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Forgetting in Social Chains: The Impact of Cognition on Information Propagation

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Abstract

Listening to a speaker selectively practicing previously encoded information leads to better memory for the practiced information, but at the same time results in induced forgetting of related memories. These effects have been found to occur due to the concurrent, and covert, retrieval of information on the part of the listener. Using a modified version of the method of serial reproduction (Bartlett, 1932), this study explored the degree to which rehearsal and retrieval-induced forgetting effects propagated in 64 3-person-chains of connected participants. We manipulated the degree of concurrent retrieval from the part of the listener by activating high and low relational motivations during the listening task. We showed that the degree of propagation of retrieval-induced forgetting was larger when concurrent retrieval was activated (high-relational motivation) than when concurrent retrieval was attenuated (low-relational motivation). This study provides a framework that aims to bridge between micro-level cognitive phenomena and macro-level social dynamics.

Keywords

Memory is malleable. Due to this flexibility, communicators (i.e., speakers) can influence the memories of attendees (i.e., listeners). They do so in a variety of contexts, from a politician speaking at a political rally, to a newscaster addressing her audience, and to a teacher conveying information to his students. These mnemonic influence processes typically involve reinforcing existent memories, implanting new "memories," and inducing forgetting in previously encoded memories, among other possible means. A burgeoning body of research on communicative influence on memory has articulated the factors governing each of these influences (Coman, 2015; Hirst, & Echterhoff, 2015). We are concerned here in the conditions that allow for these influences to propagate beyond a single interaction. That is, if one imagines a chain of connected individuals, with Mary connected to John and John connected to Adam, but Mary not directly connected to Adam, does, for instance, the ability of Mary to influence the memories of John propagate so that Mary also influences Adam's memory?

A number of researchers in the social sciences have asked why some memories spread across a network and others do not, likening the question to what epidemiologists ask about when studying the transmission of diseases (Barret & Nyhof, 2001; Boyer & Ramble, 2001; Griffiths, Lewandowsky, & Kalish, 2013; Sperber & Hirschfeld, 2004). These researchers suggest that an answer to this question will illuminate large-scale phenomena such as the formation of norms, culture, and collective memories (Goldstone, Roberts, & Gureckis, 2008; Luhman & Rajaram, 2015; Roediger & Abel, 2015). In an attempt to explore the interaction between cognition and socio-cultural dynamics, the present study aims at investigating the processes by which individual cognition impacts information propagation in social chains.

Bartlett's (1932) serial reproduction task is often used to study the spread of memories or beliefs, at least in small groups. The task is akin to a game of telephone in which one person recounts information to the next person in the chain and so on for a specified number of steps. Using this task, a number of psychologists have shown that individuals influence each other's memories as they serially converse with one another (Barret & Nyhof, 2001; Lyons & Kashima, 2003). This work established that basic psychological principles could account for what is or is not retained across a community. This body of research does not explore, however: (1) the dynamic nature of collective memories, and (2) the possibility that the strength of these effects at a dyadic level circumscribes their degree of propagation at a community level. The present study focuses, thus, on these two concerns.

To address (1) we will explore how individuals shape each other's memories as they communicate with one other. Existing research on information

propagation typically starts with a situation in which one person learns some information and then transmits that information to others (Bartlett, 1932; Bangerter, 2000). In contrast, studies of communicative influence on memory, such as the current one, examine situations in which all parties know the information in the first place, although the exact representation of that information may differ across individuals. The focus is on how the mnemonic representation of this information changes as people communicate with one other. Such situations are common: partners reminisce about their first date, opera fans talk about spectacular past performances they attended, faculty members argue about what had transpired at previous meetings. They bear on the formation of collective memories because, as the individuals' memories are transformed in these social exchanges, there is the potential for these mnemonic representations to converge. We suspect that many of the collective memories a community holds have this character, in that they often change over time as a result of extensive communication within the community.

For (2) we will investigate whether the communicative influence A has over B propagates to C. Concerns about this propagation arise because the influence A has over B is not complete — that is, B does not end up adopting A's memory. Rather, previous studies found that A only changes B's memory without completely overwriting it (Cuc, Koppel, & Hirst, 2007). Thus, there is no guarantee that A's influence will propagate to C, inasmuch as the propagation will depend on the way B recollects the memory to C. If, for instance, Mary, John, and Adam attend a concert, and then Mary recollects to John the incident involving the singer falling on the stage, then this particular event has a higher probability of being remembered in John's subsequent interaction with Adam, compared to a situation in which Mary neglects to recollect the incident in her conversation with John. Understanding the extent of propagation becomes critical to the study of collective memory, then, because the greater the propagation of Mary's influence, the greater the chance that Mary will be able to influence multiple individuals, and in turn, facilitate the community's mnemonic convergence.

