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Collaborative recall in face-to-face and electronic groups

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When people remember shared experiences, the amount they recall as a collaborating group is less than the amount obtained by pooling their individual memories. We tested the hypothesis that reduced group productivity can be attributed, at least in part, to content filtering, where information is omitted from group products either because individuals fail to retrieve it or choose to withhold it (self-filtering), or because groups reject or fail to incorporate it (group-filtering). Three-person groups viewed a movie clip together and recalled it, first individually, then in face-to-face or electronic groups, and finally individually again. Although both kinds of groups recalled equal amounts, group-filtering occurred more often face-to-face, while self-filtering occurred more often electronically. This suggests that reduced group productivity is due not only to intrapersonal factors stemming from cognitive interference, but also to interpersonal costs of coordinating the group product. Finally, face-to-face group interaction facilitated subsequent individual recall.

Traditionally, research on human memory has treated recall as a purely intra-personal process, by focusing on cognitive processing by individuals recalling alone. In everyday life, however, recall is often an interpersonal process in which one person recounts an experienced event to another who was not present, or in which people reconstruct an event they have experienced together. What they recall does *not* take the form of an orderly list of items, but may consist instead of proposals, elaborations, comments, expressions of uncertainty, and invitations to agree or disagree. Consider this exchange among three volunteers in our collaborative memory experiment, recalling a movie they saw together:

A: yeah, and that–
the kid was like talking,
something
L: yeah he was talking
that's why he got in trouble
he was whispering in some kid's ear about something?
A: yeah
L: um
...
then he gets punished or whatever?
D: what was that, a wreath or
L: yeah it was some kind of browny–
A: yeah it was some kind of straw thing or something
L: mhm

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D: around his neck
L: so that everybody knew what he did or something?

As A, L, and D reconstruct what they saw together, they take turns (in no predetermined order). A begins with a vague proposal, which L elaborates by providing details that she seems to invite A to ratify (and he does so). L continues with another instalment, which D confirms by proposing a detail that is in turn confirmed with additional information provided by both L and A. The resulting product is richly detailed and reconstructed jointly, sometimes with one person completing another's utterance. The speakers display their confidence (or lack of confidence) about what they present, using hedges and rising intonation. After each presentation, the others display acceptance or uptake either with direct evidence (e.g., an acknowledgment such as "mhm") or indirectly (by offering the next instalment). The point is that when people recall events together, the product is shaped by their interaction. Remembering in a social context is a function of both intrapersonal and interpersonal actions, including the cognitive and communicative behaviours by which members evaluate, pool, and assemble their resources (Steiner, 1972).

It is evident from the example that people recalling together can cue each other, which supports the expectation that a person recalling in the context of a group might be more productive than one recalling alone. This reasoning was pursued by Edwards and Middleton (1986) who analysed the collaborative recall of a popular film, finding examples where one person's recollections seemed to serve as a recall cue for another. Another way in which collaboration might boost collective memory performance, but at the encoding stage, has been labelled *transactive memory* by Wegner (1987); the idea is that pairs of collaborators who know each other well can judge how best to distribute the labour of encoding information, based on what each partner knows about the other's expertise. Within the transactive memory framework, it has been shown that pairs of friends perform better together than do pairs of strangers (Hollingshead, 1998; Wegner, Erber, & Raymond, 1991). The transactive memory approach tends to focus on the process of communication during encoding; for instance, Hollingshead (1998) found that dating couples were better at pooling their knowledge when they interacted face-to-face than when they interacted electronically.

Although "two heads are better than one", in that people working together recall more than one person working alone, it is striking that collaborating groups do not recall as much as would be expected from combining individual products into nominal group products (formed by additively pooling non-redundant products of the same number of individuals who recalled alone). The finding that real groups recall less than nominal groups is highly robust (e.g., Basden, Basden, Bryner, & Thomas, 1997; N. Clark, Stephenson, & Kniveton, 1990; Finlay, Hitch, & Meudell, 2000; Hartwick, Sheppard, & Davis, 1982; Morrissett, Crannell, & Switzer, 1964; Stephenson, N. Clark, & Wade, 1986; Weldon & Bellinger, 1997; Weldon, Blair, & Huebsch, 2000; Wright & Klumpp, 2004). Additive models based on individual performance (e.g., Lorge & Solomon, 1955) simply do not scale up to what happens in real groups. What causes this loss of productivity?

One possibility researchers have considered is social loafing. Social loafing is a reduction in motivation and effort that may occur when individuals work collectively (to produce one group product) compared with working alone. Variables associated with social loafing include diffusion of responsibility, evaluation potential, and evaluation apprehension (see Karau & Williams, 1993 for review). Weldon et al. (2000) investigated this explanation for under-performance in group recall by manipulating motivation, evaluation apprehension, personal accountability, and group cohesion. None of these manipulations eliminated the inequality between nominal and collaborative group products, leading Weldon et al. to conclude that lower-than-expected productivity in groups was not due to motivational factors. It is possible, however, that other manipulations may support a social loafing explanation; for instance, if the submergence of individuals in a group provides a cloak of anonymity that allows them to reduce their effort, then electronic groups (where members interact by typing and have a harder time tracking who has typed what because they cannot see or hear one another) may recall less than face-to-face groups (see Diener, 1979; Kiesler, Siegel, & McGuire, 1984; Williams, 1977, for some comparisons of face-to-face and computer-mediated behaviour).

As research on recall by collaborating groups has burgeoned in recent years, reduced group productivity has also been explained in cognitive terms, as *collaborative inhibition* (see Basden et al., 1997; Weldon & Bellinger, 1997). The idea is that hearing other people's contributions disrupts individual organisational and retrieval strategies, an effect similar to part-set cueing inhibition, whereby providing (at recall time) some items from a studied list inhibits the retrieval of the remaining list items (for a review of part-set cueing, see Anderson & Neely, 1996; see also Basden & Basden, 1995, on part-set cueing as strategy disruption, and Diehl & Stroebe, 1991, on ''production blocking''). In studies that involve recall of word lists, the words recalled tend to be ordered by category (both within an individual's contributions and across individuals' contributions), suggesting that when one person switches from one to another category, this disrupts their partners' recall of remaining items from the first category (Basden, Basden, & Stephens, 2002; Basden et al., 1997; Finlay et al., 2000).

