yaron-Antar & Nachson, 2006). There is also a tendency for greater collective remembering of negative content and for greater collective forgetting of positive and neutral content in young adults both during and following collaboration (Choi et al., 2017). These findings—along with those noted earlier about greater sharing of emotional compared to neutral information (Berger, 2011; Berger & Milkman, 2012; Heath, 1996; Luminet et al., 2000) and the effects of sharing on regulating negative affect and strengthening social bonds (Fivush & Wang, 2005; Rimé, 2009; Q. Wang & Fivush, 2005)—raise questions about the depth of the changes that can occur in memory for emotional information. That is, can emotionally valenced information also produce greater synchrony in the ways memories become organized for group members, producing greater collective memory organization, compared to neutral information.

Beyond memory content, with respect to organization effects, it is an open question whether emotional valence would modulate memory consequences. On the one hand, emotional valence may not serve as an organizational cue (S. K. Manning & Julian, 1975), or valence by itself may not override other types of grouping (e.g., taxonomic categories) to influence individual memory (Choi et al., 2013). If this is the case, there may not be a differential effect of valence on retrieval organization, be it during or following collaboration. This lack of impact would be consistent with related findings indicating similar disruptive effects of collaborative recall on a range of to-be-recalled information (e.g., equivalent collaborative inhibition across valence and categorized/unrelated word lists; Choi et al., 2017; Marion & Thorley, 2016).

On the other hand, several studies have found that in individual recall participants cluster responses by valence and arousal, and that emotional material is more likely to be retrieved early on during a recall phase (Barber et al., 2017; Long et al., 2015; Siddiqui & Unsworth, 2011). These patterns suggest that emotional valence could play a critical role in the emergence of postcollaborative, collective retrieval organization. Relatedly, context models of retrieval have emphasized the role of gradually shifting contexts in guiding the content that is retrieved with emotion serving as one such context (Howard & Kahana, 2002; Polyn et al., 2009; Talmi et al., 2019).

Some of the most convincing evidence for the role of emotion in organizing memory structures comes from neuroscientific research. There is extensive evidence that changes in emotional state can affect the way that memories are formed and organized (Bierbrauer et al., 2021; Clewett & McClay, 2024; McClay et al., 2023; Tambini et al., 2017). Even at the item level, when stimuli become imbued with emotion, this can change how memories of those stimuli are represented. For instance, when stimuli such as faces and houses become imbued with emotion, through fear conditioning, the neural patterning shifts from representing categorical information (faces, houses) to representing emotional information (conditioned, unconditioned; Visser et al., 2011). The extent to which this shift occurs can predict long-term retention of the conditioned association (Visser et al., 2013). Moreover, emotional reactions such as stress can reshape the structure of neural representations of objects central to the stressful event, rendering them more akin to one another while distinguishing them from more distant objects. This heightened similarity correlates with improved memory retention (Bierbrauer et al., 2021).

These possibilities set up contrasting predictions for whether the formation of global collective memory organization generalizes similarly as a function of the emotional valence of material. Our study design afforded a test of these possibilities.

Collaborative Recall and Postcollaborative Consequences on Individual and Collective Memory

The collaborative memory paradigm we implement to investigate the theoretical questions outlined above has been widely used in cognitive–experimental studies to uncover cognitive mechanisms that shape group recall and postcollaborative memory (Basden et al., 1997; Rajaram & Pereira-Pasarin, 2010; Weldon & Bellinger, 1997). In a typical experiment, participants first work alone to study a set of to-be-remembered information such as words, pictures, or narratives. Later, participants work either individually or in groups to recall the studied information. The groups are generally composed of strangers (to control for the unsystematic influence of occasional relationship history) and typically include three members (Marion & Thorley, 2016; Weldon & Bellinger, 1997). Participants also often complete a second recall, working individually, allowing assessment of downstream impact of collaboration on individual recall. Collaborative memory research is not restricted to this procedure, as a growing literature has explored a range of study test materials and procedures, group composition, group size, and other variables (see Bietti & Sutton, 2015; Rajaram et al., 2024, for reviews).

When people engage in collaborate recall, several mechanisms come into play (Rajaram & Pereira-Pasarin, 2010). These mechanisms not only influence group recall but also shape postcollaborative individual memory and emergence of collective memory. Most counterintuitive among these mechanisms are retrieval disruption and retrieval inhibition. Retrieval disruption occurs when input from others disrupts people's ability to use their own retrieval strategy for recalling studied information, thereby reducing each member's output (Basden et al., 1997). This disruption is implicated in the surprising but well-replicated reduction in group recall known as collaborative inhibition (Weldon & Bellinger, 1997). Here, collaborative groups recall less than nominal groups, or groups in name only, that consist of equal size as collaborative groups (e.g., triads), and the individual recall of these participants is pooled in a nonredundant manner (Marion & Thorley, 2016; Weldon & Bellinger, 1997). This disruption can also have downstream effects, with disruption during collaboration being associated with an increase in both collective memory content and as well as in local-level, collective memory organization (A. R. Congleton & Rajaram, 2014). Furthermore, retrieval inhibition also occurs during collaborative recall where others' input inhibits the recall of some items, making them functionally inaccessible and contributing to forgetting in postcollaborative memory (Barber et al., 2015; Cuc et al., 2007). These consequences of collaborative remembering in producing impairment and forgetting underscore the importance of considering not only the remembered items but also the forgotten items when computing how people reorganize memories after working in groups, something that current measures do not accomplish.

Collaboration also improves later individual memory, and this consequence also has direct implications for integrating these additions in memory organization. Collaboration can augment memories, because a group member can be reexposed to otherwise forgotten items that another group member recalled (Blumen & Rajaram, 2008), or because one group member's recalled item can cross-cue and promote another member to remember additional items (A. R. Congleton & Rajaram, 2014; Takahashi & Saito, 2004). Group members also correct each other's recall when collaboration follows a free-flowing procedure, resulting in error pruning and increasing memory accuracy (Pereira-Pasarin & Rajaram, 2011; Ross et al., 2004). Last, group members can bring false items into collaboration and "contaminate" others' memories through social contagion (Basden et al., 2002; Choi et al., 2017; Maswood & Rajaram, 2018; Peker & Tekcan, 2009; Thorley & Dewhurst, 2007, 2009). These processes can increment the items reported in postcollaborative memory, effecting a change in the way information is organized in later individual recall.

Together, these processes associated with collaborative recall—disruption, inhibition, reexposure, cross-cuing, error pruning, and social memory contagion—shape postcollaborative memories, changing individual memory and increasing the similarity in what former group members recall or fail to report even after they no longer work in groups (Pereira-Pasarin & Rajaram, 2011; Rajaram, 2024). These changes in postcollaborative memory motivate the assessment of the depth of collaboration consequences by asking whether it is not only the content but also the organization of memory that changes following collaborative recall. We investigated the cascading effects of these collaborative processes, considering both the recalled and forgotten studied items, on the global organization of individual and collective memory.

Social Influences on Memory and Retrieval Organization

Drawing from the memory literature on individuals, the few studies that have focused on changes in the organization of recall following collaboration—both at the individual and collective levels—have also examined these possibilities at local levels (Choi et al., 2014; A. R. Congleton & Rajaram, 2014; see Greeley & Rajaram, 2023, for a recent review). For postcollaborative changes in individual memory organization, studies have reported either the pair frequency measure or the adjusted ratio of clustering measure we described earlier. Just as critically, the available approach for measuring collective memory organization, the *Shared Organization Metric Analysis* (A. R. Congleton & Rajaram, 2014) is also a local-level measure. Shared Organization Metric Analysis uses a novel application of the pair frequency measure (Sternberg & Tulving, 1977) to examine the adjacent, item-to-item transitions shared among former collaborators, focusing on pairwise clusters of remembered items without considering the forgotten items. Yet, to understand how social remembering changes memory narratives, we need to assess not only the way recalling with others changes the details that are remembered and the small clusters in which remembered details are organized, but also the interrelationships in the positioning of all the details, and the impact of forgotten information on these interrelationships. As a holistic analysis of this nature is at the crux of understanding social influences on memory narratives, we investigated the nature of global retrieval organization.

In the present study, we examine the impact of collaborative recall on retrieval organization at three levels—one, how each group member organizes their individual recall after the collaboration; two, the extent to which this memory organization becomes aligned across former group members; and three, how this alignment is greater for emotional than neutral content, thus giving rise to collective memory organization. As noted, the influence of emotion is important to investigate, because evidence on collective memory organization is not only limited to local changes in retrieval organization but also has been focused exclusively on emotionally neutral information (e.g., A. R. Congleton & Rajaram, 2014; Greeley et al., 2024). This gap is surprising given the importance of emotional valence in modulating the magnitude of individual memory (e.g., Hamann, 2001; Phelps, 2004; Szőllősi & Racsmány, 2020; Talmi et al., 2019) and the emerging evidence in collaborative memory addressing its impact on the contents of memory (Barber et al., 2015; Bärthel et al., 2017; Choi et al., 2017; Kensinger et al., 2016; Maswood et al., 2019; Wessel et al., 2015; Yaron-Antar & Nachson, 2006).

To address these questions, we introduce an index of global changes in memory organization—achieved via RSA (Kriegeskorte et al., 2008)—which enabled us to advance the current understanding of retrieval organization that has been limited to local-level changes and to only the remembered items. Central to this novel approach, we implemented RSA to holistically assess memory organization. To do this, we assessed the *relationships* among items at a global level, including studied items that are reported, henceforth called "remembered," as well as unreported items, henceforth called "forgotten," in the experimental context. This global measure allows a holistic assessment of reported memories, thus providing a path to understand how people develop integrated memory narratives.

Representational Similarity Analysis: Application to Memory Structure

To pursue our aim of computing changes in memory organization at the global level, we implemented and expanded the quantitative framework of RSA originally used to assess the organization of information representation in the brain (Kriegeskorte et al., 2008). RSA has been since applied to a wide range of topics involving information organization (Brooks & Freeman, 2018; Freund et al., 2021; Parkinson et al., 2017; Reagh & Ranganath, 2023). One can use RSA to gain insight into the organization of the mental (or neural) representation of presented stimuli. What matters in such an analysis is the *relative distances in the representational space* (e.g., if the distance between x and y is shorter than the distance between x and z, that means x and y are more closely related than x and z in the person's representation), an idea referred to as the *second-order isomorphism* (Kriegeskorte et al., 2008; Shepard & Chipman, 1970).

A key step in the use of RSA is the construction of a representational dissimilarity matrix (RDM), a square and symmetric matrix consisting of the pairwise dissimilarities between all combinations of items indexed by the row and column, similar to a pairwise correlation matrix. The (di)similarity can be measured using a variety of metrics. Specifically, given a fixed event order on both x and y axes, each cell in an RDM is the dissimilarity (e.g., 1 − correlation when the similarity is measured as correlation) between the events indexed by x and y. RDMs thus consist of $n(n - 1)/2$ pieces of unique information, with n being the number of events. Thus, RDMs carry information about how a set of representations are organized and, critically to our analyses, can be compared within-subjects across time or between-subjects. Over and above capturing representational similarity, the RSA framework provides a foundation for additional applications (Kriegeskorte & Kievit, 2013). For example, given a set of items, it is possible to explore the dissimilarity between items on varying dimensions (Chikazoe et al., 2014; Jin et al., 2015); focusing on certain features (e.g., recall output order) provides a nuanced look at representation commonality.

Our novel application of RSA applies the same logic as above to *recall outputs* produced by individuals and collaborative groups. Given a list of to-be-remembered items, this conceptualization of memory organization retains information about content—which items are reported in recall (i.e., remembered items) and which items are not reported (i.e., forgotten in the experimental context). This conceptualization also retains information about the placement of each item in recall in relation to all other items, providing novel interpretations of memory organization that include both recalled and forgotten items. The first step in our RSA analysis involves a coding step of the recall order of each recall and each participant; specifically, a fixed stimulus list can be coded with respect to an individual or group recall by noting each item's recall position. This recall order vector is then used to construct a matrix (an RDM) by computing the pairwise distance in the recall order between items. The result is a square and symmetric dissimilarity matrix representing the recall structure. Vectorizing this RDM retains all possible unique distance information among items, which reflects the global memory organization. For further details and concrete examples, see the segment Representational Similarity in Free Recall in the Method section.

This application of RSA builds on a long history of research on memory organization in individual recall, which defines memory structure in terms of retrieval organization and dynamics (Kahana et al., 2008; G. Mandler, 1967; Puff, 1979; Tulving, 1962). Critically, this body of work has focused on organization at local levels, concentrating on item-to-item transitions. Here, we extend this definition—memory organization in an RSA framework considers available information regarding the relations between all events, recalled and forgotten.

This more holistic framing provides a perspective that is particularly well suited for indexing both within-subject changes in organization and between-subject similarity. In the context of the present study, this allowed us to quantify the impact of collaborative recall on retrieval organization in a new light, by comparing both within-subject changes and between-subject similarities in memory organization. Specifically, the within-subject changes allowed us to understand changes in individual memory organization and the between-subject similarities allowed us to understand collective memory organization following collaborative recall.

The Present Study

In the present study, we advance the theoretical goal of assessing global changes in memory organization in the context of social remembering. To assess such holistic changes in memory organization, that goes beyond an analysis of collective memory content and local-level assessments of retrieval organization, we used RSA. With this approach, we make three advances—One, we compute how each group member organizes their individual recall after the collaboration, two, we examine the extent to which this memory organization becomes aligned across former group members to create collective memory organization, and three, we assess whether this alignment is greater for emotional than neutral content.

We situate these advances in the context of replicating in a large-scale behavioral experiment (Choi, 2015, Experiment 1) two phenomena of primary interest here, namely the emergence of collective memory for content following collaboration (e.g., Blumen et al., 2014; Choi et al., 2014; A. R. Congleton & Rajaram, 2014), and better memory for emotional material over neutral materials (Hamann, 2001; Williams et al., 2022).

The behavioral data consisted of three conditions and a sequential recall procedure (e.g., Blumen & Rajaram, 2008), and the study materials consisted of positive, negative, and neutral picture–word pairs (e.g., Choi et al., 2013). We chose this unpublished experiment (Choi, 2015, Experiment 1), because it was perfectly suited for applying our novel RSA, and for expanding the assessment of collective memory for not only neutral but also emotional study materials that addressed a key aim of our study. The three conditions consisted of (a) a control condition in which participants sequentially completed three individual free recalls (individual–individual–individual [III]), (b) a repeated collaborative condition in which participants sequentially completed two collaborative recalls before completing an individual recall (collaborative–collaborative–individual [CCI]), and (c) a single collaborative condition in which participants only collaborated at Recall 2 (individual–collaborative–individual [ICI]; see Figure 1).