In the present study we employ a modified serial reproduction paradigm to focus on two well-established communicative influences on memory: rehearsal and retrieval-induced forgetting effects. Both effects rest on the observation that not everything a person is capable of remembering is necessarily retold in an act of remembering (Marsh, 2007). Memories retold by the speaker are likely to be strengthened in both the speaker and her listeners (Roediger, & Butler, 2011). As to the unmentioned memories, extensive research in cognitive psychology suggests that conversations might trigger processes that lead to their forgetting. Selective retrieval of information was found to result in the

forgetting of memories related to those retrieved to a larger extent than un-retrieved memories unrelated to those retrieved (Anderson, Bjork, & Bjork, 1994). To investigate these processes, Anderson, Bjork, and Bjork (1994) asked participants to first study category-exemplar pairs (e.g., fruit-apple, fruit-orange, drinks-scotch, drinks-wine), and then to selectively recall half of the exemplars from half of the categories in a stem completion task (e.g., fruit-ap___). On a final recall test participants were more likely to forget unpracticed memories related to the selectively practiced material (e.g., orange) than un-practiced, unrelated material (e.g., scotch, wine). Anderson and his colleagues attributed this subsequent selective forgetting to inhibition. As participants selectively practiced the originally studied material, they inhibited the unre-trieved, but related to the retrieved, memories that competed for activation during the selective retrieval task. This inhibition lingers and is reflected in subsequent recall (but see Jonker, Seli, & MacLeod, 2013 for an alternative ac-count of the mechanism involved). Regardless of the mechanism responsible for the effect, retrieval-induced forgetting is a reliable, highly replicated, phe-nomenon (see Murayama, Mityatsu, Buchli, & Storm, 2014, for a meta-analysis).

More importantly, such *retrieval-induced forgetting* is relevant to the study of communicative influences on memory because in some instances listeners undergo the same selective forgetting as the speaker when they attend to the speaker's selective recollection (Abel & Bauml, 2015; Barber & Mather, 2012; Coman & Berry, 2015; Cuc, Koppel, & Hirst, 2007). That is, they will forget mem-ories related to what the speaker mentioned more so than memories unrelated to those mentioned by the speaker (Cuc, Koppel, & Hirst, 2007). This *socially shared retrieval-induced forgetting* (SSRIF) is assumed to arise because listen-ers concurrently, albeit covertly, retrieve information along with the speaker. To support this claim, Cuc, Koppel, & Hirst (2007) showed that when listeners monitored for the accuracy of the speaker's selective recollection they were more likely to experience SSRIF than when they monitored for how fluently the speaker produced the recollection. The reasoning is that the former involves deep processing and covert recollection, whereas the latter only involves su-perficial processing and no covert recollection (Craik, & Lockhart, 1972).

Current Study

We are interested here in understanding how an individual's mnemonic influ-ence propagates through social chains. This corresponds to contexts in which public speakers selectively practice information that the audience had previ-ously encoded. Listening to a radio show in which the host discusses some

of the reasons behind Donald Trump winning the presidential election at the expense of Hillary Clinton fits this class of situations. How does the selective practice that takes place during the radio show affect information propagation from the speaker to her audience, and then further among audience members? To explore such real world phenomena, we developed a paradigm that assembled individuals into social chains. The first person in a chain of connected individuals, Participant A, studied short vignettes characterized by a category-exemplar structure about members of a Peace Corps program. She was then exposed to a subset of the initially presented information in the form of an audio interview with a speaker, and finally was asked to recall the initially studied stimulus material. The second person in the chain, Participant B, underwent a similar procedure as Participant A, first studying the short vignettes and then receiving selective practice, followed by a recall test. Importantly, in the practice phase, what Participant B heard was based on the final recall of Participant A. The experiment continued in a similar manner, moving down the chain to Participant C. In this paradigm, the originator of the influence — the radio show host in the example above — is represented by the selective practice that participant A is exposed to. This influence, in the form of rehearsal and SSRIF effects, is traced through the social chain.

The main interest of this study is to investigate the conditions that facilitate or attenuate the propagation of influence in sequential interactions. To explore these interests, we will build on recent findings showing that relational motives during conversational remembering impact the strength of SSRIF (Coman, & Hirst, 2015). When listeners were motivated to relate to the speaker, this research found, they concurrently retrieved the information along with the speaker, and, as a consequence, experienced SSRIF. In contrast, when these relational motivations were absent, no SSRIF was observed. To build on our previous example, if the radio show audience member is sympathetic to the views of the show's host, such relational motivations result in concurrent retrieval from the part of the listener. In previous laboratory studies, Coman & Hirst (2015) manipulated relational motivations by using identity-based strategies. Princeton students listening to other Princeton students selectively retrieving information about a student exchange program experienced SSRIF for unpracticed, and related to the practiced, information. This was not the case, however, when Princeton students listened to a Yale student speaker selectively practicing previously learned information.