Although disruption of the organisation of memory is a plausible explanation for reduced group productivity for recall of arbitrary items such as lists of words, it is less satisfying for naturalistic material, such as the episode co-recalled in our opening example. Unlike a list of words, a story has meaning, coherence, and an inherent organisation that typically depends on the logical flow of events. Indeed, there is some evidence that cueing inhibition is less of a problem for meaningful, well-integrated memories (Basden et al., 1997). Basden et al.'s (1997) results show that when highly organised material (e.g., small categories of items) is used in recall, collaborating groups are sometimes capable of recalling as many category items as nominal groups. This result was attributed to well-organised materials leaving little room for idiosyncratic organisation (Basden et al., 1997). However, Weldon and Bellinger (1997), Experiment 2) used an audio recording of the ''War of the Ghosts'' story (first used by Bartlett, 1932) to test recall during two sessions, performed by individuals either alone or in three-person groups. The puzzle is that even though groups possessed shared knowledge of the story's organisation that they could use as a retrieval strategy, real groups *still* under-performed compared to nominal groups.

We propose that collaborative inhibition is not the only force behind reduced group productivity in real-world settings. Notably, most studies to date have considered the *products* of group recall, but not the interactive, interpersonal *process* by which these products emerge. In fact, some studies have eliminated interaction altogether by ruling out communication or limiting initiative by group members, forcing them to take ordered rather than spontaneous turns contributing items to the group product (e.g., Basden, Basden, & Henry, 2000; Wright & Klumpp, 2004). Some studies have emphasised stable input factors that are determined in advance, like group composition (e.g., Stephenson, Brandstätter, & Wagner, 1983; Stephenson et al., 1986; Vollrath, Sheppard, Hinsz, & Davis, 1989; Weldon et al., 2000) and encoding conditions (e.g., Finlay et al., 2000; Weldon et al., 2000), testing the impact of these input factors on group output. This highly controlled approach is useful for zeroing in on collaborative inhibition by itself, but rules out additional processes that, we propose, can fundamentally shape recall in small, interacting groups.

It stands to reason that the process of collaborating can affect group recall. To investigate this possibility, we look not only at group recall *products*, but also at the dynamically emerging behaviours through which group products are realised, that is, the group *process*. ''Process'' here refers to what Steiner (1972) described as the individual or collective actions of people assigned to do a task, including actions both intrapersonal and interpersonal, as well as the intellectual and communicative behaviours by which they evaluate, pool, and assemble their resources. We propose that reduced productivity in collaborative recall is affected by processes occurring at both individual and group levels.

At the individual level, there are various reasons why items that a group member is capable of recalling alone might fail to make it into the group product. Retrieval failure due to collaborative inhibition is only one of them. There may be instances where an individual actually recalls an item and intends to contribute it, but forgets to do so. There may also be instances where an individual intentionally chooses not to contribute a recalled item to the group product. This could occur when an individual is not confident enough about the accuracy or relevance of the item, or anticipates that it may be difficult to get the item accepted by the group, or finds the item too costly or difficult to express

to the group. In this study, we label as *self-filtering* all instances where items previously recalled by an individual are not presented to the group (and we will return to these kinds of self-filtering in the discussion).

At the group level as well, items recalled and presented to the group by individuals may fail to make it into the group product. An item may be unintentionally omitted if it doesn't get recorded and no one notices, or it may be intentionally omitted because another group member either overtly or covertly rejects it. Furthermore, if a group sets a goal or criterion, formally or informally, members may feel pressured to go along with it. In the case of story recall, for example, findings by Stephenson et al. (1986) suggest that groups adopt a strategy of tracing the chronological development of events, with emphasis placed on the main ideas of the story. It is possible, however, that the ''programme'' the group has set for itself might not accommodate all the memories of its members, leading to the suppression of certain items in deference to the group goal. Stephenson et al. (1986) subsequently concluded that collaboration led to the selection of ideas from the total pool of available individual ideas, based on the group's decision as to what was appropriate to talk about. However, their method did not distinguish whether the initiative for selecting information occurred at the group or the individual level. Examining the contents of individual and group recall products and comparing them to transcripts of groups' communication will, we propose, shed some light on the processes involved. In the current study, we label as *group filtering* all instances where items recalled and actually presented by individuals during the group session do not make it into the official group product.

In order to understand the impact of coordination on collective recall, we will compare situations in which the coordination costs are different. When people interact, the medium in which they do so shapes how they coordinate their activities. A particular medium makes some things easier and others, harder (Brennan & Lockridge, 2006; Clark & Brennan, 1991). For instance, speech is fairly effortless for most people to produce (but is ephemeral), whereas typing is slower and more difficult (but creates a representation that can be reviewed and edited). These costs and affordances shape the ways in which people distribute their initiative within a group. Elsewhere, we have used this *grounding framework* (Clark & Wilkes-Gibbs, 1986) to predict and explain differences that emerge between electronic vs face-to-face groups (Brennan & Ohaeri, 1999); we will appeal to that framework here. Grounding is the process of seeking and providing evidence to establish mutual understanding with a partner (Brennan, 2005), and holds that collaborators seek to minimise the effort they expend jointly (rather than just their individual effort; Clark & Wilkes-Gibbs, 1986). Collaborative recall involves not only retrieving information from memory (a step presumably sensitive to collaborative inhibition), but also evaluating that information as to its correctness and suitability for being included in a collective product. Initiative for the latter step can be taken by the individual (self-filtering) or ceded to the group (when the individual presents items, even low-confidence ones, for the group to accept or reject). The grounding framework predicts that when group members can see and hear each other, and easily produce speaking turns and nonverbal cues, individuals should rely more on other group members to assess and filter items for the collective product. When the cost of producing a turn or getting a response is higher (as it is for typing and then waiting for a response to come back), then it is more efficient for individuals to self-filter their contributions to the collective product.