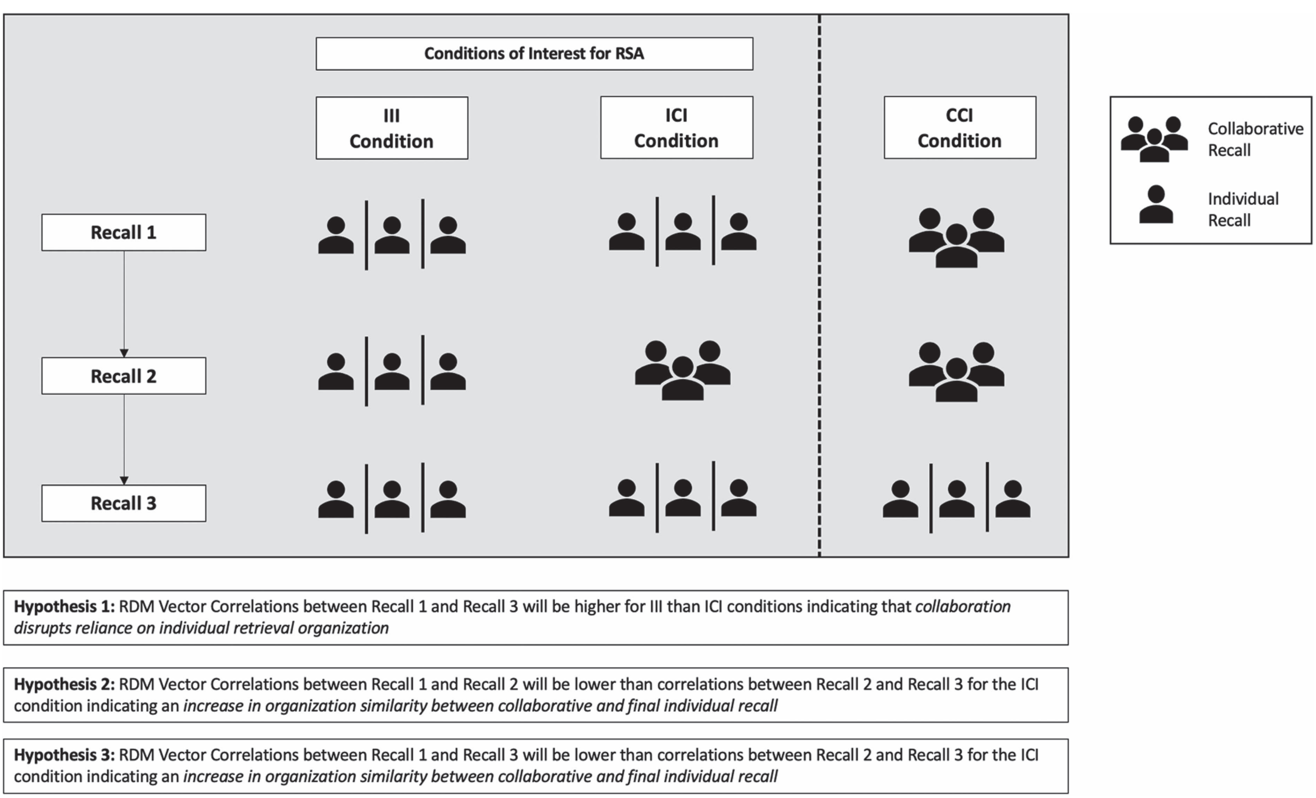
The first two conditions, III and CCI, afforded a test and replication of the emotional memory advantage in recall (Dolcos & Cabeza, 2002; Le Bigot et al., 2018; Talmi et al., 2019). The CCI condition includes collaboration in the first recall whereas the recall sequences in other two conditions (ICI and III) begin with individual recall. As such, the CCI condition makes possible measurement of collaborative recall, where prior individual recall does not influence collaborative recall. This provides an assessment of whether an emotional memory advantage occurs in initial collaborative recall in CCI without influence from prior individual recall, unlike in ICI's collaborative recall. The CCI condition also affords us an uncontaminated assessment of collection memory content across collaborative and individual recall reported in past studies for neutral materials (e.g., Blumen et al., 2014; Choi et al., 2014; A. R. Congleton & Rajaram, 2014).

Further, the availability of both the ICI and CCI conditions in the experimental design allowed for a test of collective memory content across the two collaboration arrangements, namely, ICI and CCI. As noted, the ICI sequence cannot provide an uncontaminated measure of collaboration influences on collective memory content, because individual recall occurs first in the sequence. By directly comparing ICI and CCI, we could compare collective memory content in the ICI condition against the CCI condition (where collaboration influences were unaffected by prior individual recall.) As such, this comparison afforded a particularly useful foundation for testing the key goals of the study, namely, the global and collective memory organization using the ICI conditions. Together, this experimental design with the ICI, CCI, and III recall conditions provided the backdrop for the novel questions tested in the present study with the ICI condition.

With respect to our novel application of RSA, the III and ICI conditions were of interest and made several key comparisons possible. First, the III condition serves as a baseline/control, with which the organization that emerges in the ICI condition can be compared. Likewise, within the ICI condition, as described below, we were able to assess within-subject changes to retrieval organization at a global level, indexing how collaborative recall reshapes both individual and collective memory organization. As we elaborate later, we tested these changes for recall of neutral and emotional information by quantifying—(a) the impact of collaboration on individual retrieval strategies; (b) the impact of collaboration on the convergence of retrieval strategies, and (c) the impact of collaboration on the shift from an individual to a group strategy.

Figure 1

Experimental Design and Key Hypotheses Regarding Memory Organization



Note. Experimental design and key organization-based hypotheses. See Figure 2 for more detail on the steps involved in our RDM/RSA analyses. The ICI and III conditions were of primary interest for the RSA analyses. The CCI condition served as a check for the behavioral findings for collective memory content. III = individual–individual–individual; ICI = individual–collaborative–individual; CCI = collaborative–collaborative–individual; RSA = representational similarity analysis; RDM = representational dissimilarity matrix.

Hypotheses

For our RSA analyses measuring the global memory organization, we hypothesized that: (1) With respect to the impact that collaboration has on individual retrieval strategies—if group recall disrupted individual memory organization, then the similarity in memory organization between the first (III-Recall 1 and ICI-Recall 1) and third (III-Recall 3 and ICI-Recall 3) recalls would be *lower* in the ICI condition than in the III condition. Thus, we expect lower similarity in memory organization between the first and third recalls if collaboration intervened between the two; (2) with respect to the impact collaboration has on the convergence of memory organization—if group recall has a synchronizing effect on retrieval strategies, then the memory organization similarity between the first, individual recall (ICI-Recall 1) and the second, group recall (ICI-Recall 2) would be *less* than the similarity between the second, group recall (ICI-Recall 2) and the third, individual recall (ICI-Recall 3); (3) relatedly—with respect to the impact collaboration has on shifting individual retrieval strategies—the similarity in the memory organization between the first, individual recall (ICI-Recall 1) and the third, individual recall (ICI-Recall 3) would possibly be even lower than that between the second, collaborative recall (ICI-Recall 2) and the third, individual recall (ICI-Recall 3); (4) finally, for the effects of emotional saliency, if clustering-by-valence prevails (Long et al., 2015; Siddiqui & Unsworth, 2011), then the effects of group recall on memory organization would be more pronounced for emotionally charged items than for neutral items. However, equivalent magnitudes of the collaborative inhibition effect across different types of materials, including valence in past studies (Barber et al., 2017; Choi et al., 2017; Marion & Thorley, 2016; also see Choi et al., 2013; S. K. Manning & Julian, 1975) suggest similar outcomes for the emotional and neutral items in our study.

We tested these hypotheses in the context of assessing two well-replicated patterns: We hypothesized (1) that collective memory for content would be greater among former collaborative group members than among nominal group members who never collaborated; (2) a replication of higher levels of recall emotional material than neutral material, aligning with the prior literature (Dolcos et al., 2004). With respect to the content of collective memory as a function of valence, the limited evidence suggests a tendency for people to collectively remember negative content more than positive and neutral content (Choi et al., 2017).

Method

Participants and Design

One hundred forty-four Stony Brook University students volunteered as participants in this study and received course credit for their time. The gender distribution reported in our sample was 48.23% female participants and 51.77% male participants. The mean age was 19.9 years ($SD = 3.35$, min = 18, max = 49) and the race/ethnicity distribution was as follows: 36.88% Asian, 36.17% White, 6.38% African American, and 6.38% mixed (with 14.18% indicating “Other”).[1] This study was approved by the institutional review board at Stony Brook University.

The experiment consisted of a 3 × 3 mixed design with retrieval sequence (III, CCI, and ICI) as a between-subjects factor and emotional valence (neutral, positive, and negative) as a within-subject factor. There were 48 participants per condition (yielding 16 triads per condition, composed of strangers). We examined power for the measure of collective memory *content* using previous studies as the basis. Several studies have observed large effects between conditions that are comparable to the ones reported here (i.e., that assess collective memory following one or more collaborative recall phases relative to nominal groups; Blumen et al., 2014; A. R. Congleton & Rajaram, 2014). These effects (Cohen’s *d*) have ranged from 1.24 to 2.75, with the most analogous effect being 1.77. To detect this latter effect with 80% power in a two-tailed *t* test with a .05 significance level, seven groups per condition would be needed. Given the changes in the nature and number of study materials and variations in procedure, to provide a cushion for detecting a comparatively smaller effect ($d = 1$) in the context of postcollaborative collective memory with the same testing assumptions (80% power, two-tailed, .05 significance), 17 groups per condition would be required. Finally, given the novel nature of our RSA analyses of postcollaborative memory organization, there are no existing effect sizes on which to base a reasonable estimate. In this case, we supplement our parametric approach with nonparametric methods that characterize the relationships of interest without relying solely on classic hypothesis tests and *p* values. Moreover, using nonparametric approach to test the relatedness of two RDMs is a common practice in research using RSA as the data used to test the relationships between RDMs in the RSA analysis are not independent. Thus, using nonparametric methods is a valid approach for significance testing in RSA (Kriegeskorte et al., 2008; Nili et al., 2014).

Materials

Study stimuli consisted of a total of 144 items from 18 categories, with eight items per category. There were six categories per valence (negative, positive, neutral), resulting in 48 items per valence. Eight study lists were created for counterbalancing purposes, and each study list consisted of five to-be-studied and three not-to-be-studied items from each category, resulting in 30 studied and 18 nonstudied items associated with each valence for a given participant (90 picture/word study pairs total, per participant). This item distribution across studied–nonstudied status was developed for a series of studies for author Choi’s dissertation, and as the nonstudied status of items is not relevant to the design of the present study, it will not be discussed further. Relevant to present purposes, this distribution preserved a counterbalanced presentation of all items for study.

Procedure

The procedure started with a study phase, where each trial began with a fixation (1 s), followed by a picture–word pair display (5 s). Trials were randomly intermixed within the list with respect to valence. Participants worked alone to view these stimuli while providing arousal ratings based on a scale from 1 (*very low*) to 5 (*very high*). This encoding task yields similar effects on memory performance as other conceptual-based encoding tasks for identical sets of stimuli (Choi et al., 2013), making it suitable for use. Participants knew about an upcoming memory test, but the nature of the test was unspecified, and they were also not informed whether

[1] These demographics are based on 141 participants out of the full sample (144). Information on three participants in the CCI condition was lost due to a technical error.

there would collaboration or no collaboration during the memory test. A distractor phase followed for 8 min where participants played solitaire on the computer, again working alone.

Next, participants completed three consecutive free-recall tasks. Participants in the III condition completed all three recall sessions individually. Participants in the CCI condition performed two recall attempts in three-person groups, working with the partners each time, before completing a final individual recall. Participants in the ICI condition completed the first recall individually, the second recall collaboratively in three-person groups, and the last recall individually again. Collaborative recall sessions in the CCI and ICI conditions were always free flowing such that participants could contribute responses at any point (Choi et al., 2014; Weldon & Bellinger, 1997). Regardless of condition, all participants received 9 min per recall, with a 2-min break between each recall. The entire procedure lasted approximately 1 hr.

Representational Similarity in Free Recall

In the present study, we leverage RSA and other analytical tools to assess the construction and alignment of *global* memory organization in data obtained through an experimental behavioral paradigm just described for testing collaborative remembering. Figure 2 shows the RSA analysis procedure along with details on our comparisons of interest. The first step in our RSA analysis involves a coding step of the recall order of each recall and each participant; specifically, a fixed stimulus list (e.g., here 144 items that were organized by valence) can be coded with respect to an individual or group recall by noting each item's recall position. For example, if the item "wedding" was the fourth recalled item for a particular participant in a particular recall (e.g., Recall 1), then the number "4" was assigned to this item. Given the purposes of our analyses, if an item was not recalled, we decided to code with a very larger number namely 999 (i.e., a much larger number than the length of the stimuli list of 144 items). This yields a recall order vector of the length of the stimulus list, coded for the recall (and forgotten) order position, which is then used to construct a matrix (an RDM). In the present study, RDMs are formed by computing the absolute distance between all possible pairs of items. For example, the distance between the items recalled in Output Position 5 and Output Position 20 would be 15, whereas the distance between the item recalled in Output Position 5 and a forgotten item (coded as 999) would be 994. The result is a square dissimilarity matrix that is symmetric with 0 representing the distance between the item and itself. Vectorizing either the upper or lower triangle of such an RDM retains all possible unique distance information which reflects the global memory organization. These vectorized RDMs can then be related to each other (via Spearman's rank correlations). In essence, for every recall (by every participant or by collaborating group), we end up having one column containing all the pairwise distance information between the stimuli list; these columns can be associated and compared (see Figure 2).

Transparency and Openness

The word labels used for study and recall tasks, processed data, and code are available at https://osf.io/kmrz5/?view_only=710fa765c6584af0a43e1230497e845f. The images shown during the study task were originally from Hemera Clip Art, which is no longer in business, though the images are still available at https://clipart.com/ via subscription. The images are available from the authors upon request, provided the requester confirms their subscription to https://clipart.com/. This study was not preregistered.