In the current context we use an empirically established identity-based strategy to manipulate relational motivations. Previous research has shown that promoting ingroup goals leads to positive evaluations by ingroup observers and increased estimations of similarity with these ingroup promoting members

(Dovidio, Gaerdner, Pearson, & Riek, 2005). We reasoned that American participants listening to a speaker portraying US actions in an international context as either Interventionist, and therefore deleterious to the targets of these actions, or Helpful, and therefore beneficial for the target groups, would differentially engage in concurrent retrieval of information. American listeners should be more likely to relate to a speaker who promotes group values (i.e., US has a positive influence), than to one who might threaten them (i.e., US has a negative influence). This should lead to an increased likelihood of concurrently retrieving the information with someone discussing a "helpful" program rather than an "interventionist" program, and, as a result, SSRIF should be stronger in the Helpful condition than the Interventionist condition. We hypothesize, thus, that this differential concurrent retrieval will lead to differences in propagation rates of SSRIF between the two conditions, with higher propagation rates in the Helpful than in the Interventionist condition.

The current study will provide a cognitively grounded understanding of information propagation that is in line with current theoretical developments (Schacter, 2001; Hirst & Echterhoff, 2009). Its strength is in isolating and rigorously investigating the mechanisms involved in information propagation in ecologically valid lab experiments.

1   Methods

1.1   *Participants*

Participants were recruited over Mechanical Turk, a crowdsourcing marketplace used to conduct psychological studies online (Mason & Suri, 2012). Recruitment occurred in 3 waves, corresponding to the 3 generations of the experimental design, from this point forward referred to as Generation 1, 2, and 3. Each participant in Generation 2 was uniquely matched to a participant in Generation 1, and each participant in Generation 3 was uniquely matched to a participant in Generation 2. The matching was random. All qualified participants were American. Thirty-four participants were replaced because they reported technical issues, answered "don't remember" for every cue given in the recall phase or failed one of two attention check questions. These exclusion criteria were established before the initiation of the data collection phase. The dropout rate was similar across conditions and generations. After conducting power analyses based on effect sizes we observed in previous SSRIF studies, we aimed to recruit 64 participants in each Generation, for a total of 192 participants across the three generations. This cell size allowed for a completely balanced experimental design (see below) and constituted the stopping rule

for participant recruitment. The average age (in years) and the percentage of female participants were, for Generation 1, 41.23 (S.D.=12.62), 56% female; for Generation 2, 36.36 (S.D.=10.80), 50% female; and for Generation 3, 39.08 (S.D.=12.20), 65% female.

1.2 *Materials*

Study phase. In Qualtrics, we developed a presentation describing a fictional but realistic humanitarian aid program initiated by the American Peace Corps. The presentation consisted of an introductory section outlining the program, followed by descriptions of four Peace Corps volunteers, each stationed on a different continent with a distinct mission. The four volunteers were: Rachel (environmental protection — South America), Alex (refugee assistance — Europe), Christine (post-disaster recovery — Asia), and Jim (HIV/AIDS prevention — Africa). For each volunteer, four of their projects with the program were presented in separate brief paragraphs ($M_{Word-number}$ = 36.75). A photo illustrated each project. For instance, Rachel was involved in: a) protecting endangered species, b) preventing deforestation, c) distributing natural fertilizer, and d) cleaning beaches. We treated each volunteer as a unitary category, and each project undertaken by the volunteer as an exemplar within the category. We conducted two preliminary studies over Mechanical Turk in order to balance the 16 activities on relevance and memorability across the four categories.

Practice phase. For this phase, we created audio clips in which the speaker on the recording talked about two of four actions performed by two of the four Peace Corps volunteers. The decision to use a radio-show paradigm was made because: (1) the first author has technical expertise in this domain, being the host of a radio show, and (2) it involves an ecologically valid manipulation. These audio clips differed in content across the three generations, as described below.

For Generation 1, the speaker in the audio clip offered a redacted version of the original material, discussing half of the exemplars from half of the original categories. The format was that of a radio show in which the manager of a fictional "New Initiatives Program" in the American Peace Corps was being interviewed. Before the interview began, the radio host described the US actions abroad as either Interventionist (negative for the target populations) or Helpful (positive for the target populations), citing a *New York Times* article. A brief introduction of the manager of the "New Initiatives Program" followed, after which the radio show host asked a general question about the program (e.g., "Please tell us about the New Initiatives Program.") and the program manager would respond. In the response, the program manager would describe, for

instance, Rachel's work protecting endangered species and preventing defor-estation, and Alex's work organizing temporary schools and providing transla-tion services. In this example, no mention was made of Christine or Jim, the other two Peace Corps volunteers. The speaker's selective retrieval of catego-ries (volunteers) and exemplars (projects) created three types of items: previ-ously studied items that were mentioned by the speaker (Rp+, e.g., protecting endangered species), previously studied items that went unmentioned, but were from the same category as those mentioned (Rp-, e.g., distributing natural fertilizer), and previously studied items that were unmentioned and unrelated to those mentioned (Nrp, e.g., all the items in Christine's and Jim's categories). In order to counterbalance which exemplars served as Rp+, Rp-, and Nrp items, we recorded 4 versions. For each version, two separate recordings were made with either male or female program managers, producing a total of 16 record-ings. Recordings lasted an average of 261 seconds (range: 241 to 278).