When people interact they are driven not only by task-related needs, but also by social needs or ''face management'', which include preserving one's own self-esteem, not threatening that of others, providing options to others, not imposing, and showing solidarity (Brown & Levinson, 1978). If one group member presents an idea she is uncertain about (especially if the other members might recall it correctly), she risks losing face unless she indicates that uncertainty. And if another group member explicitly rejects her idea, he risks insulting her. In both cases, group members who have nonverbal options for expressing uncertainty about their own and each other's ideas should find it easier to negotiate which propositions that come up during the interaction survive to make it into the collective recall product. Elsewhere we have found that face-management costs differ in face-to-face versus electronic interaction (Brennan & Ohaeri, 1999).

Our main goals in this paper are to investigate the source of productivity loss in collaborative groups as compared to nominal groups, and to examine the impact of recalling in groups on

recall by individuals later on. We did this by having triads of participants (who were strangers) recall a movie that they had watched in groups of three. They recalled first alone, then in groups interacting spontaneously either face-to-face or electronically, and finally alone again. This design provided an initial baseline for examining the impact of recall in groups, as well as an opportunity to test the impact of group recall on subsequent individual recall. We examined the content of collective recall products, as did previous studies, but we also compared the group product to what group members said as they discussed and produced it. Finally, we manipulated the instructions given to face-to-face groups: half of our face-to-face groups were explicitly instructed to come to a consensus on all submitted material and half were not. We added this manipulation to check for the possibility that group productivity might suffer due to failure to achieve consensus. In many previous studies of collaborative recall (e.g., N. Clark et al., 1990; Hartwick et al., 1982; Hollin & Clifford, 1983; Stephenson et al., 1983, 1986, 1991; Vollrath et al., 1989; Warnick & Sanders, 1980) groups were explicitly instructed to reach consensus. However, we did not make any predictions with regard to this manipulation. We summarise our predictions as follows:

- Group recall products will be greater than initial individual recall products, not only in the quantity of propositions recalled but also in their quality (with more correct and fewer incorrect items), due to groups having more resources for correcting errors than do individuals.
- As in previous studies, interacting groups will under-perform compared to nominal groups. This will be due to filtering mechanisms on the part of both group and individuals.
- If social loafing were a significant force, face-to-face groups should recall more propositions than electronic groups because members are more identifiable when they can see and hear one another. However, consistent with the grounding framework, we predict that both kinds of groups will adjust their joint effort to do the collective recall task equally well (producing products of equivalent quantity and quality).
- Group members will distribute their filtering efforts according to the costs of coordinating individual actions within the communication medium. There should be more group-filtering face-to-face, and more self-filtering with electronic text communication.
- If groups indeed have superior resources for filtering out incorrect items and reinforcing items that an individual member did not recall alone, then recalling in a group should improve the subsequent solitary recall (individuals should recall more after recalling in a group with other people than before). A post-group boost in recall by individuals should be especially likely when the communication medium affords easy-to-use mechanisms for proposing and ratifying contributions to the joint product (e.g., as nonverbal cues do when people interact face-to-face).

METHOD

Participants

A total of 130 Stony Brook University undergraduates volunteered to participate in exchange for two research credits that they could use to satisfy a requirement in a psychology class. Participants were required to be native speakers of English and to be able to type. They were also required not to have seen the movie *The Secret of Roan Inish*. The experiment took approximately 3 hours. A total of 39 participants were tested in three-person groups in the electronic condition (with consensus requirement), 39 were tested in three-person groups in the face-to-face condition (with consensus requirement), 39 were tested in three-person groups in the face-to-face condition (without consensus requirement), and 13 were tested alone in the control condition. Group members were grouped according to the appointment times they happened to sign up for, and groups were randomly assigned to conditions; no attempt was made to balance for gender composition. Approximately 70% of the participants were female.

Design

We tested the effects of repeated recall within subjects; each participant in the experimental conditions was first tested alone (Session 1),

then in collaboration with two other participants (Session 2), and finally alone again (Session 3). Session 1 provided a baseline for what each participant could recall alone, and Session 3 provided a measure of the strength of the group's influence on individual memories. The second variable, communication medium (face-to-face vs electronic), was tested between subjects; collaborating groups during Session 2 were tested in either the face-to-face (speech) or the electronic (text) condition. A third variable, instructions, was tested between subjects; the groups in Session 2 interacted with or without an explicit requirement to reach consensus. This variable was manipulated for face-to-face groups only, as a check on whether three people recalling together would attempt to reach consensus naturally, and so that the results would be comparable to previous face-to-face studies in which consensus was required. In sum, there were three group conditions for Session 2, each involving 13 three-person groups: Electronic (with consensus), Face-to-face (with consensus), and Face-to-face (without consensus).

A total of 13 additional participants were tested alone over three recall sessions to provide a control condition in order to provide a potential baseline for other known influences on repeated recall: (1) a possible fading of memory over time and (2) hypermnesia, or ''net improvements in recall across tests'' (Wheeler & Roediger, 1992, p. 241).

Materials

All participants viewed an 8-minute clip from a John Sayles film (*The Secret of Roan Inish*), of an old man telling a story to his granddaughter. The presentation was on a 19-inch colour television screen. Electronic collaboration was carried out using networked Macintosh computers with 16-inch monitors and Aspects™, a collaboration software program by Logic Technologies. For the electronic condition, a chat window and a blank document for text editing were opened side-by-side. The chat window was used for idea presentation and discussion and indicated which individuals (identified only by the labels A, B, or C) produced which statements. The text document was used to paste and edit the group recall product. The two windows were displayed side by side on each group member's monitor, so that information in the chat and text windows was shared by all three group members. At the bottom of the chat window was an edit window for typing contributions. This was the only space that was not shared; that is, the edit window was visible only to the person typing in it. Ideas were then sent to the chat window by hitting the ''Return'' button. All editing was done in the edit window (and edits not sent to the chat window were not permanently recorded); once ideas were sent to the chat window, they could not be edited. The text document was fully editable, but only by the designated scribe.

Procedure

Study phase. Each three-person group watched the movie clip together in the same room, after being instructed to pay close attention to what happened in the movie. Then participants did a 5-minute distractor task (listing as many countries as they could think of). In the control condition, each participant watched the clip alone and then did the same distractor task.

Session 1 test: Pre-group individual recall. Following the distractor task, each participant was seated in a separate room (with closed door) where they typed their recollections using Microsoft WORD. They were instructed to recall as much of the movie as they could and to be as complete and accurate as possible. There was no time limit imposed on this task. Group members who finished first stayed in their rooms and waited for the others. When all were finished, they rejoined the group.