Results

We present the results in three sections. First, to situate the RSA analyses for assessing global memory organization, we report the behavioral replications for the emergence of collective memory content and better recall for emotional than neutral information.[2] Second, following the reports of these behavioral findings, we present the RSA analyses that are at the heart of our aims. These analyses probe the extent to which collaboration alters the global, individual retrieval strategies and aligns the global organization of collective memory for neutral and emotional information. Finally, we present multidimensional scaling (MDS) to visualize the memory organization changes in the ICI condition, where changes in the individual memory organization and its consequences for emergence of collective memory organization can be examined.

Where relevant, we append recall session information to condition codes to highlight what is being compared (e.g., III-Recall 1) and explicitly state the level of analysis (i.e., individual or group recall). When reporting our novel RSA application, only the III and ICI conditions are of interest. We are specifically interested in the three comparisons that we described in the Hypotheses section (see Figures 1 and 2): (a) III-Recall 1 to III-Recall 3 versus ICI-Recall 1 to ICI-Recall 3, (b) ICI-Recall 1 to ICI-Recall 2 (group) versus ICI-Recall 2 (group) to ICI-Recall 3, (c) ICI-Recall 1 to ICI-Recall 3 versus ICI-Recall 2 (group) to ICI-Recall 3.

With respect to collective memory content, all comparisons focused on Recall 3 and, by necessity, involved assessing memory at the group level (i.e., the number of items of a given emotion [positive, negative, neutral] recalled by all members of a group; Choi et al., 2017; A. R. Congleton & Rajaram, 2014). For effects of emotion in the study materials, all assessments focused on Recall 1. We assessed free recall performance as a function of negative, positive, or neutral materials within each condition (i.e., III-Recall 1 and ICI-Recall 1 at the level of individuals; CCI-Recall 1, at the level of collaborative groups).

Behavioral Findings: Replications

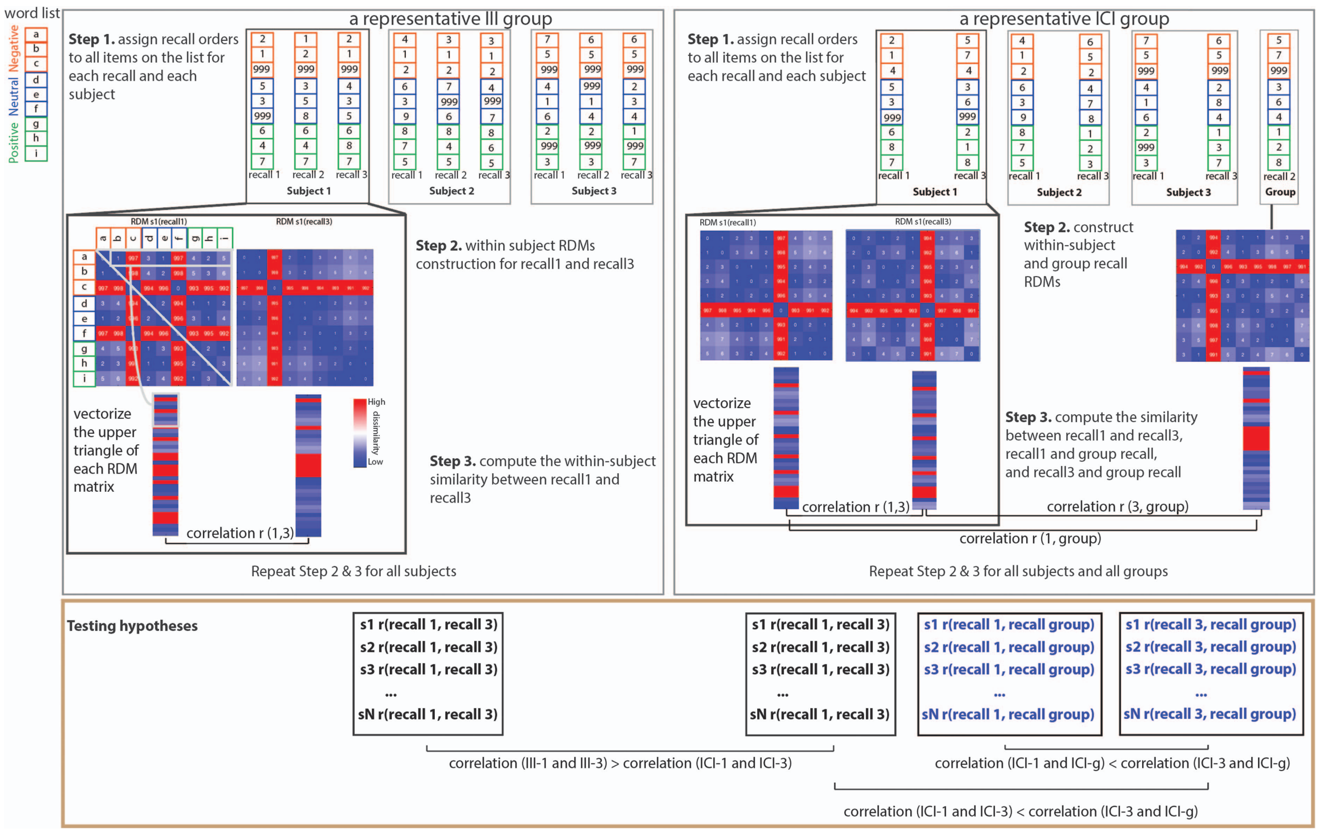
Collective Memory Content

In line with expectations, collective memory content, that is, the studied items recalled by all three participants who were earlier in a group, at Recall 3 was greater in both the ICI and CCI conditions compared to the III condition, $F(1, 30) = 32.60$, $p < .001$, $\eta^2 = .521$; $F(1, 30) = 32.19$, $p < .001$, $\eta^2 = .518$, respectively. Thus, any collaboration contributed to the emergence of collective memory. This finding is particularly useful given that the collaborative recall of interest for the RSA analyses reported below came from the ICI condition where individual recall preceded collaborative recall. Equivalent levels of collective memory content between the ICI condition and the CCI condition (where collaboration was not

[2] We include other results pertaining to recall levels in the Supplemental Materials, as they were not a focus in the present study.

Figure 2

Steps Involved in Applying RSA to Free Recall Data



Note. Here, we provide a schematic of the RSA analysis procedure using hypothetical data. Small letters a–i represent specific items in the memory task. Individual subjects are indexed by s1, s2, … sN. III and ICI represent individual–individual–individual and individual–collaborative–individual conditions. In the recall order coding, forgotten items were treated as taking infinite amount of time to recall, and was thus coded as 999, a number much larger than the total number of items on the list (which was 144 items). III-1 and III-3 indicates the Recall 1 and the Recall 3 under the III condition; ICI-1, ICI-g, and ICI-3 indicate Recall 1, Recall 2 (collaborative), and Recall 3 under the ICI condition. Colors in the RDM and vectors indicate the pairwise distance from low (blue) to high (red). Here, the correlation used is Spearman's rank correlation to take into consideration the potential nonlinearity. RSA = representational similarity analysis; RDM = representational dissimilarity matrix; r = correlation.

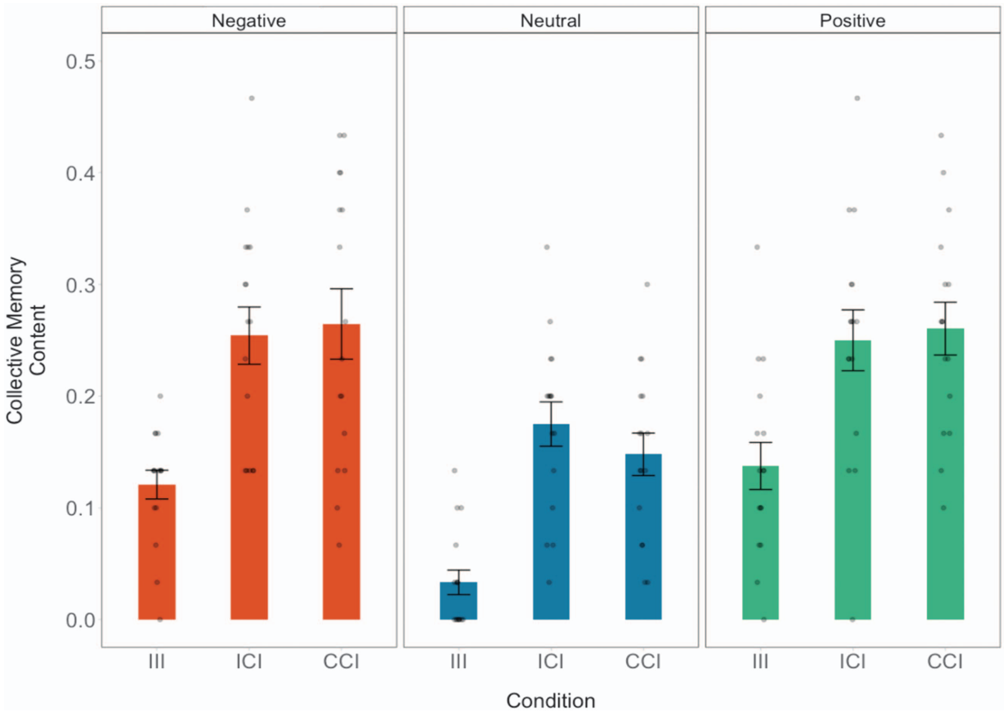
affected by prior individual recall) show that the data from the present ICI condition were well suited for the RSA analyses of collective memory structure. There was not an interaction between collaboration condition and emotional valence, indicating that emotional valence did not moderate the size of the collective memory content across the three recall conditions, $F(4, 90) = 0.50$, $p = .7361$, partial $\eta^2 = .019$.

Overall, the collective memory scores for emotional items (both negative and positive) were consistently higher than the scores for neutral items, regardless of retrieval condition. In the baseline III condition, the collective memory scores for positive ($M = 0.14$, $SD = 0.08$) and negative ($M = 0.12$, $SD = 0.05$) items were higher than for the neutral ($M = 0.03$, $SD = 0.04$) items, with no difference between positive and negative items. The same patterns were observed in both the ICI and the CCI conditions. In the ICI condition, collective memory scores for positive ($M = 0.25$, $SD = 0.11$) and negative ($M = 0.25$, $SD = 0.10$) items were higher than for the neutral ($M = 0.18$, $SD = 0.08$) items, with no difference between positive and negative items. Similarly, in the CCI condition, collective memory scores for positive ($M = 0.26$, $SD = 0.09$) and negative ($M = 0.26$, $SD = 0.13$) items were higher than for the neutral ($M = 0.14$, $SD = 0.08$) items, with no difference between positive and negative items. These trends are evident in Figure 3 (distributions and means) and statistical tests are available in Table 1.

These results support the expectation that collaborative recall would increase the alignment in the content of memory (i.e., lead to greater collective remembering). With respect to valence, collective memory for emotional information was greater than for neutral information and it was equivalent for negative versus positive information. These 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-Recall 3) produced higher overlapping memories for emotional information. Together, these findings show that the overall recall and the levels of collective memory were higher when participants collaborated compared to no collaboration, and for emotional items compared to neutral items; further, these levels did not vary as a function of the retrieval sequences. These patterns prepared the grounds for examining global memory organization in the retrieval sequence condition of ICI, as we describe next.

Figure 3

Recall 3: Collective Memory Content as a Function of Valence Across Conditions



Note. Each bar represents 16 triads consisting of a sample of 48 participants, and each dot represents one triad. Collective recollection is the proportion of items of a given valence recalled by all members of a group. Distributions represent underlying data. Bars are at mean, and error bars are standard errors. Collaborative recall contributes to the emergence of collective memory—irrespective of valence. Likewise, emotionally valenced material was collectively recalled better than neutral material (see Table 1 for specific comparisons). III = individual–individual–individual; ICI = individual–collaborative–individual; CCI = collaborative–collaborative–individual.

Recall of Negative, Positive, and Neutral Information

Next, we present the behavioral findings concerning standard effects in recall of emotional information. Across the board, we observed better recall of negative and positive information compared to neutral information. Focusing first on individual recall, repeated measure analyses of variance revealed significant effects of emotion in both the III and ICI conditions; III-Recall 1 (individual recall), $F(2, 94) = 55.40$, $p < .001$, $\eta^2 = .51$; ICI-Recall 1 (individual recall), $F(2, 94) = 26.96$, $p < .001$, $\eta^2 = .34$. These patterns hold when assessing group recall outputs; CCI-Recall 1 (collaborative recall), $F(2, 30) = 16.42$, $p < .001$, $\eta^2 = .49$.

Subsequent *t* tests revealed that negative ($III_M = .36$, $III_{SD} = .10$; $ICI_M = .34$, $ICI_{SD} = .12$; $CCI_M = .56$, $CCI_{SD} = .15$) and positive ($III_M = .39$, $III_{SD} = .12$; $ICI_M = .36$, $ICI_{SD} = .15$; $CCI_M = .56$, $CCI_{SD} = .12$) items were recalled better than neutral ($III_M = .22$, $III_{SD} = .10$; $ICI_M = .23$, $ICI_{SD} = .11$; $CCI_M = .39$, $CCI_{SD} = .13$) items in all three conditions. There was no difference between negative and positive items in any condition (statistical tests are reported in Table 2).

These patterns in the conditions of interest for the RSA analyses, that is, ICI and III, are consistent with the past findings in individual memory literature that emotional content is remembered better than nonemotional content (e.g., Buchanan, 2007; Williams et al., 2022; Yonelinas & Ritchey, 2015). The additional check pertaining to the CCI and III condition shows that the findings that the basic phenomena observed in individual recall often carry into group recall (e.g., Weldon & Bellinger, 1997). We now turn to the RSA analyses that are of novel interest.