For Generation 2, in order to standardize the content of the recall, we used the audio clips already recorded for the practice phase for Generation 1 to cre-ate redacted versions that corresponded to each final recall of Generation 1 participants. The format was similar with that for Generation 1 participants, but now the radio host was ostensibly interviewing a listener of the show who had called in. We decided to change the nature of the information source from the manager of the program (Generation 1) to a listener of the radio program (Generation 2) to maintain high ecological validity for both the stimulus mate-rials as well as the situations that participants find themselves in during their day-to-day lives. To make these second-generation audio clips, each recol-lection from Generation 1 participants was coded for the items recalled. The original audio clips were then edited and reassembled to capture the material each Generation 1 participant recalled. As before, the audio clip began with a description of the New Initiatives program as helpful or interventionist. Rather than including all the items remembered by Generation 1 participants, the audio only included items that were remembered in the Rp categories (Rp+ and Rp-), and not items that were remembered in the Nrp categories. This allowed the Nrp items to serve as a consistent baseline for all three participants in each chain. Importantly, the choice to maintain the Nrp (baseline) categories simi-lar across the three participants in a chain was made in order to allow for the computation of SSRIF and rehearsal effects. Without this constant baseline, no statistical analyses of these effects can be computed. The same procedure was employed to create the audio clips for Generation 3 participants, but, this time, based on Generation 2 participants' final recalls. Recordings for Generation 2 participants lasted an average of 161 seconds (range: 75 to 223). Recordings for Generation 3 participants lasted an average of 157 seconds (range: 77 to 222).

1.3   *Design and Procedure*

Participants were recruited on Mechanical Turk and then referred to a Qualtrics site. Each participant went through 4 phases: (a) study phase, (b) selective practice phase, (c) manipulation check, and (d) final recall test. In *a study phase*, they first learned about all 4 volunteers. As they did so, they were not told that a memory test would follow so that they wouldn't be tempted to take notes during this phase. After a 3-minute distracter task, the *selective practice phase* began, with each generation listening to their corresponding audio clip. They were told to pay attention to the audio clip, as they will be asked to evaluate the presented information in a later phase. For this phase, participants were randomly assigned to either the "Helpful" version or the "Interventionist" version of the audio. Immediately after the practice phase, as a *manipulation check*, participants were asked to indicate their agreement with the statement: "Overall, I believe that the United States has a positive impact in the world," (on a 7-point Likert scale from 1-Strongly Disagree to 7-Strongly agree) and to answer the following question: "To what degree do you support the New Initiative Program?" (on a 9-point Likert scale from 1-Strongly oppose to 7-Strongly support). In order to assess the level of engagement during the listening task, we also asked participants to report how much attention they paid to the speaker in the audio. A *final recall test* was administered following a 3-minute distracter task. The name and background information for the four volunteers was provided, with the instruction to remember the initially presented information about each. Participants typed their responses. Because the materials were uniquely tailored for each participant, Generation 2 participants were recruited 34 days after Generation 1 participants. They followed the same procedure as those in Generation 1, but received in the practice phase an audio clip containing the items remembered by their randomly matched Generation 1 participant. Generation 3 participants were recruited 55 days later and proceeded in the same manner as Generation 2, but they listened to an audio clip containing the items remembered by their matched Generation 2 participant (Fig. 1). Participants in each generation completed the study within one experimental session that took, on average, 21 minutes.

1.4   *Coding*

Two individuals, blind to the participants' condition, coded 100% of the cued-recall data to identify the items presented in the study phase (Cohen's κ=0.90). A third coder resolved all the discrepancies. We computed two types of analyses for each of the two effects (i.e., SSRIF and Rehearsal effects): an analysis of the propagation of the originator's influence in the chain (i.e., the practice implemented by the initial audio) and a separate analysis for the
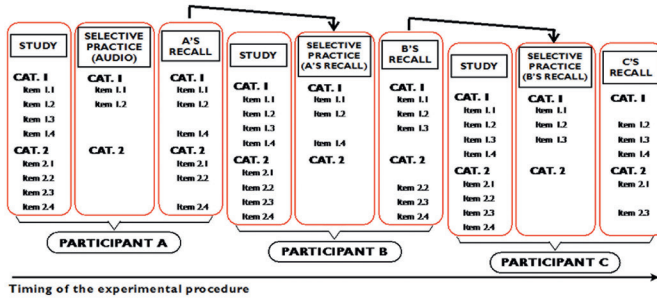
FIGURE 1   Phases of the experimental procedure, with hypothetical recall data. The chain of participants is comprised of 3 participants: A in Generation 1, B in Generation 2, and C in Generation 3. The top arrows indicate that information is transferred from a participant's recall to another participant's selective practice. Note that only information in the practiced category is transmitted, to allow for the computation of the rehearsal and SSRIF effects in all participants in a chain.