Session 2 test: Group recall. Following the pre-group session, participants were assigned to one of the three collaborative group conditions: face-to-face (with a consensus requirement), face-to-face (without a consensus requirement), or electronic (with a consensus requirement). In the face-to-face conditions, a tape-recorder and microphone were set up beside the computer to record all spoken discussion by the group, and the three group members sat around one computer, so that all could see the monitor. Before the session began, the experimenter asked for one member to volunteer as the session scribe, responsible for typing up the group's product. If no one volunteered, the experimenter randomly assigned this role to one of the members. Typing (rather than handwriting) was required to allow face-to-face groups the same editing capability as electronic groups. In the electronic condition, after brief instruction on

how to use the collaboration software, participants were sent to their separate rooms. As in the face-to-face condition, one participant had the task of pulling the group product together onto the text document. While all participants could see and comment on what was written on the text document, only the assigned person could write in it. A transcript of the session (both chat and text windows) was saved.

Group members were instructed to discuss the story with one another and to come up with a group account of the story. Groups with a consensus requirement were further instructed to include only those items that they could all agree on; those without the requirement were not given explicit instructions about agreement. There was no time limit set on this task.

Session 3 test: Post-group individual recall. After Session 2, documents were again saved and closed, and blank ones were opened. Participants were then asked to recall the film clip alone in their separate rooms one last time. As in the other sessions, there was no time limit. After this session, participants were debriefed, thanked for their help, and dismissed.

Coding

Two undergraduate research assistants naive to the experimental hypotheses were trained by the first author to do the coding. First, the coders watched the movie clip a couple of times to become familiar with the story. They were also provided with a written transcript of the clip, to serve as a reference in coding what had been correctly recalled from the stimulus. Coding was done in several phases, as follows.

Segmenting recall products. Products from Sessions 1, 2, and 3 were segmented into propositions that contributed new information. Noun phrases indicating place or sequence of events, descriptive adjectives, temporal and spatial locatives, and quantities were coded as independent propositions. Proper names or other references to individuals, as well as adjectives, were counted at first mention only (redundant expressions were not counted). For example, ''an old wrinkly man'' was counted as three propositions at first occurrence but was not subsequently segmented in reference to the same man. Phrases containing no information relevant to the content of the story (e.g., ''she said something here but I forgot what it was'') were not coded. Verb phrases were segmented into propositions as follows. For intransitive verbs, the propositional unit cut-off was after the verb. For sentences with transitive verbs the cut-off was after the object of the sentence. However, for sentences that also contained proper names, adjectives, etc. this transitive/intransitive rule was overridden in order to identify these items as independent propositions (see http://www.psychology.sunysb.edu/sbrennan-/memory.htm for a sample segmented file).

Categorising recall products. Propositions were coded into four mutually exclusive categories: *Correct* details of the story (whether central or peripheral); *inferred* details, consistent with the story, but not explicitly depicted; *meta-statements*, including, for instance, comments on story structure, expressions of the participant's attitude towards an event, or judgements about characters (Clark, Stephenson, & Kniveton, 1990): and *incorrect* information. Note that mis-identifying a character at first mention was coded as an incorrect proposition. However, if the information subsequently provided in relation to this character was correct (even if the identity was still wrong), the information was coded as correct (to avoid cascading errors).

Computing nominal products. For each group the three pre-group individual products were pooled, including redundant ideas only once. This yielded a measure of quantity (total propositions) but not quality for nominal groups, as it is not clear for a given item how to meaningfully combine errors with correct propositions.

Coding of group interaction transcripts. The audiotapes from the face-to-face group sessions were transcribed and double-checked for accuracy; the transcripts from electronic sessions were logged automatically. Word counts were computed for each group discussion (excluding unintelligible speech and nonverbal sounds such as laughter). Transcripts of the group sessions were organised into turns labelled with an identifying letter for each group member. Turns were segmented into propositions and classified using the same criteria and categories as for the recall products.

Finally, coded transcripts from the interactions in Session 2 were compared with the coded recall products from Sessions 1, 2, and 3. Propositions recalled by individuals in Session 1 and presented in Session 2 but not included in the official group product were coded as having been *group-filtered*.

Propositions appearing in the pre-group product (Session 1) but in neither the official product nor the interaction transcript from the group session (Session 2) were coded as having been *self-filtered*. Note that this category did not distinguish among items that failed to be retrieved, or that were recalled and forgotten before they could be presented, or that were recalled but intentionally withheld. Finally, propositions filtered out in the group session (by self or group) but reappearing in individual products in Session 3 were coded as having been *restored*. Incorrect items were examined to determine how many errors from group products persisted in post-group products.

Reliability. The coders received detailed written and verbal instructions from the lead author. They segmented a given recall product independently and then met to resolve any discrepancies, ending up with a single segmented file. Finally, they independently categorised the segmented propositions in this file. They did this for one entire individual and one entire group recall product, yielding 80% and 92% agreement, respectively (because individual protocols included more inferences, meta-statements, and peripheral information, additional instruction about those categories was provided).

Then both coders independently segmented and categorised an arbitrarily chosen set of 39 recall products and interaction transcripts (approximately 11% of all products and interaction transcripts from the experiment, which included 3 products from each of 13 controls plus 7 products each—3 in Session 1, 1 in Session 2, and 3 in Session 3—from the 39 triads, plus the 39 interaction transcripts from Session 2). To ensure that coding was consistent, coders then met to identify, discuss, and resolve any discrepancies in either segmentation or categorisation, agreeing on a single version of the coding for each file. The coders were then each randomly assigned to code the rest of the folders; the same person coded the pre- and post-group individual protocols, as well as the group product and session transcript, for a given group of three.

RESULTS

Analyses

We analysed recall products for both quantity and quality. Concerning quantity, mean numbers of propositions per product were compared for overall productivity. For quality, proportions of correct items, incorrect items, inferred items, and meta-statements were calculated for each product. Because some of the proportions were small for some of these categories (e.g., incorrect items), arcsine transformations were done on each proportion to normalise the distribution of values, as suggested by Lindman (1974). Unless otherwise specified, three-person groups were treated as the random factor. Repeated measures ANOVAs with session as a within factor and communication medium as a between factor were used to compare products of the 39 groups to mean individual recall products (each group's mean from Session 2 compared to the mean of its three individual members in Sessions 1 or 3), as well as for comparing pre- and post-group individual products.[1] ANOVAs (repeated measures wherever the same individuals were involved) were used for planned comparisons. Repeated measures ANOVAs were used to compare true group to nominal group products, as well as to look for hypermnesia by the 13 controls who recalled alone repeatedly.