Global Memory Organization: Postcollaborative Changes in Individual and Collective Memory

As noted earlier, we applied the RSA to data from the III and the ICI conditions, as these conditions provide the necessary recall data that allow a comparison between the formation of global memory organization pre- and postcollaborative recall. Likewise, we were specifically interested in three comparisons: (a) III-Recall 1 to III-Recall 3 versus ICI-Recall 1 to ICI-Recall 3 RDM vector correlations, (b) ICI-Recall 1 to ICI-Recall 2 (group) versus ICI-Recall 2 (group) to ICI-Recall 3 RDM vector correlations, and (c) ICI-Recall 1 to ICI-Recall 3 versus ICI-Recall 2 (group) to ICI-Recall 3 RDM vector correlations (see Figure 2 and its description in the Method section for how these RDM vectors are computed). For each comparison, we start by presenting correlations and comparisons based on RDM vectors derived from each participant's study list (90 items; a given RDM vector consists of 4,005 unique distances). We then present the same correlations and comparisons

Table 1

Recall 3: Collective Memory Comparisons as a Function of Valence Across Conditions

Condition/valence	*t*	*df*	*p*	*d*	*d* [95% CI]
III					
Positive versus neutral	5.354	15	<.001	1.339	[0.645, 2.009]
Negative versus neutral	6.801	15	<.001	1.700	[0.912, 2.466]
Positive versus negative	0.968	15	.348	0.242	[−0.259, 0.736]
ICI					
Positive versus neutral	3.308	15	.005	0.827	[0.246, 1.388]
Negative versus neutral	3.362	15	.004	0.841	[0.257, 1.404]
Positive versus negative	−0.129	15	.899	−0.032	[−0.522, 0.458]
CCI					
Positive versus neutral	5.783	15	<.001	1.446	[0.725, 2.143]
Negative versus neutral	3.500	15	.003	0.875	[0.285, 1.445]
Positive versus negative	−0.127	15	.901	−0.032	[−0.521, 0.459]

Note. Effects across comparisons suggest, consistently and across conditions, that emotionally valenced material is collectively recalled better than neutral material, but there is no statistically significant difference in collective memory content between positively and negatively valenced material. The reported *p* values are rounded to three decimal points. III = individual–individual–individual; ICI = individual–collaborative–individual; CCI = collaborative–collaborative–individual; CI = confidence interval.

split by valence (30 items per valence; a given RDM vector consists of 435 unique distances). Likewise, for each comparison, we present parametric and nonparametric results. Finally, we describe the MDS to visualize the memory organization changes in the ICI condition.

III Versus ICI: Recall 1–3

RSA Analysis Across Valence. Recall 1–3 RDM vector correlations in the III condition ($N = 48$, $M = 0.61$, $SD = 0.12$) were higher than correlations in Recall 1–3 correlations in the ICI condition ($N = 48$, $M = 0.32$, $SD = 0.11$). The difference was statistically significant, $t(94) = 11.90$, $p < .001$. Our nonparametric analysis, which involved comparing the observed t value to a null distribution simulated by shuffling the condition assignment 10,000 times, was consistent with this result (observed $t = 11.90$, null 95% quantile [−1.98, 1.97]).

Negative. Restricting the RDM vectors to distances between negatively valenced targets, III correlations ($N = 48$, $M = 0.56$, $SD = 0.21$) were higher than ICI correlations ($N = 48$, $M = 0.29$, $SD = 0.18$). Our parametric results, $t(94) = 6.32$, $p < .001$, and nonparametric results (observed $t = 6.32$, null 95% quantile [−2.01, 1.97]) were consistent.

Neutral. Restricting the RDM vectors to distances between neutral targets, III correlations ($N = 48$, $M = 0.64$, $SD = 0.16$) were higher than ICI correlations ($N = 47$, $M = 0.33$, $SD = 0.16$). Our parametric results, $t(93) = 7.78$, $p < .001$, and nonparametric results (observed $t = 7.78$, null 95% quantile [−1.99, 1.92]) were consistent.

Positive. Restricting the RDM vectors to distances between positively valenced targets, III correlations ($N = 48$, $M = 0.59$, $SD = 0.23$) were again higher than ICI correlations ($N = 48$, $M = 0.31$, $SD = 0.21$). Our parametric results, $t(94) = 5.42$,

Table 2

Recall 1 Statistical Tests: Individual (III and ICI) and Group-Level (CCI) Valence Comparisons

Condition/valence	*t*	*df*	*p*	*d*	*d* [95% CI]
III					
Positive versus neutral	9.356	47	<.001	1.350	[0.954, 1.739]
Negative versus neutral	9.513	47	<.001	1.373	[0.973, 1.765]
Positive versus negative	1.648	47	.106	0.238	[−0.050, 0.524]
ICI					
Positive versus neutral	6.886	47	<.001	0.994	[0.644, 1.337]
Negative versus neutral	6.225	47	<.001	0.899	[0.559, 1.231]
Positive versus negative	0.725	47	.472	0.105	[−0.180, 0.388]
CCI					
Positive versus neutral	5.646	15	<.001	1.412	[0.700, 2.100]
Negative versus neutral	4.533	15	<.001	1.133	[0.488, 1.756]
Positive versus negative	0.120	15	.906	0.030	[−0.461, 0.520]

Note. III and ICI data are at individual level, CCI data are at group level. The recall advantage for emotionally valenced material holds across individual and collaborative retrieval conditions. III = individual–individual–individual; ICI = individual–collaborative–individual; CCI = collaborative–collaborative–individual; CI = confidence interval.

$p < .001$, and nonparametric results (observed $t = 5.42$, null 95% quantile [−2.00, 1.97]) were consistent.

Interim Summary. These results are consistent with our first RSA hypothesis and suggest that a collaborative recall that takes place between two individual recalls (as in the case of the ICI condition) disrupts the subsequent use of an earlier idiosyncratic retrieval strategy. Recall 1–3 correlations were always higher in the III condition, such that the same pattern is observed when considering full study list RDM vectors and when splitting by valence. This general relationship is depicted in Figure 4 (correlation distributions) and Figure 5 (top row; nonparametric results).

ICI: Recall 1–2 (Individual–Collaborative) Versus Recall 2–3 (Collaborative–Individual)

Across Valence. Within the ICI condition, Recall 1–2 correlations ($N = 48$, $M = 0.15$, $SD = 0.10$) were lower than Recall 2–3 correlations ($N = 48$, $M = 0.33$, $SD = 0.12$). The difference was statistically significant, $t(47) = −10.61$, $p < .001$. Our nonparametric results aligned with this, pointing to a significant difference (observed $t = −10.61$, null 95% quantile [−2.24, 2.23]).

Negative. Restricting RDM vectors to distances between negatively valenced targets, Recall 1–2 correlations ($N = 48$, $M = 0.12$, $SD = 0.13$) were lower than Recall 2–3 correlations ($N = 48$, $M = 0.30$, $SD = 0.19$). Our parametric results, $t(47) = −6.11$, $p < .001$, and nonparametric results (observed $t = −6.11$, null 95% quantile [−2.16, 2.19]) were consistent.

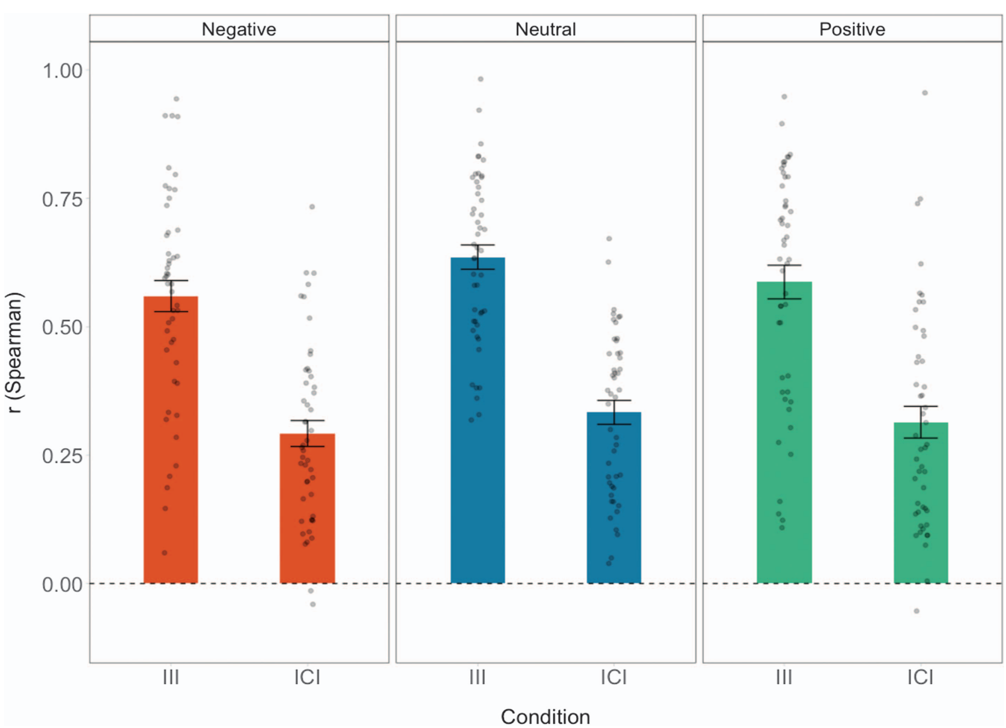
Neutral. Restricting RDM vectors to distances between neutral targets, Recall 1–2 correlations ($N = 47$, $M = 0.17$, $SD = 0.15$) were lower than Recall 2–3 correlations ($N = 48$, $M = 0.36$, $SD = 0.18$). Our parametric results, $t(46) = −8.03$, $p < .001$, and nonparametric results (observed $t = −8.03$, null 95% quantile [−2.10, 2.11]) were consistent.

Positive. Restricting RDM vectors to distances between positively valenced targets, Recall 1–2 correlations ($N = 48$, $M = 0.14$, $SD = 0.19$) were lower than Recall 2–3 correlations ($N = 48$, $M = 0.31$, $SD = 0.17$). Our parametric results, $t(47) = −7.68$, $p < .001$, and nonparametric results (observed $t = −7.68$, null 95% quantile [−1.36, 1.34]) were consistent.

Interim Summary. These results are consistent with our second RSA hypothesis and suggest that retrieval organization changes drastically when going from an individual recall into a collaborative group recall (i.e., relatively low Recall 1–2 correlations). Moreover, relatively elevated Recall 2–3 correlations suggest that the retrieval strategy employed during collaboration is still applied in a subsequent individual recall (which is a precondition for the emergence of collective organization). Finally, this pattern of results was observed for negative, positive, and neutral items. This trend is plotted in

Figure 4

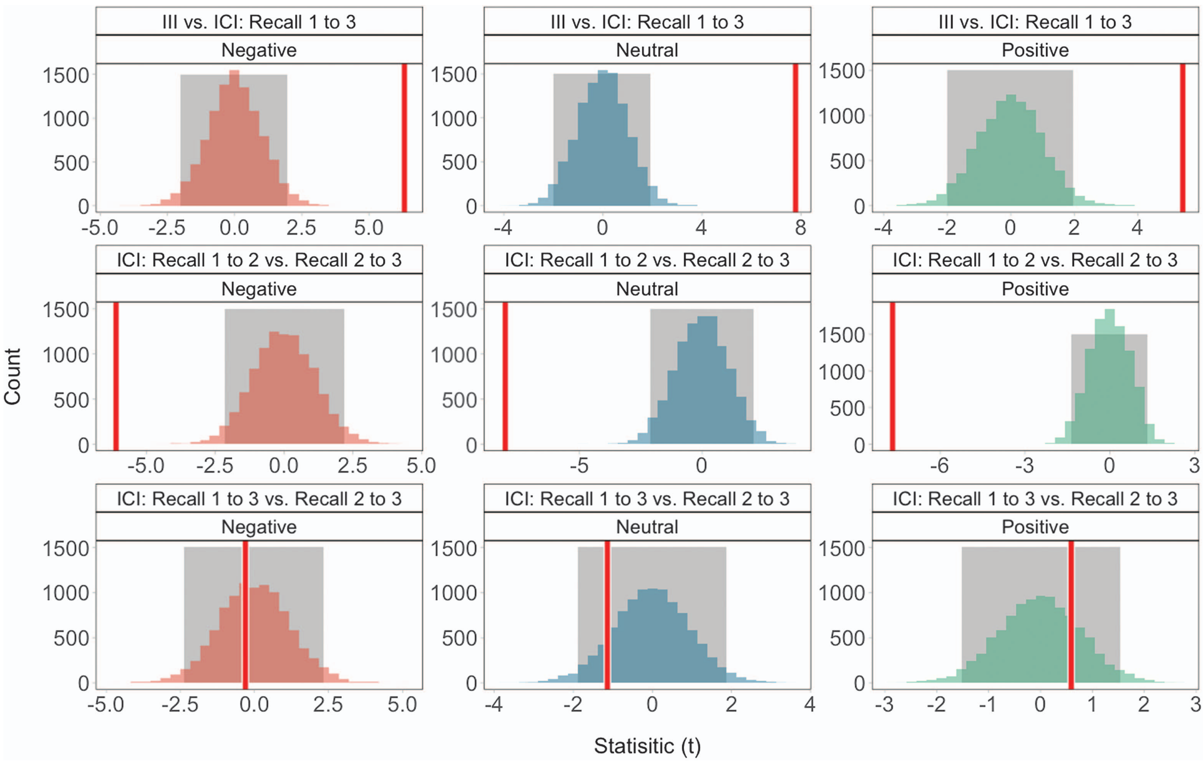
Recall 1–3 Valence-Specific Representational Dissimilarity Matrix Vector Correlations Across the III and ICI Conditions



Note. Note how correlations are consistently higher (and always greater at a statistically significant level) in the III condition. This indicates that an interleaved collaborative recall disrupts the use of an earlier individual recall, although positive correlations in the ICI conditions suggest that some idiosyncratic organization is retained. Correlations were r-to-z transformed prior to analysis. III = individual–individual–individual; ICI = individual–collaborative–individual.

Figure 5

Nonparametric Results Across Valence Comparisons



Note. Red vertical lines are at the observed *t* value for the given comparison. Histograms are simulated null distributions, computed by conducting 10,000 *t* tests with randomly shuffled condition assignments (in the case of the III vs. ICI: Recall 1–3 comparisons), or randomly shuffled recall-to-recall labels (in the case of the paired ICI comparisons). The gray bands cover the 95% quantile of the simulated null; if the red line (observed *t* value) falls outside of this region, we consider the difference significant. III = individual–individual–individual; ICI = individual–collaborative–individual; vs. = versus.

Figure 6A (correlation distributions) and above in Figure 5 (middle row; nonparametric results).