influence experienced by each generation during their tailored practice phase (a generation-specific effect computed relative to the selective practice that each participant in the chain was exposed to). For the propagation effect we wanted to investigate the effect of the selective practice implemented in the audio on the way information propagated in the social chain. For this purpose, SSRIF and rehearsal effects were computed for each participant in each generation relative to the selective practice implemented for Generation 1 participants. That is, the categorization of Rp+, Rp-, and Nrp items follows the one implemented for Generation 1 participants, regardless of the items presented to Generation 2 or 3. We computed an absolute SSRIF effect by subtracting the Rp — recall proportion from the Nrp recall proportion. To determine the rehearsal effect, we subtracted the recall proportion of Nrp items from the recall proportion of Rp+ items. For orientation purposes, rehearsal and SSRIF scores of .10 are considered moderate effects, based on previous results. Because the recall of the baseline (i.e., Nrp) categories differed between the two conditions we also computed relative impairment and relative practice scores by dividing the absolute SSRIF and practice scores, respectively, by the recall proportion of Nrp items. This allowed us to perform between-condition comparisons with a standardized score as it is typically performed in the situation of baseline difference (see Stone et al., 2012, for a similar procedure). For the generation-specific analysis, we computed similar SSRIF and Rehearsal effects scores, but now based on what each participant was exposed to during the practice phase.

2   Results

Manipulation check. We expected that participants in the Helpful condition would view the United States' contribution on the international stage more positively and be more supportive of the Peace Corps program than in the Interventionist condition. Repeated Measures ANOVA's with *Generation* (Generation 1 vs. 2 vs. 3) and *Condition* (Helpful vs. Interventionist) as independent variables revealed a main effect for *Condition* for both *positive view of US, F*(1, 62) = 10.91, p < .002, η_p^2 = .15 ($M_{Helpful}$=4.64; $M_{Interventionist}$=4.12), and for *support of the program, F*(1, 62) = 9.17, p < .004, η_p^2 = .13 ($M_{Helpful}$=7.77; $M_{Interventionist}$=7.05). No main effects for *Generation* or for the interaction were found. This pattern provides support for our decision to use the Helpful/Interventionist manipulation as an identity based strategy to influence concurrent retrieval processes. These types of identity based manipulations, even though indirect, were previously found to influence concurrent retrieval processes (see Coman, & Hirst, 2015; Coman, & Berry, 2015). Also, no effects of gender or age were found on the variables of interest, so we collapsed data analyses across these variables.

Score standardization. We first explored whether the Helpful and Interventionist conditions led to different levels of overall recall. Inasmuch as Nrp items were not susceptible to the effect of selective remembering, we focused our analyses on them. A Repeated Measures ANOVA with *Generation* and *Condition* as independent variables, and recall proportion of Nrp items as an outcome variable revealed a main effect for *Condition, F*(1, 62) = 8.12, p < .006, η_p^2 = .12, but not for *Generation, F*(2, 124) = .18, p = .84, η_p^2 = .00, or for their interaction, *F*(2, 124) = 1.75, p = .17, η_p^2 = .03. (See Table 1 for the means and standard deviations for the Rp+, Rp-, and Nrp recall proportions). The motivational forces that were triggered in the Helpful condition might have resulted in a generalized enhanced recall performance for the stimulus materials ($M_{Helpful}$=.52; $M_{Interventionist}$=.42). Given these results, we used a typical procedure to standardize the scores for comparisons involving conditions (Anderson, Bjork, & Bjork, 1994; Stone et al., 2012). We divided SSRIF and rehearsal effect absolute scores by the recall proportion of Nrp items. We will refer to these standardized scores as relative impairment and relative strengthening, respectively. For within-condition analyses, we will use the absolute scores, since there are no within-condition systematic differences in remembering Nrp items between the 3 generations. For between-condition comparisons, we will employ the relative scores. We note that the absolute and relative strengthening and impairment scores reveal the same pattern of results.

TABLE 1 Means and standard deviations for the recall proportion of Rp+, Rp-, and Nrp items, separate by condition (Interventionist; Helpful), and by Generation (Generation 1, 2, and 3). These recall scores are those used for the propagation analyses, therefore they are computed based on Generation 1's Rp+/Rp-/Nrp categorization of items

	Interventionist			Helpful		
	Rp+	Rp-	Nrp	Rp+	Rp-	Nrp
Gen. 1	.66 (.32)	.34 (.28)	.41 (.25)	.69 (.31)	.42 (.32)	.54 (.26)
Gen. 2	.44 (.30)	.48 (.31)	.39 (.24)	.57 (.33)	.48 (.28)	.55 (.24)
Gen. 3	.51 (.29)	.52 (.29)	.45 (.21)	.54 (.31)	.54 (.32)	.46 (.21)

Propagation of SSRIF from the originating audio source. In order to examine the propagation of SSRIF, we conducted a Repeated Measures ANOVA, with the relative impairment score as on outcome variable and *Generation* and *Condition* as independent variables. There was a main effect for *Generation,* $F(2, 124) =$ 4.41, p < .02, $\eta_p^2 = .07$, and a significant interaction between *Generation* and *Condition,* $F(2, 124) = 2.99$, p < .05, $\eta_p^2 = .05$. No main effect for *Condition* was found, $F(1, 62) = 1.32$, p = .25, $\eta_p^2 = .02$. Given the significant interaction, we examined the two conditions separately in posthoc analyses using absolute impairment scores.