Consensus requirement. There was no difference in productivity between face-to-face groups with the consensus instruction (79.69 propositions, $SD = 24.05$) and those without (76.08, $SD = 17.97$), $F(1, 24) = 0.19$, $MSE = 450.82$, *ns.* Neither were there any differences in the proportions of the different measurement categories. Consequently, to simplify the analyses, data from these two otherwise identical face-to-face conditions were collapsed (yielding 26 face-to-face groups and 13 electronic groups).

Recall by individuals, groups, and nominal groups

Total productivity. As expected, three-person groups (Session 2) recalled more propositions (with all measurement categories combined) from the film than did the average individual acting alone (Session 1), $F(1, 37) = 14.68$, $MSE = 334.22$, $p < .001$ (see Table 1). Also as expected, collaborative group products were smaller than nominal group products (the pooled

[1] Note that repeated measures comparisons of pre- and post-group individual products yielded the same results whether individual recall was compared for the 117 individual participants or collapsed into 39 three-person means, so for consistency we report the latter.

TABLE 1
Individual, collaborative group, nominal group, and post-group recall

	Recalled propositions included in product				
Condition	*Total*	*Correct*	*Incorrect*	*Inferred*	*Meta*[a]
Pre-group individual products					
M	64.00	55.73 (.87)[b]	4.58 (.07)	2.47(.04)	1.17(.02)
SD	14.79	13.48	1.84	1.15	1.43
Group products					
M	76.90	69.26 (.90)	4.23 (.06)	2.87(.04)	.79(.01)
SD	20.94	19.53	2.51	1.72	1.06
Nominal group products					
M	124.05	106.08 (.86)	8.95 (.07)	5.15(.04)	2.87(.02)
SD	26.51	24.90	4.38	2.84	4.11
Post-group individual products					
M	77.36	68.49(.88)	4.54(.06)	3.24(.04)	1.03(.01)
SD	19.73	18.74	2.07	1.27	1.04

[a]Meta-statements.
[b]Values in parentheses represent proportions of total product.

non-redundant items recalled by individual group members in Session 1), $F(1, 37) = 160.37$, $MSE = 259.51$, $p < .001$.

Product quality. Table 1 shows total numbers of items recalled, broken down into correct, incorrect, inferred, and meta-commentary. Group products were of higher quality than pre-group individual products: The proportion of correct items in group products was greater than that in pre-group individual products, $F(1, 37) = 14.91$, $MSE = .0027$, $p < .001$. Moreover, a lower proportion of errors were made in groups than had been made by the same people recalling alone in Session 1, $F(1, 37) = 10.83$, $MSE = .001$, $p = .002$. Individual products in Session 1 also tended to include more idiosyncratic commentary than did group products; the proportion of meta-statements was significantly greater in pre-group individual than group products, $F(1, 37) = 8.27$, $MSE = .00049$, $p = .007$. There was no difference in proportions of inferences made in Sessions 1 vs 2.

Productivity of face-to-face versus electronic groups

Total productivity. Only half as many words were typed by electronic groups as were spoken by face-to-face groups, $t(24) = 3.79$, $p < .001$. This is what we expected, as many of our participants were not fast typists (see Brennan & Ohaeri, 1999). However, electronic and face-to-face groups both did the task well, recalling equal quantities of propositions, $F(1, 37) = 0.17$, $MSE = 448.15$, *ns* (see Table 2).

Product quality. There were no significant differences between face-to-face and electronic groups (Session 2) in proportions of correct, incorrect, inferred, or meta-statement propositions (see Table 2).

Effects of recalling in groups on subsequent recall by individuals

Total productivity. Recalling the story as a group (Session 2) improved subsequent individual recall; individuals recalled an average of 13.36 more items in Session 3 than they had recalled in Session 1, $F(1, 37) = 22.31$, $MSE = 164.06$, $p < .001$. Participants in the control condition who recalled the film clip alone for all three sessions showed no productivity differences between Sessions 1, 2, and 3 (68.62, 68.85, and 67.15 propositions respectively, with *SD*s of 18.24, 20.48, and 19.80, respectively), $F(2, 24) = 0.29$, $MSE = 37.86$, *ns.* So hypermnesia (see Wheeler & Roediger, 1992) is not a likely explanation for the boost in post-group recall.

The communication medium used by a group *did* affect subsequent recall by its members; solitary recall after group recall interacted with the group's communication medium,

TABLE 2
Individual and collaborative recall for face-to-face and electronic groups

	Recalled propositions included in product				
Session	*[a]Total*	*Correct*	*Incorrect*	*Inferred*	*Meta[b]*
FTF groups N = 26 groups					
Pre-group individual products					
M	62.99	55.72(.88)[c]	3.91(.06)	2.40(.04)	.94(.02)
SD	16.65	15.00	1.57	1.11	.86
Group products					
M	77.88	70.62(.90)	3.81(.05)	2.88(.04)	.96(.01)
SD	20.89	20.29	2.14	1.77	1.22
Post-group individual products					
M	82.51	73.60(.89)	4.46(.06)	3.35(.04)	1.10(.01)
SD	20.84	19.79	1.79	1.33	1.01
Electronic groups N = 13 groups					
Pre-group individual products					
M	66.03	55.74(.84)	5.92(.09)	2.62(.04)	1.64(.03)
SD	10.41	10.31	1.61	1.27	2.15
Group products					
M	74.92	66.54(.89)	5.08(.06)	2.85(.04)	.46(.01)
SD	21.75	18.40	3.04	1.68	.52
Post-group individual products					
M	67.05	58.26(.87)	4.69(.07)	3.03(.05)	.87(.01)
SD	12.46	11.20	2.62	1.14	1.13

[a]Total propositions in recall product (correct + incorrect + inferred + meta-statements).
[b]Meta-statements.
[c]Values in parentheses represent proportions of total product.