These Figures 5 and 6 show the joint impact of preexisting retrieval strategies and collaboration-induced changes in retrieval strategies. Specifically, Recall 1–3 correlations are very similar to Recall 2–3 correlations (and they do not differ significantly.) This indicates that, above and beyond the changes that collaboration brings about in organizational strategy, some earlier idiosyncratic organization is retained, even if one completes a collaborative recall between individual recalls (i.e., Recall 2). In other words, despite the disruption caused by an interleaved collaborative recall, postcollaborative global retrieval strategies seem to be a function of *both* the previous collaborative strategy and precollaborative idiosyncratic strategies. Thus, global memory organization can be flexible but robust; following collaborative recall, former collaborators converge on a similar strategy, but they also retain aspects of their individual, precollaborative idiosyncratic strategies. It is not surprising that people retain their precollaborative individual strategies as these strategies likely reflect the idiosyncratic cognitive structures they developed from extensive experiences throughout life. It is impressive that a single collaboration experience can influence this strategy, demonstrating the power of social exposure to information and the learning that accrues from it.

ICI: Recall 1–3 (Individual–Individual) Versus Recall 2–3 (Collaborative–Individual)

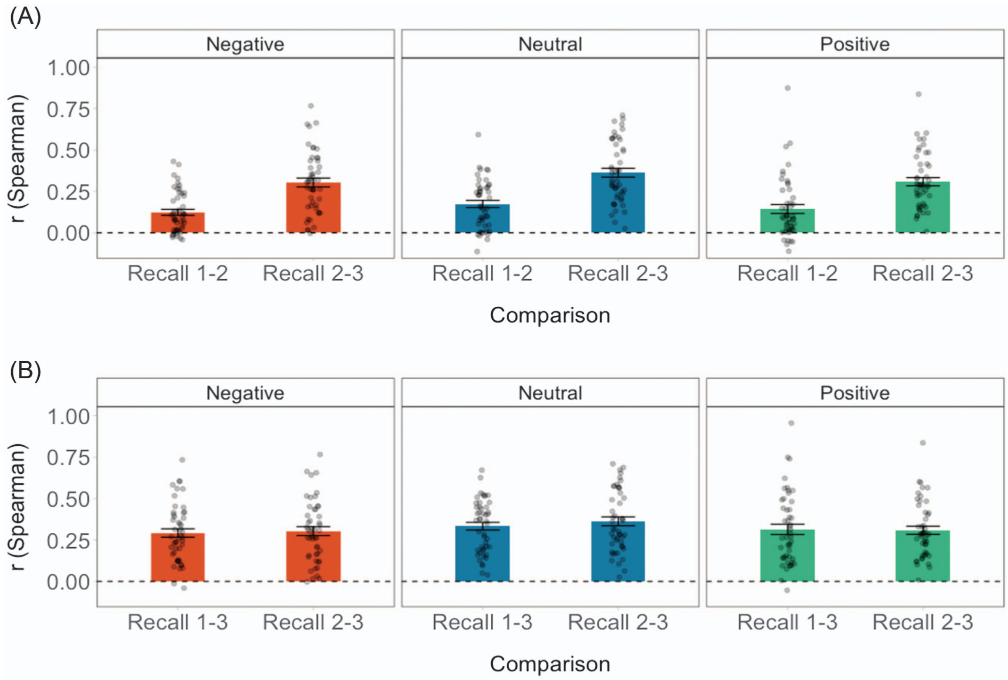
Across Valence. Within the ICI condition, Recall 1–3 correlations (N = 48, M = 0.32, SD = 0.11) were similar to Recall 2–3 correlations (N = 48, M = 0.33, SD = 0.12). The difference between these sets of correlations was not statistically significant, $t(47) = -0.22$, $p = .4150$. Our nonparametric analysis was consistent with this null result (observed $t = -0.22$, null 95% quantile [−1.99, 2.03]).

Negative. Restricting RDM vectors to distances between negatively valenced targets, Recall 1–3 correlations (N = 48, M = 0.29, SD = 0.18) were similar to Recall 2–3 correlations (N = 48, M = 0.30, SD = 0.19). Our parametric results, $t(47) = -0.31$, $p = .3806$, and nonparametric results (observed $t = -0.31$, null 95% quantile [−2.37, 2.34]) were consistent.

Neutral. Restricting RDM vectors to distances between neutral targets, Recall 1–3 correlations (N = 47, M = 0.33, SD = 0.16) were similar to Recall 2–3 correlations (N = 48, M = 0.36, SD = 0.18).

Figure 6

Valence-Specific Representational Dissimilarity Matrix Vector Correlations in the Individual–Collaborative–Individual Condition



Note. (A) Recall 1 to Recall 2 (group) correlations, compared to Recall 2 (group) to Recall 3 correlations; (B) Recall 1 to Recall 3 correlations, compared to Recall 2 (group) to Recall 3 correlations. Note the low Recall 1 to Recall 2 correlations in (A), relative to the Recall 2 to Recall 3 correlations, which are reliably positive. This indicates that collaboration reshapes the organizational strategy employed at Recall 1, and that Recall 3 organization is shaped by the previous collaboration (Recall 2). At the same time, consider (B). Recall 1–3 correlations are very similar to Recall 2–3 correlations (and they do not differ significantly). This indicates that, above and beyond the changes that collaboration brings about in organizational strategy, some earlier idiosyncratic organization is retained, even if one completes a collaborative recall between individual recalls (i.e., Recall 2). Correlations were r-to-z transformed prior to analysis.

Our parametric results, $t(46) = -1.14$, $p = .1300$, and nonparametric results (observed $t = -1.14$, null 95% quantile [−1.89, 1.87]) were consistent.

Positive. Restricting RDM vectors to distances between positive targets, Recall 1–3 correlations ($N = 48$, $M = 0.31$, $SD = 0.21$) were again similar to Recall 2–3 correlations ($N = 48$, $M = 0.31$, $SD = 0.17$). Our parametric results, $t(47) = 0.59$, $p = .7213$, and nonparametric results (observed $t = 0.59$, null 95% quantile [−1.52, 1.53]) were consistent.

Interim Summary. These results are not consistent with our third RSA hypothesis and suggest that, on average, Recall 1–3 and Recall 2–3 correlations do not differ. That is, retrieval organization at Recall 3 seems to be informed by one's previous idiosyncratic strategy (from Recall 1) *and also* the group's organizational strategy established at Recall 2. In other words, a collaborative recall that follows an individual recall disrupts one's original retrieval strategy to some extent, but it does not render it unusable. With respect to the emergence of collective organization, such a result implies some overlap; given consistently elevated Recall 2–3 correlations, former collaborators are employing aspects of the group retrieval strategy when recalling alone during subsequent retrieval attempts. These trends are plotted in Figure 6B (correlation distributions) and above in Figure 5 (bottom row; nonparametric results). In brief, final collective memory organization shows imprints of both the initial retrieval strategy and the subsequent retrieval strategy. We elaborate on this discovery in the Discussion section.

Multidimensional Scaling: Visualizing ICI Group Memory Organization

To visually explore the extent to which a single collaborative recall alters and furthermore synchronizes individual retrieval strategies, we conducted non-MDS which is typically used for visualizing an RDM (MDS; Borg et al., 2013; Chikazoe et al., 2014; Kriegeskorte et al., 2008). MDS is a method for visualizing complex information by projecting information that is in a high-dimensional space to a lower dimensional space (e.g., two-dimensional space), while trying to reserve the relative distances as much as possible. While these reduced dimensions are sometimes used to generate interpretations of constructs, this is not the goal here. In the present study, our purpose was to visualize the synchronizing effect of group recall and the relative extent to which each member of a group gravitates toward the group strategy in their postcollaborative recall retrieval strategy compared to precollaborative recall strategy. For each ICI triad, we computed RDM vectors for the seven relevant recalls (i.e., each participant has an individual Recall 1 and 3, for a total of six individual recalls, plus the group Recall 2). We then generated, for each group, a matrix of distances, holding the Euclidean distance between each pair of RDM vectors. Finally, we submitted each group's distance matrix to MDS, specifying a two-dimensional solution. When plotting, each of the six recalls is represented as a dot in a two-dimensional space (Figure 7). Inspection of the relative distances between the seven recalls reveals a striking pattern, pointing to a clear trend that informs the novel goals of this study—to varying degrees, following collaboration, individual retrieval strategies drift toward the group strategy (symbolized by a red triangle in Figure 7), and therefore each other.

Discussion

Over a century of findings from cognitive research on human memory come from studies where people perform tasks in isolation. However, remembering is also a ubiquitous social activity, yet empirical as well as theoretical accounts of social remembering remain in infancy. To this end, we investigated the nature of social remembering, focusing on a fundamental property of memory—how we organize remembered information across emotional valences.

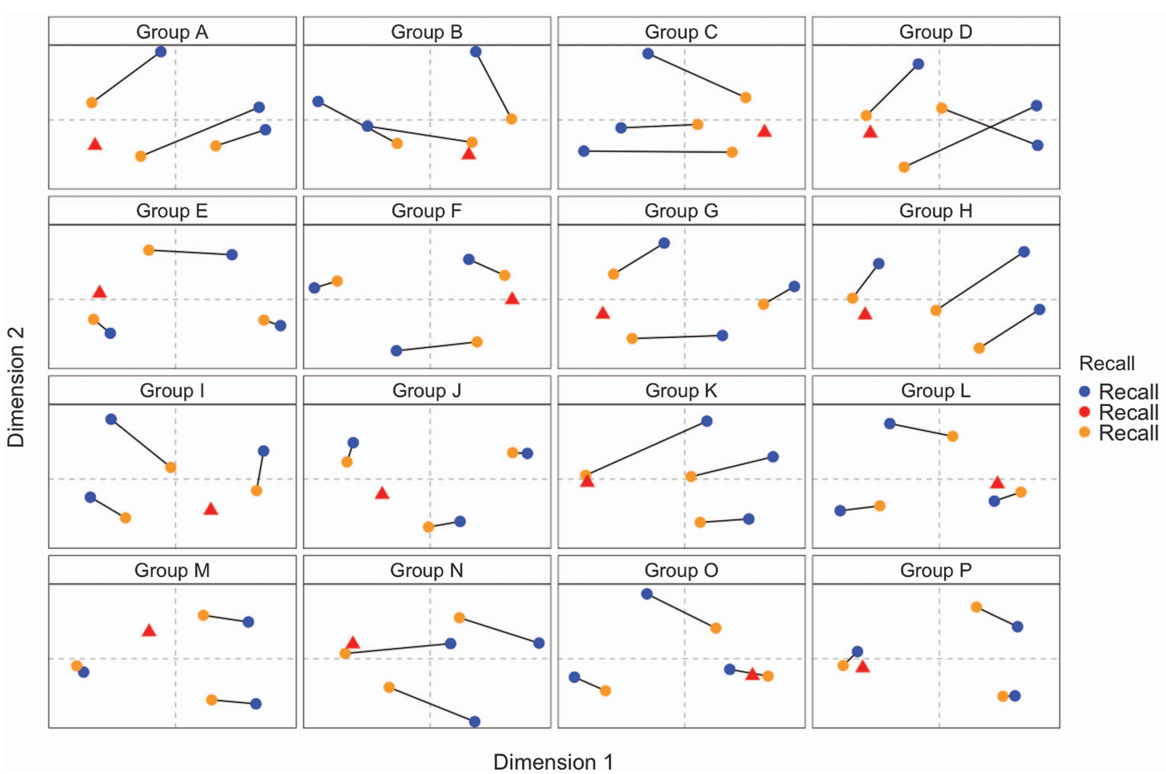
Critically, our understanding of retrieval organization is also limited to local level measurements that focus on small units of recall. This is not only the case in the sparse studies on how social influences change retrieval organization but also in the extensive literature on individual memory organization. This state of knowledge leaves unanswered how the rememberer holistically organizes in recall the entire contents of the encoding experience. Yet, assessment of a holistic and integrated organization of the encoding experience is crucial for understanding how we construct memory narratives and how social influences alter them. In this article, we report a large experimental study on collaborative and a novel application of an analytic tool, the RSA to investigate these key questions about the social influences on the emergence of memory organization and a global measurement of such memory organization.

Further, we examined memory content and organization not only for neutral information but also emotional information, which is less commonly assessed but is integral to everyday memory content. While the influences of emotion on memory have been widely documented, we have limited knowledge about how recalling with others may impact the memory content as well as the memory organization of emotional versus nonemotional content.

We replicated two memory phenomena of interest. First, at the collective level, former collaborators collectively recalled more of the same content than those who never collaborated (Barber et al., 2012; Choi et al., 2014, 2017; A. R. Congleton & Rajaram, 2014; Cuc et al., 2007; Greeley & Rajaram, 2023; Harris et al., 2008; Pepe et al., 2021; Stone et al., 2010). Likewise, collective memory for

Figure 7

Nonclassical Multidimensional Scaling: Two-Dimensional Solution Across Individual–Collaborative–Individual Groups and Recalls



Note. Individual participants' Recall 1 and Recall 3 values are connected by a line (Recall 1 as blue, Recall 3 as orange). Group Recall 2 values are indicated with red triangles. Stress values: $M = 0.16$, $SD = 0.04$, minimum = .09, maximum = .23.

emotional information was better than for neutral information in every condition. Second, at the individual level, we again found the expected patterns; emotional content, on average, was remembered better than neutral content, with no significant difference between positive and negative content, suggesting a role of arousal (Kensinger, 2004; Kensinger & Corkin, 2004). This pattern held for both individual and collaborative group recall. These findings suggests that emotional contents are in general better remembered than neutral content at the individual level, which is consistent with previous findings (Barber et al., 2015; Bärthel et al., 2017; Choi et al., 2017; Kensinger et al., 2016; Maswood et al., 2019; Wessel et al., 2015; Yaron-Antar & Nachson, 2006). This better memory for emotional content increases the likelihood of common emotional items being shared within a group. Collaboration then further enhanced the retrieval of common emotional items, likely due to reexposure emotional items during collaboration (Blumen & Rajaram, 2008).

Turning to our novel aims related to the application of RSA and our questions relating to global memory organization, we report several key effects. First, even a single collaborative recall interferes with precollaborative retrieval strategies evident in earlier individual recall. This held across emotion-specific comparisons and reveals global-level retrieval organization beyond the demonstrations in prior research assessing the ways in which retrieval is reshaped at a local level following collaboration (Choi et al., 2014). That even a single collaborative recall alters individual memory structures at a global/holistic level is remarkable because these interactions occurred with conversational partners who were strangers and for information that was general and nonautobiographical. These findings show that holistic memory organization is responsive to social influence.