In the *Helpful* condition, a Repeated measures ANOVA with *Generation* as an independent variable, and absolute impairment as an outcome variable revealed a significant effect for *Generation,* $F(2, 62) = 5.27$, p < .01, $\eta_p^2 = .15$. The same analysis, but now conducted for the *Interventionist condition* revealed a similar main effect for *Generation,* $F(2, 62) = 4.01$, p < .03, $\eta_p^2 = .12$. We followed up on this result by investigating whether the SSRIF effect caused by the speaker in the audio listened to by Generation 1 reached significance in Generations 2 and 3. These analyses were conducted separately for each Condition and for each Generation. In the *Helpful condition*, we found significant SSRIF effects for both Generation 1 and Generation 2, but by Generation 3, the SSRIF effect was no longer statistically significant. In the *Interventionist condition*, the SSRIF effect did not reach significance for any of the 3 generations (see Table 2, Fig. 2). This pattern holds regardless of how one calculates the SSRIF effect (i.e., absolute vs. relatives scores). We can conclude, based on these results, that the SSRIF effect propagates 2 degrees away from the influence source when relational motivations are activated, but it fails to propagate when these motivations are absent.

TABLE 2　Pairwise comparisons of the recall proportion of Rp- items and Nrp items (SSRIF), and Rp+ items and Nrp items (rehearsal effect), separately by condition (Interventionist; Helpful), and by Generation (Generation 1, 2, and 3). T test values, effect sizes (Cohen's d), and significance values (p) are reported for each comparison. The degree of freedom for each comparison is 31. See Table 3 in the Appendix for the recall proportions of Rp+, Rp-, and Nrp items used for these analyses

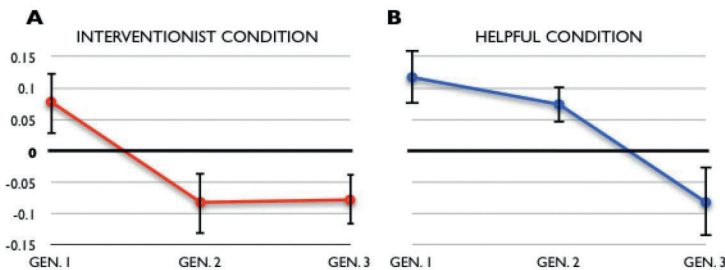| | SSRIF | | | | | | Rehearsal effect | | | | | |
| | Interventionist | | | Helpful | | | Interventionist | | | Helpful | | |
	t	d	p	t	d	p	t	d	p	t	d	p
Gen. 1	1.56	.29	=.13	2.50	.44	<.02	4.92	.86	<.001	3.62	.65	<.001
Gen. 2	-1.57	.28	=.13	2.60	.50	<.02	1.09	.18	=.29	.34	.06	=.73
Gen. 3	-1.68	.28	=.10	-1.37	.24	=.18	1.23	.22	=.23	1.54	.27	=.13

FIGURE 2　The degree of SSRIF computed as the difference between the recall proportion of Nrp items and the recall proportion of Rp — items (Y axis), separated by Generation (X axis). An SSRIF score of .10 (on the Y axis) is considered a moderate SSRIF effect, based on previous studies. Panel A, Interventionist condition, Panel B, Helpful condition. Error bars represent standard errors.

To further test the degree of propagation for the SSRIF effect, we also compared the size of the absolute impairment between Generations. In the *Helpful condition*, the degree of SSRIF experienced by Generation 1 (M=.12, SD=.27) was not significantly different from the degree of SSRIF experienced by Generation 2 participants (M=.07, SD=.16); Generation 2 participants experienced a significantly higher SSRIF effect than Generation 3 participants (M=-.08, SD=.29). In the *Interventionist condition*, the SSRIF experienced by Generation 1 participants (M=.08, SD=.28) was significantly higher than that experienced by

TABLE 3   Pairwise comparisons of the degree of rehearsal effect and SSRIF effect between Generations (Gen 1 vs. Gen 2; Gen. 2 vs. Gen 3), separately by condition (Interventionist; Helpful). T test values, effect sizes (Cohen's d), and significance values (p) are reported for each comparison. The degree of freedom for all comparisons is 31

	SSRIF						Rehearsal effect					
	Interventionist			Helpful			Interventionist			Helpful		
	t	d	p	t	d	p	t	d	p	t	d	p
Gen. 1 vs. 2	2.34	.44	<.03	.81	.13	=.42	3.09	.55	<.01	2.10	.48	<.05
Gen. 2 vs 3	-.12	.01	=.90	2.59	.47	<.02	-.32	.07	=.75	-1.08	.17	=.29

Generation 2 participants (M=-.08, SD=.30). The SSRIF effect did not differ significantly between Generation 2 and Generation 3 (M=-.07, SD=.25) (see Table 3, Fig. 2). This constitutes further support for the conclusion that SSRIF propagates 2 degrees away in the Helpful condition, but its propagation is limited in the Interventionist condition.