$F(1, 37) = 7.35$, $MSE = 92.09$, $p = .01$ (see Figure 1). As Table 2 shows, individuals from face-to-face groups recalled 15.46 more items when working alone in Session 3 than did those from electronic groups, $F(1, 37) = 6.03$, $MSE = 343.68$, $p < .05$. This difference was apparently due to the experience of recalling in a face-to-face group, as there had been no initial productivity differences among these two randomly-assigned groups of individuals when they recalled alone in Session 1, $F(1, 37) = 0.36$, $MSE = 222.59$, *ns.* In fact, after collaborating face-to-face, individuals actually recalled 6% more (4.63 more items) in Session 3 than their groups had recalled together in Session 2, $F(1, 25) = 4.28$, $MSE = 64.98$, $p < .05$. Collaborative recall conducted via text was not so helpful for electronic groups; in fact, they recalled 7.87 marginally fewer items (11%) when working alone again in Session 3 than they had recalled together in Session 2, $F(1, 12) = 2.71$, $MSE = 148.55$, *ns.*

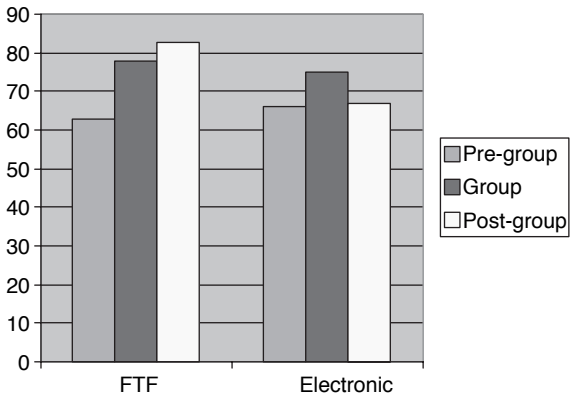

Figure 1. Mean number of propositions in pre-group, group, and post-group products of participants in face-to-face and electronic media.

Product quality. Overall, groups were still more accurate than individuals were when recalling post-group, $F(1, 37) = 6.37$, $MSE = .0019$, $p < .02$. Recalling in a group improved individuals' recall performance from Session 1 to Session 3, with an increase in the proportion of correct items in post-group individual products compared to pre-group individual products, $F(1, 37) = 4.62$, $MSE = .0017$, $p < .05$ (see Table 1). Converging evidence comes from a small but significant

reduction in the proportion of incorrect items in individual recall in Session 3 compared to Session 1, $F(1, 37) = 7.45$, $MSE = .0009$, $p = .01$.

Collaborative recall in groups not only had benefits for subsequent individual recall, but also costs. We examined the contents of all errors made in any of the three sessions by particular triads and discovered that 44% of the errors in group products persisted; that is, group members carried over the errors from their group into their post-group individual products. This means that although collaborative recall in Session 2 led to improved individual recall in Session 3, it also led to some distortions. Another way to look at this finding is that 54% of the errors made by an individual in Session 3 involved information that had been left out of that individual's product in Session 1, but was introduced in incorrect form by the group. The rest of the errors in Session 3 either originated in that individual's own Session 1 (38%), or had actually been correct in that individual's pre-group recall but were distorted by the group (8%).

Content filtering

We returned to the transcribed exchanges from the electronic chat windows and the recordings of face-to-face sessions, in order to compare these to the lists of recalled items that the groups produced (official group products). Recall that based on comparison with these transcripts and Session 1 products, propositions from the Session 2 products were coded as to whether they were unaltered, group-filtered, or self-filtered.

Group-filtering versus self-filtering. In the group sessions there was evidence of both group-filtering and self-filtering (see Table 3). Keep in mind that an item was coded as group-filtered if it was presented by an individual during the text or spoken discussion from group session but failed to be included in the official group product. On the other hand, an item was coded as self-filtered if it was included in an individual's pre-group recall but was not at all presented during the group session (so as a coding category, self-filtering does not distinguish forgotten from

TABLE 3
Content-filtering in face-to-face and electronic groups

	Recalled propositions included in product				
Filtering	[a]*Total*	*Correct*	*Incorrect*	*Inferred*	*Meta*[b]
Group-filtered items (Session 2)					
FTF groups					
M	16.77	13.04 (.76)[c]	2.42 (.15)	1.31 (.09)	0.00
SD	7.62	6.56 (.12)	1.90 (.10)	1.23 (.10)	0.00
Electronic groups					
M	14.54	10.39 (.77)	2.38 (.13)	1.77 (.10)	0.00
SD	10.54	7.32 (.18)	2.63 (.10)	1.87 (.11)	0.00
Weighted mean of both groups					
M	16.03	12.15 (.77)	2.41 (.14)	1.46 (.09)	0.00
SD	8.36	6.84 (.14)	2.14 (.10)	1.47 (.10)	0.00
Self-filtered items (Session 2)					
FTF groups					
M	9.18	6.72 (.71)	1.49 (.20)	.68 (.07)	.31 (.04)
SD	5.18	3.85 (.20)	1.05 (.20)	.71 (.06)	.52 (.09)
Electronic groups					
M	14.67	9.97 (.67)	3.00 (.22)	.77 (.06)	.85 (.05)
SD	6.36	5.25 (.13)	1.36 (.09)	.50 (.04)	1.87 (.09)
Weighted mean of both groups					
M	11.01	7.80 (.70)	1.99 (.20)	.71 (.06)	.49 (.04)
SD	6.11	4.57 (.18)	1.35 (.17)	.64 (.05)	1.16 (.08)

[a]Total propositions in recall product (correct + incorrect + inferences + meta-statements).
[b]Meta-statements.
[c]Values in parenthesis represent the proportion of the total product.

recalled but withheld propositions). Overall, group filtering occurred marginally more often than self-filtering, $F(1, 37) = 3.30$, $MSE = 73.01$, $p < .08$. That there was so much group-filtering suggests that reduced productivity in collaborative recall (compared to nominal recall) is not due to cognitive interference alone, but is also affected by group interaction. Only about 17% of all group-filtered propositions were *explicitly* filtered ($SD = 0.20$) (as evident from verbal evidence in the transcripts in which one member explicitly questioned or debated what another member presented); the rest appear to have been simply ignored. Note that explicit filtering occurred equally often whether face-to-face groups were told to reach consensus or not, $F(1, 24) = 0.50$, $MSE = 4.92$, *ns.*

Filtering in Session 2 was not based on accuracy. Of the group-filtered items, 77% were actually correct ($SD = 0.14$). And, of the self-filtered items, 70% were correct ($SD = 0.18$).