Second, when recalling alone following a group retrieval phase, the similarity in global retrieval organization to the previous group strategy is greater compared to the similarity between precollaborative and group strategies. In other words, groups converge on a global strategy that carries forward into subsequent individual retrieval attempts. Finally, despite the interference caused by an interleaved collaborative recall, postcollaborative global retrieval strategies seem to be a function of both the previous collaborative strategy and precollaborative idiosyncratic strategies. Thus, global memory organization can be flexible but robust; following collaborative recall, former collaborators converge on a similar strategy, but they also retain aspects of their individual, precollaborative idiosyncratic strategies.

The retention of individual, precollaborative retrieval strategies, and the changes that occur due to collaboration, may reflect not only organizational changes in memory but may be also linked to the strength of memories. In this view, the retrieval strategies may be modulated by suppression and reinforcement of items during collaboration.[3] Suppression may be viewed as similar to the mechanisms of disruption and inhibition we described in the introduction, and reinforcement may be similar to reexposure that we described in the introduction. Reinforcement may also arise from relearning through retrieval, a mechanism we have proposed to be operating for the person who does the recalling (as opposed to the listener who experiences reexposure to what others are recalling), where such retrieval reinforces the memory for an item (see Rajaram & Pereira-Pasarin, 2010). The present study design did not include a delayed recall condition that can be diagnostic of whether changes in global memory organization represent transient shifts affected by the mechanisms of suppression and reinforcement or more enduring alterations in memory organization. In past research where we included delayed recall, memory organization at local levels persisted after a delay of 1 week between study and test, an impressive length of time for sustained changes in recall sequences (A. R. Congleton & Rajaram, 2014). Memory organization was also stronger after two collaborative recalls than one. In light of these theoretical possibilities and lines of evidence, future research may speak to the extent to which changes in global memory organization following collaboration represent transient shifts or more enduring alterations, as well as whether repeated recall opportunities can fully replace individual preferences in organizing retrieval (see also Tulving, 1966).

Taken as a whole, combined with other recent work on collective retrieval organization that has examined the question at more local levels (A. R. Congleton & Rajaram, 2014; Greeley et al., 2022, 2024), the current results provide converging evidence in support of a fundamental set of ideas. First, memory organization/retrieval strategies are robust but malleable such that collaborative recall changes global-level memory organization of people who collaborated. Second, memory organization/retrieval strategies are malleable in a specific sense such that collaborative recall synchronizes global-level memory organization across collaborators. The application of MDS illustrates this synchronization clearly where, following collaboration, members of the group moved closer to the group performance (Figure 7). Finally, the influence of collaboration on the organization of recalled content was similar for emotionally neutral and emotionally valenced information, favoring one of the two hypotheses outlined in the introduction that the formation of global collective memory organization generalizes across emotional valence of material.

Broader Implications

The present study has several broader implications that touch on topics beyond the boundary of basic memory research and stem from two distinct but related sources. First, our use of RSA provides a flexible example of how computational tools from neuroscience can be leveraged to understand behavioral memory, in this case, the recall of past experiences. That is, application of RSA in a recall context provides a robust proof of concept for the measurement of intra-subject retrieval organization. This also allows a computational capture of alignment of such organization across individuals, giving us an index of collective memory organization, adding to its use in the study of the neural representation of valence (Chikazoe et al., 2014; Jin et al., 2015), the representation of stimuli dimensionality (Kriegeskorte et al., 2008), and context-bound representations (Hannula et al., 2013; Jonker et al., 2018). Second, the current results speak to the broader relevance of memory organization, both in terms of how they are shaped by social interactions (such as collaborative recall) and how they are synchronized. Considering that beliefs and attitudes often stem from memory (Schacter & Scarry, 2001), and that socialization is crucial in constructing our models of the world (Fivush et al., 2011), our findings may speak to fundamental processes underpinning the

[3] We thank an anonymous reviewer for suggesting the memory strength interpretation relating to suppression and reinforcement that led us to delve into these theoretical considerations.

formation of individual and collective beliefs, attitudes, and other representations.

Several features of the RSA make it promising for considering it in the study of narratives in future research. An RSA application can be agnostic or sensitive to stimuli features such as semantic relatedness or emotional valence—so long as the recalled material has some organization (i.e., specific units). This flexibility is a desirable property for researchers interested in the organization of more naturalistic stimuli (Reagh & Ranganath, 2023). For example, consider prose passages and their sentences that can be classified in terms of particular features (e.g., subject names and attributes; Shimmerlik, 1978). While measures like adjusted ratio of clustering can quantify clustering based on such features (e.g., Myers et al., 1973), the RSA application presented here could simultaneously assess such clustering and also the extent to which participants recall according to particular narrative organizations. As noted, retrieval organization to date has been quantified at local levels and item-to-item transitions through measures of category clustering, subjective organization, and temporal contiguity (Polyn et al., 2009; Sederberg et al., 2008), and more recently, exploring broader relationships that primarily consider iterative local-level changes/local-level operations (Ortmann et al., 2024). While these methods provide valuable insights into the nature of memory and retrieval, a more global and holistic framing could expand these insights. Our application of RSA offers a template for capturing holistic recall patterns, aiding researchers interested in more applied questions in memory.

In this vein, recent research has leveraged neuroimaging techniques to map the functional architecture of memory in brain activation. For example, work examining neural-level similarity in activation occurring at study and at recall reveals biological evidence for the tendency people have for reorganizing information to create a new memory structure, one that is altered relative to the original experience (Chen et al., 2017). Further, recalling the event, whereupon memory structures come into shape for the original event, to communicate it to someone who did not experience the event activates similar patterns of activation in the brain of the listener as the person recalling the event (Zadbood et al., 2017). This neural process of similarity is reminiscent of Bartlett's (1932) case studies we noted in the introduction where one person's recall of the story became the encoding material for the next person, and so on, distilling the story as social transmission of memory progressed. There is also emerging neural evidence for alignment in teacher–student brain activation patterns following students' listen to a teacher's lecture recording for students with increased correlation for students who exhibited good learning (Nguyen et al., 2022).

The reports of neural-level similarity in memory activation patterns offer a foundation for thinking about structural similarity in behavioral data during collaborative recall. For instance, neural pattern similarity across recalling and listening resonates with the expectation that collaborative remembering increases similarity in the memory architecture of conversational partners. Here, we show that collaboration establishes holistic similarity in memory structures, transformation that can be directly observed in behavioral manifestation of changing and aligning memory structures. This behavioral evidence has particularly important and wide-ranging implications, such as understanding the impact of collaboration on memory in educational settings (see Wissman & Rawson, 2015, 2016), which are more feasible to explore through behavioral research. Thus, behavioral assessments of holistic memory structures in collaborative paradigms offer important complementarity to pursuing theoretical and practical advances across research domains.

Turning to even broader implications of our results, the homogenization of what and how people recall—including when it is emotional content they are recalling—may have important implications for research on the emergence of shared narratives and beliefs after frequent interaction. For instance, the collaborative dynamics present in parent–child conversations could well scaffold the emergence of shared autobiographical memories (Q. Wang & Fivush, 2005) that, in turn, underpin the development of shared beliefs and attitudes (A. R. Congleton & Rajaram, 2014). In group coordination tasks, collaboration may shape the emergence of roles or shared beliefs about roles (Goldstone et al., 2024; Rabb et al., 2019). Our results from RSA and MDS application point to retrieval strategy synchrony, resonating with the recent use of MDS to capture the clustering of public events memories in an interconnected manner (Mutlutürk et al., 2023). As this work has shown, social interactions in larger sociopolitical contexts may shape individuals' representations of beliefs, attitudes, and emotions, with the clustering of public events in memories as linked to one's sociopolitical identity. Experimental work complements the importance of such findings by delineating how memory organization changes and how collective memory organization emerges for emotionally neutral and valenced information.

In this vein, applications of RSA may also be a powerful tool to study the impact of culture, given the noted importance of social–cultural environment in shaping not only what to think about but also how (e.g., Vygotsky, 1980). The general notion of a global level, structural synchrony that builds on shared memory content also has implications for the formation of collective beliefs and the role expertise plays in the social shaping of memory (Koppel et al., 2014; Meade et al., 2009; Vlasceanu et al., 2020). Such applications have the potential to provide a window into how culture shapes learning and memory (Gutchess & Rajaram, 2023) by capturing convergences and divergences across cultures in individual and collective memory organization.

Finally, our results have implications for collective memory in an even broader sense. While the present study adheres to the traditional cognitive psychological approach of assessing collective memory—and shared organization—via recall of word lists, our results speak to powerful synchronizing force of collaboration. Not only do former collaborators recall more of the same content, they do so in a more similar and holistic manner, while also retaining their precollaborative idiosyncratic retrieval strategy. What might this imply about the emergence of collective memory in a political or a more sociological sense (Rabb et al., 2021)? Wertsch (2008) highlighted the importance of collective narratives; collective memory in this context is not the simple act of recalling (or forgetting) the same people or events, it is the recalling of a particular narrative or story. Quantifying such a notion requires the proper computational machinery, a tool that can capture both global organization and the dimensions that characterize a rich narrative (e.g., valence). While our results cannot speak directly to the recall of narratives, they do provide evidence that global organization emerges following collaboration. This lays the groundwork for future research on how collective narratives emerge in more ecological social networks.

Constraints on Generality

We identify the aspects of the present study that may constrain the generality of our findings. First, like previous work on local-level organization in individual and collaborative recall, we used discrete units of information for study and recall, in this case word–picture pairs of different emotional valence, to investigate global-level organization. The use of controlled stimuli for study and recall in the present study may place constraints on generalization, and considerable work may be needed to translate such quantitative assessment to ecological valid materials. A successful application of the RSA in our study using controlled stimuli provides the foundational steps for establishing the principles and methods for investigating such efforts in future research. Concerns that these items are less connected among themselves than stories and similar narratives are alleviated to the extent that people show a propensity to organize retrieval even of unrelated stimuli across successive retrieval trials (Gates, 1917; Mulligan, 2002; Tulving, 1962). Thus, these stimuli provide a solid link to prior work on retrieval organization, emotional memory, and collaborative recall while lending themselves to a novel quantitative application to assess global retrieval organization. At the same time, in real life, memory content often consists of materials with other connections such as logical or sequential connections. With its capabilities to assess interrelationships in the positioning of all stimuli while factoring in both remembered and forgotten elements, the RSA application holds promise for such future applications. To what extent collaboration changes memory organization under such conditions remain to be examined in future research.

Two methodological aspects of this study, the group size of three and the group composition specific to strangers, followed prevalent literature practices to leverage our novel tests on well-established procedures. This foundational work provides a basis to seek generality of our findings with other group characteristics such as larger groups and groups composed of acquaintances, friends, family, and people with specific group affiliations (e.g., political beliefs) in future research. Last, our participants are university students at a U.S. university. Hence, the findings are more directly generalizable to young adults in the general population. It remains to be tested how our findings hold across gender, race, and ethnicity distributions, whether they hold for people in other age ranges, cultures and nations, and for people with neurological (e.g., dementia), or psychiatric conditions pertaining to emotional well-being (e.g., social anxiety).

References

Assmann, J., & Czaplicka, J. (1995). Collective memory and cultural identity. *New German Critique*, *65*, 125–133. https://doi.org/10.2307/488538

Bair, J. L., Patrick, S. D., Noyes, E. T., Hale, A. C., Campbell, E. B., Wilson, A. M., Ransom, M. T., & Spencer, R. J. (2023). Semantic clustering on common list-learning tasks: A systematic review of the state of the literature and recommendations for future directions. *Journal of Clinical and Experimental Neuropsychology*, *45*(7), 652–692. https://doi.org/10.1080/13803395.2023.2270204

Barber, S. J., Castrellon, J. J., Opitz, P., & Mather, M. (2017). Younger and older adults' collaborative recall of shared and unshared emotional pictures. *Memory & Cognition*, *45*(5), 716–730. https://doi.org/10.3758/s13421-017-0694-3

Barber, S. J., Harris, C. B., & Rajaram, S. (2015). Why two heads apart are better than two heads together: Multiple mechanisms underlie the collaborative inhibition effect in memory. *Journal of experimental psychology. Learning, memory, and cognition*, *41*(2), 559–566. https://doi.org/10.1037/xlm0000037

Barber, S. J., Rajaram, S., & Fox, E. B. (2012). Learning and remembering with others: The key role of retrieval in shaping group recall and collective memory. *Social Cognition*, *30*(1), 121–132. https://doi.org/10.1521/soco.2012.30.1.121

Barnier, A. J., & Sutton, J. (2008). From individual to collective memory: Theoretical and empirical perspectives. *Memory*, *16*(3), 177–182. https://doi.org/10.1080/09541440701828274

Bärthel, G. A., Wessel, I., Huntjens, R. J. C., & Verwoerd, J. (2017). Collaboration enhances later individual memory for emotional material. *Memory*, *25*(5), 636–646. https://doi.org/10.1080/09658211.2016.1208248

Bartlett, F. C. (1977). *Remembering: A study in experimental and social psychology* (1st ed. 1932). Cambridge University Press.