Generation-specific SSRIF. Consistent with our hypothesis, we found that the retrieval-induced forgetting effect propagates to a larger degree in the Helpful condition than in the Interventionist condition. We tested this hypothesis by measuring retrieval-induced forgetting relative to the selective practice implemented in the audio that the Generation 1 participants were exposed to. But a similar pattern should be observed if we compute retrieval-induced forgetting effects based on the selective practice implemented for each generation, since the audio presented to each generation contained the same manipulation as the audio presented to participants in Generation 1. That is, in the Helpful condition, since the same manipulation is operating with regards to attitude towards the speaker across the three generations, items related to those practiced by Generation 2 participants should be remembered less well than baseline items, and the same should be the case for Generation 3 participants, relative to what they selectively practiced. In contrast, this pattern should not be observed in the Interventionist condition. And indeed, the SSRIF effect in the Helpful condition was significant for Generation 2 participants, t(28)[1]=2.26,

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1   The degrees of freedom for these analyses varies from 27 to 31 due to the fact that some participants did not remember any Rp+ and Rp- items, and so the items could not be categorized as such for the next participant(s) in the chain.

p<.03, and marginally significant for Generation 3 participants, t(30)=2.01, p=.055. As expected, the SSRIF effect was not significant in the Interventionist condition, for neither Generation 2 participants, t(27)=1.41, p=.16, nor for Generation 3 participants, t(29)=1.29, p=.21. In essence, this pattern is not only a three-wave replication of the same effect, but also provides explanatory power to the propagation pattern we obtained above (see Figure 2). In other words, for the effect of the initial selective practice implemented for Generation 1 participants to propagate to Generation 2 and Generation 3 participants two conditions are necessary: (a) the effect should be strong to begin with (large degree of SSRIF in Generation 1) and (b) every subsequent generation should be influential in affecting their counterpart's memory. As shown here, the Helpful condition met both criteria, whereas the Interventionist condition met neither, which accounts for the differences in the degree of propagation between the two conditions.

Propagation of Rehearsal Effects from the originating audio source. A Repeated Measures ANOVA with the relative strengthening score as an outcome variable and *Generation* and *Condition* as independent variables revealed a marginally significant main effect for *Generation, F*(2, 124) = 2.80, p = .07, η_p^2 = .04, but no main affect for *Condition, F*(1, 62) = .52, p = .48, η_p^2 = .01, and no significant interaction between *Generation* and *Condition* (*F*(2, 124) = .85, p = .43, η_p^2 = .01. We also compared the recall proportion of Rp+ items with that of Nrp items, separate for each Condition and for each Generation. In the *Helpful condition*, we found a significant rehearsal effect for Generation 1, but not for Generation 2 and Generation 3 participants. A similar pattern emerged in the *Interventionist condition* (see Table 2, Fig. 3). As to the comparison of the degree of the rehearsal effect, in the *Helpful condition*, the rehearsal effect experienced by Generation 1 (M=.15, SD=.23) was significantly higher than the rehearsal effect experienced by Generation 2 (M=.02, SD=.32). There was no statistically significant difference between Generation 2 and Generation 3 (M=.08, SD=.30). In the *Interventionist condition*, the practice effect experienced by Generation 1 (M=.25, SD=.29) was significantly larger than that experienced by Generation 2 (M=.04, SD=.22). The rehearsal effect did not differ significantly between Generation 2 and Generation 3 participants (M=.06, SD=.27) (see Table 3, Fig. 3). This suggests that the rehearsal effect is only observed one degree away from the influence source, regardless of condition. These results are consistent with previous findings that fail to find an impact of relational motivations on rehearsal effects (Coman & Hirst, 2015) and point to a dissociation between rehearsal and SSRIF effects.