Restoration. Propositions were coded as *restored* if they had been filtered out in the group session (by self or group) but reappeared in individuals' products in Session 3. Of items filtered out in Session 2, 28% were restored ($SD = 0.11$); these included 31% of all self-filtered items ($SD = 0.17$) and 24% of all group-filtered items ($SD = 0.11$). With regard to accuracy, 84% of all restored items were correct ($SD = 0.15$). This pattern suggests that individuals were attuned to accuracy even when their groups made errors.

Filtering and restoration in face-to-face versus electronic groups. Overall, there was no difference in total filtering between face-to-face and electronic groups (with group-filtering and self-filtering during Session 2 considered together). However, consistent with the grounding framework, group-filtering was higher in face-to-face than in electronic groups and self-filtering was higher in electronic groups than face-to-face (see Figure 2). This interaction of medium and filtering was marginally significant, $F(1, 37) = 3.53$, $MSE = 73.01$, $p < .07$, driven by a much lower amount self-filtering face-to-face than in the electronic medium, $F(1, 37) = 8.34$, $MSE = 31.29$, $p = .006$. There were similar numbers of items group-filtered in face-to-face and electronic groups, $F(1, 37) = 0.57$, $MSE = 75.24$, $p = .45$, *ns.* There was no difference in items restored by face-to-face and electronic groups.

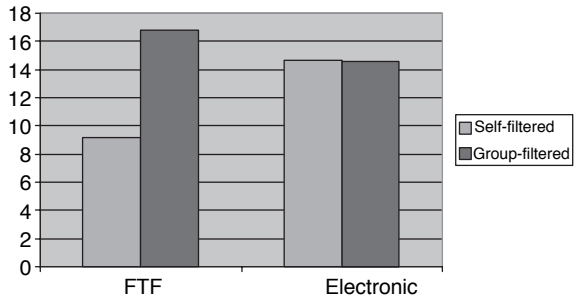

Figure 2. Mean group-filtered and self-filtered propositions in face-to-face and electronic groups.

DISCUSSION

The main goals of this study were (1) to investigate the source of the productivity loss in collaborating groups as compared to nominal groups, as a function of group communication medium, and (2) to discover the effects of recalling in groups on subsequent solitary recall. We began by establishing that in our naturalistic recall task, groups recalled a higher proportion of correct, central ideas and a lower proportion of incorrect propositions and meta-statements than their individual members had in the pre-group recall session. This finding that group products were of higher quality than pre-group individual products suggests that groups have mechanisms for error checking that individuals do not have. Also as expected, spontaneously interacting groups under-performed nominal groups, both in the quantity and quality of recall products. These findings confirm our first two predictions that aimed to establish consistency with previous studies, most of which used list-learning tasks and allowed little or no interaction among group members.

Concerning the reason for recall under-performance in groups, our results fail to support a social loafing explanation (prediction #3), as electronic groups, even with their increased opportunities for anonymity, recalled just as many propositions as did face-to-face groups. The comparable performance of electronic and face-to-face groups in Session 2 is consistent with studies of mediated communication; even when bandwidth is limited or production is more difficult, collaborators adjust their effort in order to meet the performance criteria of the task (Brennan & Lockridge, 2006; Brennan & Ohaeri, 1999; Clark & Brennan, 1991; Karsenty, 1999; Whittaker, 2002).

Moreover, the results demonstrate that in spontaneously interacting groups, there is a reduction in productivity *in addition* to the reduction that can be attributed to one member's recall interfering with another's (when a group member recalls a proposition but fails to report it because she is derailed by having to wait while hearing her partners discuss another proposition). The advantage of examining not only the official recall product, but also the transcript of the group's interaction while they did the task together (and by comparing the two records), is that we can tease apart the existence of distinct mechanisms for how content comes to be filtered out of a group product: there is significant filtering at both the individual and the group levels. There is no reason to suppose that there should be more cognitive interference in electronic groups than in face-to-face groups; if anything there should be *less*, since group members are not distracted by seeing and hearing one another. So even though our self-filtering category cannot distinguish cognitive interference from the intentional withholding of propositions, the fact that there is so much *more* self-filtering in electronic than face-to-face groups supports the strategic allocation of collaborative effort predicted by the grounding framework (prediction #4).

In particular, it was confirmed that group-filtering was more likely in the face-to-face medium, whereas self-filtering was more likely in the electronic medium. This finding shows that the distribution of initiative during interpersonal coordination is a relevant factor. When the currency of interaction is text, producing an utterance and completing a conversational exchange takes more time and effort than does speaking. And when partners are not co-present to one another's intonation or facial expressions, their nonverbal cues are limited. Speakers use such cues to display their commitment to what they are saying, and addressees pick up on those cues (Brennan & Williams, 1995; Smith & Clark, 1993; Swerts & Krahmer, 2005). It should be less effortful for someone in the face-to-face medium to present everything he can recall, including propositions he is not confident about (accompanied by the intonation or facial expression to mark this lack of confidence) and let the group filter it out (either explicitly or via nonverbal cues) than it would be for someone in the electronic medium to offer a proposition and more painstakingly explain that it may be dubious. In the latter situation, she might well choose to withhold the proposition, as it takes so much effort to negotiate its acceptance into the group product. Similarly, groups interacting face-to-face have more mechanisms with which to indirectly reject each other's proposals without risking insult, as we have shown elsewhere (Brennan & Ohaeri, 1999). When nonverbal cues are limited, our transcripts show that electronic groups still try to use such cues occasionally, even when they have to type them out:

P3: and the grandmother told him to quit rambling superstitions . . .
P2: his wife scolded him for scaring the child
P3: nod
P1: does that sound ok?
[Electronic Group 7]

P3: or maybe it was just a nice way to close the story . . . you know . . . a bed time story . . . the girl goes to sleep . . . the grandmother lights the fire . . . and then the fade out
P2: whateva
P3: shrug
P3: the end
[Electronic Group 7]

The finding that collaborators distribute the responsibility for rejecting low-confidence or incorrect items among individuals themselves (predominating in the electronic medium) versus the other group members (predominating in the face-to-face medium) is consistent with the grounding framework. Grounding predicts that individuals flexibly shift their resources and distribute their effort in order to reach the performance criterion for a collective task, and that *who does what* depends on the affordances of the communication medium (Brennan & Lockridge, 2006; Clark & Brennan, 1991).