Basden, B. H., Basden, D. R., Bryner, S., & Thomas, R. L. I., III. (1997). A comparison of group and individual remembering: Does collaboration disrupt retrieval strategies? *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *23*(5), 1176–1189. https://doi.org/10.1037/0278-7393.23.5.1176

Basden, B. H., Reysen, M. B., & Basden, D. R. (2002). Transmitting false memories in social groups. *The American Journal of Psychology*, *115*(2), 211–231. https://doi.org/10.2307/1423436

Berger, J. (2011). Arousal increases social transmission of information. *Psychological Science*, *22*(7), 891–893. https://doi.org/10.1177/0956797611413294

Berger, J., & Milkman, K. (2012). What makes online content viral? *Journal of Marketing Research*, *49*(2), 192–205. https://doi.org/10.1509/jmr.10.0353

Bierbrauer, A., Fellner, M. C., Heinen, R., Wolf, O. T., & Axmacher, N. (2021). The memory trace of a stressful episode. *Current Biology*, *31*(23), 5204–5213.e8. https://doi.org/10.1016/j.cub.2021.09.044

Bietti, L. M., & Sutton, J. (2015). Interacting to remember at multiple timescales: Coordination, collaboration, cooperation and culture in joint remembering. *Interaction Studies*, *16*(3), 419–450. https://doi.org/10.1075/is.16.3.04bie

Blumen, H. M., & Rajaram, S. (2008). Influence of re-exposure and retrieval disruption during group collaboration on later individual recall. *Memory*, *16*(3), 231–244. https://doi.org/10.1080/09658210701804495

Blumen, H. M., Young, K. E., & Rajaram, S. (2014). Optimizing group collaboration to improve later retention. *Journal of Applied Research in Memory and Cognition*, *3*(4), 244–251. https://doi.org/10.1016/j.jarmac.2014.05.002

Bookbinder, S. H., & Brainerd, C. J. (2017). Emotionally negative pictures enhance gist memory. *Emotion*, *17*(1), 102–119. https://doi.org/10.1037/emo0000171

Borg, I., Groenen, P. J. F., & Mair, P. (2013). *Applied multidimensional scaling*. Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-642-31848-1

Brooks, J. A., & Freeman, J. B. (2018). Conceptual knowledge predicts the representational structure of facial emotion perception. *Nature Human Behaviour*, *2*(8), 581–591. https://doi.org/10.1038/s41562-018-0376-6

Buchanan, T. W. (2007). Retrieval of emotional memories. *Psychological Bulletin*, *133*(5), 761–779. https://doi.org/10.1037/0033-2909.133.5.761

Chan, J. C. K., Manley, K. D., Davis, S. D., & Szpunar, K. K. (2018). Testing potentiates new learning across a retention interval and a lag: A strategy change perspective. *Journal of Memory and Language*, *102*, 83–96. https://doi.org/10.1016/j.jml.2018.05.007

Chan, J. C. K., Meissner, C. A., & Davis, S. D. (2018). Retrieval potentiates new learning: A theoretical and meta-analytic review. *Psychological Bulletin*, *144*(11), 1111–1146. https://doi.org/10.1037/bul0000166

Chen, J., Leong, Y. C., Honey, C. J., Yong, C. H., Norman, K. A., & Hasson, U. (2017). Shared memories reveal shared structure in neural activity across individuals. *Nature Neuroscience*, *20*(1), 115–125. https://doi.org/10.1038/nn.4450

Chikazoe, J., Lee, D. H., Kriegeskorte, N., & Anderson, A. K. (2014). Population coding of affect across stimuli, modalities and individuals. *Nature Neuroscience*, *17*(8), 1114–1122. https://doi.org/10.1038/nn.3749

Choi, H.-Y. (2015). *Social transmission of emotional memory* [Ph.D. thesis, State University of New York at Stony Brook]. ProQuest Dissertations & Theses. https://www.proquest.com/pqdtglobal/docview/1734112430/abstract/BFA75BEE5A864FD4PQ/1

Choi, H.-Y., Blumen, H. M., Congleton, A. R., & Rajaram, S. (2014). The role of group configuration in the social transmission of memory: Evidence from identical and reconfigured groups. *Journal of Cognitive Psychology*, *26*(1), 65–80. https://doi.org/10.1080/20445911.2013.862536

Choi, H.-Y., Kensinger, E. A., & Rajaram, S. (2013). Emotional content enhances true but not false memory for categorized stimuli. *Memory & Cognition*, *41*(3), 403–415. https://doi.org/10.3758/s13421-012-0269-2

Choi, H.-Y., Kensinger, E. A., & Rajaram, S. (2017). Mnemonic transmission, social contagion, and emergence of collective memory: Influence of emotional valence, group structure, and information distribution. *Journal of Experimental Psychology: General*, *146*(9), 1247–1265. https://doi.org/10.1037/xge0000327

Clewett, D., & McClay, M. (2024). Emotional arousal lingers in time to bind discrete episodes in memory. *Cognition and Emotion*. Advance online publication. https://doi.org/10.1080/02699931.2023.2295853

Congleton, A., & Rajaram, S. (2012). The origin of the interaction between learning method and delay in the testing effect: The roles of processing and conceptual retrieval organization. *Memory & Cognition*, *40*(4), 528–539. https://doi.org/10.3758/s13421-011-0168-y

Congleton, A. R., & Rajaram, S. (2014). Collaboration changes both the content and the structure of memory: Building the architecture of shared representations. *Journal of Experimental Psychology: General*, *143*(4), 1570–1584. https://doi.org/10.1037/a0035974

Conway, M. A., Cohen, G., & Stanhope, N. (1991). On the very long-term retention of knowledge acquired through formal education: Twelve years of cognitive psychology. *Journal of Experimental Psychology: General*, *120*(4), 395–409. https://doi.org/10.1037/0096-3445.120.4.395

Conway, M. A., & Rubin, D. C. (1993). The structure of autobiographical memory. In A. F. Collins, S. E. Gathercole, M. A. Conway, & P. E. Morris (Eds.), *Theories of memory* (pp. 103–137). Lawrence Erlbaum Associates.

Crowder, R. G. (1976). *Principles of learning and memory: Classic edition* (1st ed.). Taylor & Francis.

Cuc, A., Koppel, J., & Hirst, W. (2007). Silence is not golden: A case for socially shared retrieval-induced forgetting. *Psychological Science*, *18*(8), 727–733. https://doi.org/10.1111/j.1467-9280.2007.01967.x

Cuc, A., Ozuru, Y., Manier, D., & Hirst, W. (2006). On the formation of collective memories: The role of a dominant narrator. *Memory & Cognition*, *34*(4), 752–762. https://doi.org/10.3758/BF03193423

Dolcos, F., & Cabeza, R. (2002). Event-related potentials of emotional memory: Encoding pleasant, unpleasant, and neutral pictures. *Cognitive, Affective & Behavioral Neuroscience*, *2*(3), 252–263. https://doi.org/10.3758/CABN.2.3.252

Dolcos, F., LaBar, K. S., & Cabeza, R. (2004). Interaction between the amygdala and the medial temporal lobe memory system predicts better memory for emotional events. *Neuron*, *42*(5), 855–863. https://doi.org/10.1016/S0896-6273(04)00289-2

Dubova, M., Galesic, M., & Goldstone, R. L. (2022). Cognitive science of augmented intelligence. *Cognitive Science*, *46*(12), Article e13229. https://doi.org/10.1111/cogs.13229

Farrell, S. (2012). Temporal clustering and sequencing in short-term memory and episodic memory. *Psychological Review*, *119*(2), 223–271. https://doi.org/10.1037/a0027371

Fivush, R., Habermas, T., Waters, T. E. A., & Zaman, W. (2011). The making of autobiographical memory: Intersections of culture, narratives and identity. *International Journal of Psychology*, *46*(5), 321–345. https://doi.org/10.1080/00207594.2011.596541

Fivush, R., & Wang, Q. (2005). Emotion talk in mother-child conversations of the shared past: The effects of culture, gender, and event valence. *Journal of Cognition and Development*, *6*(4), 489–506. https://doi.org/10.1207/s15327647jcd0604_3

Freund, M. C., Etzel, J. A., & Braver, T. S. (2021). Neural coding of cognitive control: The representational similarity analysis approach. *Trends in Cognitive Sciences*, *25*(7), 622–638. https://doi.org/10.1016/j.tics.2021.03.011

Gates, A. I. (1917). *Recitation as a factor in memorizing*. The Science Press. https://archive.org/details/recitationasfact00gaterich

Goldstone, R. L., Andrade-Lotero, E. J., Hawkins, R. D., & Roberts, M. E. (2024). The emergence of specialized roles within groups. *Topics in Cognitive Science*, *16*(2), 257–281. https://doi.org/10.1111/tops.12644

Greeley, G. D., Chan, V., Choi, H.-Y., & Rajaram, S. (2024). Collaborative recall and the construction of collective memory organization: The impact of group structure. *Topics in Cognitive Science*, *16*(2), 282–301. https://doi.org/10.1111/tops.12639

Greeley, G. D., Peña, T., & Rajaram, S. (2022). Social remembering in the digital age: Implications for virtual study, work, and social engagement. *Memory, Mind & Media*, *1*, Article e13. https://doi.org/10.1017/mem.2022.3

Greeley, G. D., & Rajaram, S. (2023). Collective memory: Collaborative recall synchronizes what and how people remember. *Wiley Interdisciplinary Reviews: Cognitive Science*, *14*(4), Article e1641. https://doi.org/10.1002/wcs.1641

Gutchess, A., & Rajaram, S. (2023). Consideration of culture in cognition: How we can enrich methodology and theory. *Psychonomic Bulletin & Review*, *30*(3), 914–931. https://doi.org/10.3758/s13423-022-02227-5

Halbwachs, M. (1980). *The collective memory* (1st ed.). Harper & Row.

Hamann, S. (2001). Cognitive and neural mechanisms of emotional memory. *Trends in Cognitive Sciences*, *5*(9), 394–400. https://doi.org/10.1016/S1364-6613(00)01707-1

Hannula, D. E., Libby, L. A., Yonelinas, A. P., & Ranganath, C. (2013). Medial temporal lobe contributions to cued retrieval of items and contexts. *Neuropsychologia*, *51*(12), 2322–2332. https://doi.org/10.1016/j.neuropsychologia.2013.02.011

Harris, C. B., Paterson, H. M., & Kemp, R. I. (2008). Collaborative recall and collective memory: What happens when we remember together? *Memory*, *16*(3), 213–230. https://doi.org/10.1080/09658210701811862

Heath, C. (1996). Do people prefer to pass along good or bad news? Valence and relevance of news as predictors of transmission propensity. *Organizational Behavior and Human Decision Processes*, *68*(2), 79–94. https://doi.org/10.1006/obhd.1996.0091

Hirst, W., & Manier, D. (2008). Towards a psychology of collective memory. *Memory*, *16*(3), 183–200. https://doi.org/10.1080/09658210701811912

Howard, M. W., & Kahana, M. J. (2002). When does semantic similarity help episodic retrieval? *Journal of Memory and Language*, *46*(1), 85–98. https://doi.org/10.1006/jmla.2001.2798

Jin, J., Zelano, C., Gottfried, J. A., & Mohanty, A. (2015). Human amygdala represents the complete spectrum of subjective valence. *The Journal of Neuroscience*, *35*(45), 15145–15156. https://doi.org/10.1523/JNEUROSCI.2450-15.2015

Jonker, T. R., Dimsdale-Zucker, H., Ritchey, M., Clarke, A., & Ranganath, C. (2018). Neural reactivation in parietal cortex enhances memory for episodically linked information. *Proceedings of the National Academy of Sciences of the United States of America*, *115*(43), 11084–11089. https://doi.org/10.1073/pnas.1800006115

Kahana, M. J. (2012). *Foundations of human memory*. Oxford University Press.

Kahana, M. J., Howard, M. W., & Polyn, S. M. (2008). Associative retrieval processes in episodic memory. In H. L. Roediger, III (Ed.), *Learning and memory: A comprehensive reference* (pp. 1–24). Elsevier. https://doi.org/10.1016/B978-012370509-9.00185-6

Kensinger, E. A. (2004). Remembering emotional experiences: The contribution of valence and arousal. *Reviews in the Neurosciences*, *15*(4), 241–251. https://doi.org/10.1515/REVNEURO.2004.15.4.241

Kensinger, E. A., Choi, H.-Y., Murray, B. D., & Rajaram, S. (2016). How social interactions affect emotional memory accuracy: Evidence from collaborative retrieval and social contagion paradigms. *Memory & Cognition*, *44*(5), 706–716. https://doi.org/10.3758/s13421-016-0597-8

Kensinger, E. A., & Corkin, S. (2004). Two routes to emotional memory: Distinct neural processes for valence and arousal. *Proceedings of the National Academy of Sciences of the United States of America*, *101*(9), 3310–3315. https://doi.org/10.1073/pnas.0306408101

Koppel, J., Wohl, D., Meksin, R., & Hirst, W. (2014). The effect of listening to others remember on subsequent memory: The roles of expertise and trust in socially shared retrieval-induced forgetting and social contagion. *Social Cognition*, *32*(2), 148–180. https://doi.org/10.1521/soco.2014.32.2.148

Kriegeskorte, N., & Kievit, R. A. (2013). Representational geometry: Integrating cognition, computation, and the brain. *Trends in Cognitive Sciences*, *17*(8), 401–412. https://doi.org/10.1016/j.tics.2013.06.007

Kriegeskorte, N., Mur, M., & Bandettini, P. (2008). Representational similarity analysis—Connecting the branches of systems neuroscience. *Frontiers in Systems Neuroscience*, *2*, Article 4. https://doi.org/10.3389/neuro.06.004.2008

Le Bigot, L., Knutsen, D., & Gil, S. (2018). I remember emotional content better, but I'm struggling to remember who said it! *Cognition*, *180*, 52–58. https://doi.org/10.1016/j.cognition.2018.07.001

Long, N. M., Danoff, M. S., & Kahana, M. J. (2015). Recall dynamics reveal the retrieval of emotional context. *Psychonomic Bulletin & Review*, *22*(5), 1328–1333. https://doi.org/10.3758/s13423-014-0791-2

Luminet, O., Bouts, P., Delie, F., Manstead, A. S. R., & Rime, B. (2000). Social sharing of emotion following exposure to a negatively valenced situation. *Cognition & Emotion*, *14*(5), 661–688. https://doi.org/10.1080/02699930050117666

Mandler, G. (1967). Organization and memory. In K. W. Spence & J. T. Spence (Eds.), *Psychology of learning and motivation* (Vol. 1, pp. 327–372). Academic Press. https://doi.org/10.1016/S0079-7421(08)60516-2

Mandler, J. M., & Johnson, N. S. (1977). Remembrance of things parsed: Story structure and recall. *Cognitive Psychology*, *9*(1), 111–151. https://doi.org/10.1016/0010-0285(77)90006-8

Manning, J. R., & Kahana, M. J. (2012). Interpreting semantic clustering effects in free recall. *Memory*, *20*(5), 511–517. https://doi.org/10.1080/09658211.2012.683010

Manning, S. K., & Julian, L. (1975). Recall of emotional words. *Journal of General Psychology*, *92*(2), 237–244. https://doi.org/10.1080/00221309.1975.9710849

Marion, S. B., & Thorley, C. (2016). A meta-analytic review of collaborative inhibition and postcollaborative memory: Testing the predictions of the retrieval strategy disruption hypothesis. *Psychological Bulletin*, *142*(11), 1141–1164. https://doi.org/10.1037/bul0000071

Maswood, R., & Rajaram, S. (2018). Social transmission of false memory in small groups and large networks. *Topics in Cognitive Science*, *11*(4), 687–709. https://doi.org/10.1111/tops.12348

Maswood, R., Rasmussen, A. S., & Rajaram, S. (2019). Collaborative remembering of emotional autobiographical memories: Implications for emotion regulation and collective memory. *Journal of Experimental Psychology: General*, *148*(1), 65–79. https://doi.org/10.1037/xge0000468

McClay, M., Sachs, M. E., & Clewett, D. (2023). Dynamic emotional states shape the episodic structure of memory. *Nature Communications*, *14*(1), Article 6533. https://doi.org/10.1038/s41467-023-42241-2

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

Mulligan, N. W. (2002). The emergence of item-specific encoding effects in between-subjects designs: Perceptual interference and multiple recall tests. *Psychonomic Bulletin & Review*, *9*(2), 375–382. https://doi.org/10.3758/BF03196296

Mulligan, N. W. (2005). Total retrieval time and hypermnesia: Investigating the benefits of multiple recall tests. *Psychological Research*, *69*(4), 272–284. https://doi.org/10.1007/s00426-004-0178-5

Mutlutürk, A., Tekcan, A. İ., & Boduroglu, A. (2023). The structure and organization of collective memory representations. *Memory Studies*, *16*(5), 1343–1359. https://doi.org/10.1177/1750698020988778

Myers, J. L., Pezdek, K., & Coulson, D. (1973). Effect of prose organization upon free recall. *Journal of Educational Psychology*, *65*(3), 313–320. https://doi.org/10.1037/h0035507

Neath, I., & Surprenant, A. M. (2009). *Principles of memory*. Psychology Press.