With regard to group filtering, groups appeared to include only the propositions they believed were necessary for the task. Group products contained significantly higher proportions of correct central ideas from the story, whereas individual products contained significantly higher proportions of meta commentary. This is consistent with Stephenson et al.'s (1991) suggestion that while individuals give accounts of events in ''characteristically different ways reflecting their idiosyncratic notions of what is appropriate to talk about, 'groups' produce accounts which focus strictly on the action and events, but ignore situational comment on the

setting and the motives and character of those they have observed'' (p. 465). In other words, collaboration leads to the selection of propositions from the total pool of available individual propositions, based on the group's decision as to what is appropriate to talk about (Stephenson et al., 1991).

The transcripts of the interactions showed that groups sometimes do set a task criterion. Criterion setting was explicitly negotiated in 14 of the 39 groups, and occurred about equally in face-to-face and electronic groups. In some cases the criterion was set explicitly by a partner saying, for instance, ''let's get this done quickly and get out of here''. In other cases criterion negotiation was done less directly, for example, by a partner asking ''do we really need to go to that much detail?'' or ''do you think that x is important?'' or ''do you want to include x?'' The answer was sometimes ''yes'' and sometimes ''no''. But even in cases where a criterion was not explicitly set, it is likely that group members judged what was appropriate to talk about based on the kind of information their partners were presenting. Recall that relatively few group-filtered propositions were filtered explicitly (17%), usually by partners saying that the proposed item was incorrect or that they did not remember it that way. Most other filtered items were simply ignored (or at least generated no verbal evidence of explicit filtering in the transcript).

Concerning our second main goal (and final prediction): It was confirmed that recall by an individual was improved by the experience of having recalled in a collaborating group. Although groups (Session 2) recalled a higher quantity of propositions than did individuals in Session 1, individuals in Session 3 recalled just as many propositions as had their groups (when face-to-face and electronic groups were combined). Moreover, the experience of recalling in a group seemed to have, overall, a positive effect on the *quality* of recall products, with individuals in Session 1 recalling a higher proportion of incorrect items than in Session 2 groups, but the same proportion in those groups as subsequently in Session 3. Even so, groups did sometimes introduce distortions into post-group individual products; this was most likely to happen when a proposition had been entirely absent from an individual's pre-group recall product. The good news is that individuals who recalled a proposition correctly the first time rarely let the groups' incorrect propositions distort their own post-group recall.

The resemblance of post-group products to the group product is consistent with previous studies showing that groups have greater confidence in their collective memory, correct as well as incorrect, than individuals do in their own memories (Alper, Buckout, Chern, Harwood, & Slimovits, 1976; Hinsz, 1990; Stephenson et al., 1986; Warnick & Sanders, 1980). It has also been suggested that the act of communication seems to transform or reconstruct the cognitive representation of relevant information such that memory thereafter remains consistent with the transformed version (Higgins, 1992; Loftus, 1975; Zimmerman & Bauer, 1956). This effect of communication on memory is consistent with a cognitive dissonance interpretation (Brehm & Cohen, 1962; Festinger, 1957; Festinger & Carlsmith, 1959); in this case, participants who have publicly committed to the group product, by accepting it as an accurate representation of the story, are likely to adhere to it (see Kiesler, 1971).

Concerning communication medium, recalling in face-to-face groups boosted post-group solitary recall in Session 3, whereas recalling electronically did not; this was the case even though the groups in both media conditions recalled just as many propositions during Session 2. Why should face-to-face spoken interaction be so much more beneficial to individual memory than electronic text? We suggest the following account: Before group members get together to recall collaboratively, their memories of the co-experienced event are relatively idiosyncratic; this is the reason nominal group products, by definition, turn out to include more propositions than do individual products (that is, if the individual members all independently recalled the same items, then their nominal product would be no higher than their pre-group individual products). What happens during collaboration by interacting groups is that this original diversity is reduced; while creating a collective product, individual partners can rehearse, elaborate, and improve their own memories for the event, and these memories become more similar. This should happen to a greater degree when the medium affords mechanisms that make it clear whether individual presentations have been taken up or ratified by the group. We propose that the nonverbal cues that are available face-to-face for grounding

contributions to the collective product are particularly likely to support a boost in post-group recall by individuals.

Our focus has been on collaborative recall in groups that can interact spontaneously as in the real world, and so we did not restrict contributions by group members or enforce an order of turn taking (e.g., as in Basden et al., 2000). One limitation of the current study is that the measures made on the interaction transcripts fail to establish precisely and directly which amounts of self-filtering are due to collaborative inhibition alone, as opposed to retrieving an item and meaning to present it but inadvertently failing to do so, or else to retrieving it but intentionally withholding it. Future studies will attempt to distinguish precisely these causes of productivity loss. However, the items in our group-filtered category were lost due to forces other than collaborative inhibition, as (by definition) they were all mentioned by individuals in the interaction transcripts but failed to appear group products. The finding of significant group-filtering in our study (particularly in face-to-face groups) demonstrates that coordination costs in naturalistic group settings can tax an interacting group, resulting in under-performance compared to a nominal group.

CONCLUSION

Memory is not solely an intrapersonal cognitive process, but often an interpersonal one. When a group of individuals witnesses an event, each encodes it somewhat differently; this may be a function not only of probabilistic influences on what any one person is likely to recall, but also of individual differences in knowledge, focus, biases, and perspective. When individuals recollect by grounding their idiosyncratic versions within a group, the memory is co-created and transformed to be part of their common ground. The resulting collective version is distinct from the original versions to the extent that it has been effectively filtered, grounded, and enhanced by the group; it represents a more certain product, and under some circumstances may improve subsequent recall. The act of coordinating interaction has the potential to influence both the quantity and the quality of collective memory.

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