Neisser, U. (1998). Stories, selves, and schemata: A review of ecological findings. In M. A. Conway, S. E. Gathercole, & C. Cornoldi (Eds.), *Theories of memory II* (pp. 171–186). Psychology Press. https://doi.org/10.4324/9781315804507

Nguyen, M., Chang, A., Micciche, E., Meshulam, M., Nastase, S. A., & Hasson, U. (2022). Teacher–student neural coupling during teaching and learning. *Social Cognitive and Affective Neuroscience*, *17*(4), 367–376. https://doi.org/10.1093/scan/nsab103

Nili, H., Wingfield, C., Walther, A., Su, L., Marslen-Wilson, W., & Kriegeskorte, N. (2014). A toolbox for representational similarity analysis. *PLOS Computational Biology*, *10*(4), Article e1003553. https://doi.org/10.1371/journal.pcbi.1003553

Ortmann, A. F., Bixter, M. T., & Luhmann, C. C. (2024). Great minds think alike: New measures to quantify the similarity of recalls. *Behavior Research Methods*, *56*(5), 4239–4254. https://doi.org/10.3758/s13428-023-02174-6

Parkinson, C., Kleinbaum, A. M., & Wheatley, T. (2017). Spontaneous neural encoding of social network position. *Nature Human Behaviour*, *1*(5), Article 0072. https://doi.org/10.1038/s41562-017-0072

Peker, M., & Tekcan, A. İ. (2009). The role of familiarity among group members in collaborative inhibition and social contagion. *Social Psychology*, *40*(3), 111–118. https://doi.org/10.1027/1864-9335.40.3.111

Pepe, N. W., Wang, Q., & Rajaram, S. (2021). Collaborative remembering in ethnically uniform and diverse group settings. *Journal of Applied Research in Memory and Cognition*, *10*(1), 95–103. https://doi.org/10.1016/j.jarmac.2020.08.001

Pereira-Pasarin, L. P., & Rajaram, S. (2011). Study repetition and divided attention: Effects of encoding manipulations on collaborative inhibition in group recall. *Memory & Cognition*, *39*(6), 968–976. https://doi.org/10.3758/s13421-011-0087-y

Phelps, E. A. (2004). Human emotion and memory: Interactions of the amygdala and hippocampal complex. *Current Opinion in Neurobiology*, *14*(2), 198–202. https://doi.org/10.1016/j.conb.2004.03.015

Polyn, S. M., Norman, K. A., & Kahana, M. J. (2009). A context maintenance and retrieval model of organizational processes in free recall. *Psychological Review*, *116*(1), 129–156. https://doi.org/10.1037/a0014420

Puff, C. R. (1979). *Memory organization and structure*. Academic Press.

Rabb, N., Fernbach, P. M., & Sloman, S. A. (2019). Individual representation in a community of knowledge. *Trends in Cognitive Sciences*, *23*(10), 891–902. https://doi.org/10.1016/j.tics.2019.07.011

Rabb, N., Han, J., & Sloman, S. (2021). How others drive our sense of understanding of policies. *Behavioural Public Policy*, *5*(4), 454–479. https://doi.org/10.1017/bpp.2020.40

Rajaram, S. (2024). Collaborative remembering and collective memory. In M. J. Kahana & A. D. Wagner (Eds.), *The Oxford handbook of human memory, two volume pack: Foundations and applications* (pp. 2169–2192).

Oxford University Press. https://doi.org/10.1093/oxfordhb/9780190917982.001.0001

Rajaram, S., Greeley, G. D., & Peña, T. (2024). Collaborative memory: A selective review. In J. H. Byrne (Ed.), *Reference module in neuroscience and biobehavioral Psychology* (2nd ed., pp. 53–70). Academic Press. https://doi.org/10.1016/B978-0-443-15754-7.00045-6

Rajaram, S., & Pereira-Pasarin, L. P. (2010). Collaborative memory: Cognitive research and theory. *Perspectives on Psychological Science*, *5*(6), 649–663. https://doi.org/10.1177/1745691610388763

Reagh, Z. M., & Ranganath, C. (2023). Flexible reuse of cortico-hippocampal representations during encoding and recall of naturalistic events. *Nature Communications*, *14*(1), Article 1279. https://doi.org/10.1038/s41467-023-36805-5

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

Roediger, H. L., III, & Wertsch, J. V. (2022). *National memories: Constructing identity in populist times*. Oxford University Press. https://doi.org/10.1093/oso/9780197568675.001.0001

Roenker, D. L., Thompson, C. P., & Brown, S. C. (1971). Comparison of measures for the estimation of clustering in free recall. *Psychological Bulletin*, *76*(1), 45–48. https://doi.org/10.1037/h0031355

Ross, M., Spencer, S. J., Linardatos, L., Lam, K. C. H., & Perunovic, M. (2004). Going shopping and identifying landmarks: Does collaboration improve older people's memory? *Applied Cognitive Psychology*, *18*(6), 683–696. https://doi.org/10.1002/acp.1023

Schacter, D. L., & Scarry, E. (2001). *Memory, brain, and belief*. Harvard University Press.

Sederberg, P. B., Howard, M. W., & Kahana, M. J. (2008). A context-based theory of recency and contiguity in free recall. *Psychological Review*, *115*(4), 893–912. https://doi.org/10.1037/a0013396

Shepard, R. N., & Chipman, S. (1970). Second-order isomorphism of internal representations: Shapes of states. *Cognitive Psychology*, *1*(1), 1–17. https://doi.org/10.1016/0010-0285(70)90002-2

Shimmerlik, S. M. (1978). Organization theory and memory for prose: A review of the literature. *Review of Educational Research*, *48*(1), 103–120. https://doi.org/10.3102/00346543048001103

Siddiqui, A. P., & Unsworth, N. (2011). Investigating the role of emotion during the search process in free recall. *Memory & Cognition*, *39*(8), 1387–1400. https://doi.org/10.3758/s13421-011-0125-9

Sternberg, R. J., & Tulving, E. (1977). The measurement of subjective organization in free recall. *Psychological Bulletin*, *84*(3), 539–556. https://doi.org/10.1037/0033-2909.84.3.539

Stone, C. B., Barnier, A. J., Sutton, J., & Hirst, W. (2010). Building consensus about the past: Schema consistency and convergence in socially shared retrieval-induced forgetting. *Memory*, *18*(2), 170–184. https://doi.org/10.1080/09658210903159003

Szőllősi, Á., & Racsmány, M. (2020). Enhanced mnemonic discrimination for emotional memories: The role of arousal in interference resolution. *Memory & Cognition*, *48*(6), 1032–1045. https://doi.org/10.3758/s13421-020-01035-3

Takahashi, M., & Saito, S. (2004). Does test delay eliminate collaborative inhibition? *Memory*, *12*(6), 722–731. https://doi.org/10.1080/09658210344000521

Talmi, D., Lohnas, L. J., & Daw, N. D. (2019). A retrieved context model of the emotional modulation of memory. *Psychological Review*, *126*(4), 455–485. https://doi.org/10.1037/rev0000132

Tambini, A., Rimmele, U., Phelps, E. A., & Davachi, L. (2017). Emotional brain states carry over and enhance future memory formation. *Nature Neuroscience*, *20*(2), 271–278. https://doi.org/10.1038/nn.4468

Thorley, C., & Dewhurst, S. A. (2007). Collaborative false recall in the DRM procedure: Effects of group size and group pressure. *European Journal of Cognitive Psychology*, *19*(6), 867–881. https://doi.org/10.1080/09541440600872068

Thorley, C., & Dewhurst, S. A. (2009). False and veridical collaborative recognition. *Memory*, *17*(1), 17–25. https://doi.org/10.1080/09658210802484817

Tulving, E. (1962). Subjective organization in free recall of "unrelated" words. *Psychological Review*, *69*(4), 344–354. https://doi.org/10.1037/h0043150

Tulving, E. (1966). Subjective organization and effects of repetition in multi-trial free-recall learning. *Journal of Verbal Learning and Verbal Behavior*, *5*(2), 193–197. https://doi.org/10.1016/S0022-5371(66)80016-6

Umanath, S., & Abel, M. (2022). United States and Germany's collective memories of pride and shame for american and german history. In H. L. Roediger, III & J. V. Wertsch (Eds.), *National memories: Constructing identities in populist times* (pp. 236–254). Oxford University Press.

Visser, R. M., Scholte, H. S., Beemsterboer, T., & Kindt, M. (2013). Neural pattern similarity predicts long-term fear memory. *Nature Neuroscience*, *16*(4), 388–390. https://doi.org/10.1038/nn.3345

Visser, R. M., Scholte, H. S., & Kindt, M. (2011). Associative learning increases trial-by-trial similarity of BOLD-MRI patterns. *The Journal of Neuroscience*, *31*(33), 12021–12028. https://doi.org/10.1523/JNEUROSCI.2178-11.2011

Vlasceanu, M., Morais, M. J., Duker, A., & Coman, A. (2020). The synchronization of collective beliefs: From dyadic interactions to network convergence. *Journal of Experimental Psychology: Applied*, *26*(3), 453–464. https://doi.org/10.1037/xap0000265

Vygotsky, L. S. (1980). *Mind in society: Development of higher psychological processes* (M. Cole, V. John-Steiner, S. Scribner, & E. Souberman, Eds.). Harvard University Press. https://doi.org/10.2307/j.ctvjf9vz4

Wang, B., Cheng, C., Jin, Z., Wu, S., & Xiang, L. (2021). The influence of negative emotional intensity on dual-processing recognition. *Biological Psychology*, *161*, Article 108083. https://doi.org/10.1016/j.biopsycho.2021.108083

Wang, Q., & Fivush, R. (2005). Mother–child conversations of emotionally salient events: Exploring the functions of emotional reminiscing in European-American and Chinese families. *Social Development*, *14*(3), 473–495. https://doi.org/10.1111/j.1467-9507.2005.00312.x

Weldon, M. S. (2001). Remembering as a social process. In D. L. Medin (Ed.), *The psychology of learning and motivation: Advances in research and theory* (Vol. 40, pp. 67–120). Academic Press.

Weldon, M. S., & Bellinger, K. D. (1997). Collective memory: Collaborative and individual processes in remembering. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *23*(5), 1160–1175. https://doi.org/10.1037/0278-7393.23.5.1160

Wertsch, J. V. (2008). The narrative organization of collective memory. *Ethos*, *36*(1), 120–135. https://doi.org/10.1111/j.1548-1352.2008.00007.x

Wertsch, J. V., & Roediger, H. L. I., III. (2008). Collective memory: Conceptual foundations and theoretical approaches. *Memory*, *16*(3), 318–326. https://doi.org/10.1080/09658210701801434

Wessel, I., Zandstra, A. R. E., Hengeveld, H. M. E., & Moulds, M. L. (2015). Collaborative recall of details of an emotional film. *Memory*, *23*(3), 437–444. https://doi.org/10.1080/09658211.2014.895384

Williams, S. E., Ford, J. H., & Kensinger, E. A. (2022). The power of negative and positive episodic memories. *Cognitive, Affective, & Behavioral Neuroscience*, *22*(5), 869–903. https://doi.org/10.3758/s13415-022-01013-z

Wissman, K. T., & Rawson, K. A. (2015). Why does collaborative retrieval improve memory? Enhanced relational and item-specific processing. *Journal of Memory and Language*, *84*, 75–87. https://doi.org/10.1016/j.jml.2015.05.003

Wissman, K. T., & Rawson, K. A. (2016). How do students implement collaborative testing in real-world contexts? *Memory*, *24*(2), 223–239. https://doi.org/10.1080/09658211.2014.999792

Xie, W., & Zhang, W. (2017). Negative emotion enhances mnemonic precision and subjective feelings of remembering in visual long-term memory. *Cognition*, *166*, 73–83. https://doi.org/10.1016/j.cognition.2017.05.025

Yamashiro, J. K., & Hirst, W. (2014). Mnemonic convergence in a social network: Collective memory and extended influence. *Journal of Applied*

Research in Memory and Cognition, *3*(4), 272–279. https://doi.org/10.1016/j.jarmac.2014.08.001

Yaron-Antar, A., & Nachson, I. (2006). Collaborative remembering of emotional events: The case of Rabin's assassination. *Memory*, *14*(1), 46–56. https://doi.org/10.1080/09658210444000502

Yonelinas, A. P., & Ritchey, M. (2015). The slow forgetting of emotional episodic memories: An emotional binding account. *Trends in Cognitive Sciences*, *19*(5), 259–267. https://doi.org/10.1016/j.tics.2015.02.009

Zadbood, A., Chen, J., Leong, Y. C., Norman, K. A., & Hasson, U. (2017). How we transmit memories to other brains: Constructing shared neural representations via communication. *Cerebral Cortex*, *27*(10), 4988–5000. https://doi.org/10.1093/cercor/bhx202

Zaromb, F. M., & Roediger, H. L., III. (2010). The testing effect in free recall is associated with enhanced organizational processes. *Memory & Cognition*, *38*(8), 995–1008. https://doi.org/10.3758/MC.38.8.995

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