Generation-specific Rehearsal Effects. We were interested in whether the rehearsal effect differed between the two conditions if we conducted analyses based on the selective practice implemented for each generation. Given that
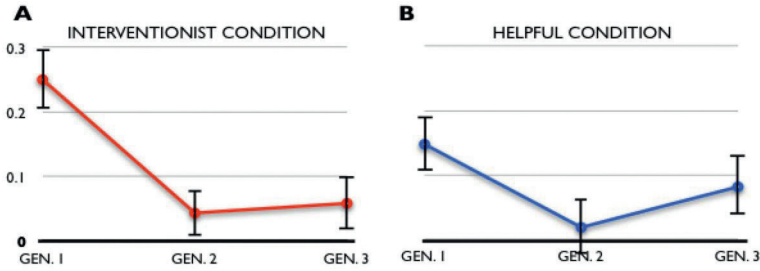
FIGURE 3   The degree of rehearsal effect computed as the difference between the recall proportion of Rp+ items and the recall proportion of Nrp items (Y axis), separate by Generation (X axis). A rehearsal effect score of .10 (on the Y axis) is considered a moderate rehearsal effect, based on previous studies. Panel A, Interventionist condition, Panel B, Helpful condition. Error bars represent standard errors.

there was no difference between the two conditions for the rehearsal effect experienced by Generation 1 participants, we expected to find rehearsal effects in both Generations 2 and 3, regardless of condition. And indeed, in the Helpful condition we found a marginally significant rehearsal effect for Generation 2, $t(29)=1.79$, $p=.08$, and a significant effect for Generation 3, $t(31)=4.27$, $p<.001$. Similarly, in the Interventionist condition we found a significant rehearsal effect for Generation 2, $t(28)=2.80$, $p<.001$, and a significant effect for Generation 3, $t(30)=4.65$, $p<.001$. As with SSRIF, if the effect of the selective practice implemented for Generation 1 participants is to propagate to Generation 2 and Generation 3 participants, the effect should be strong to begin with and subsequent generations should be influential in affecting their counterpart's memory. In the case of the rehearsal effect, despite the fact that both these criteria were met for both conditions, the propagation of the rehearsal effect stops after Generation 1 (Figure 3). This failure of the rehearsal effect to propagate beyond one generation could be due to the fact that items change their status from Rp+ to Rp-, and therefore experience retrieval-induced forgetting in subsequent chains. And indeed, 36% of items in both the Helpful and Interventionist conditions change status from Rp+ to Rp — from Generation 1 to Generation 2. It is plausible, thus, that the rehearsal effect triggered in the case of 64% of the items might be offset by the suppression effect triggered for 36% of the items that change retrieval status from Rp+ to Rp-.

3   Discussion

The present study is one of the first to build on the burgeoning work on communicative influences on memory to investigate information propagation. Using a

modified version of the method of serial reproduction, we found that cognitive processes manifested at an individual level influence information propagation in social exchanges. These propagation effects were shown to be dependent on the degree to which individuals concurrently retrieved the information with the speaker (Coman, & Hirst, 2015). This work validates and at the same time extends previous research on information propagation in chains of individuals. Coman & Hirst (2012) for instance, found that rehearsal and SSRIF effects propagate in conversations between attitudinally similar dyads, but not in attitudinally dissimilar dyads. The current study extends previous research in two important ways. First, it involves the investigation of longer social chains, which provides a more complex understanding of the strength of propagation of information and is one step closer to understanding how these effects propagate in larger social networks (Coman, Momennejad, Geana, & Drach, 2016). Second, it isolates a mechanistic explanation of how information propagation happens, by specifically investigating the ways in which the strength of concurrent retrieval in sequential interactions affects this propagation.

More importantly, these results suggest that other factors previously found to modulate the strength of SSRIF at a dyadic level, such as the listener's epistemic motivations (Cuc, Koppel, & Hirst, 2007), the speaker's perceived expertise (Koppel et al., 2014), and the degree of speaker-listener perceived similarity (Barber, & Mather, 2012) will probably affect information propagation in similar ways. Exploring the impact of these factors in a programmatic — theoretically informed — fashion, constitutes a promising avenue of psychological investigation. This is because the approach proposed herein could be used to formulate predictions as to how the propagation of influence in social networks could give rise to large-scale emergent properties, such as the formation of collective memory (Roediger & DeSoto, 2015). When the influence propagates in social chains, a community-wide effect is expected, whereas when this influence is attenuated during propagation, no such emergent effects are expected (Coman et al., 2016; Luhman & Rajaram, 2015).

It is important to add a cautionary note. Even when we created the context for relational motivations to impact information propagation, the SSRIF effect only propagated two degrees away from the originating source. On the one hand, this suggests that SSRIF might only minimally impact the emergence of collective memories in networks in which the average degree of separation exceeds 2. On the other hand, the influence one person exerts over another in real-world social networks is rarely isolated to one conversation. Similarly, two individuals could be connected through multiple (conversational) routes, therefore strengthening the inter-personal influence one individual could have over another. An important contribution of the current study is, thus, to provide an empirically tractable framework to investigate the impact of

socio-cognitive processes on large-scale mnemonic convergence (Coman et al., 2016). Research delving into the interaction between socio-cognitive phenomena and social network structure, composition, and size, has the potential to bridge between individual level mnemonic micro-processes and large-scale macro dynamics in ways heretofore underappreciated in the cognitive and social sciences (Sun, 2012).

Beyond their theoretical relevance, these findings have meaningful pragmatic implications. Originators of these mnemonic influences could be politicians, educators, newscasters, and, more generally, people who address public audiences. It is important, thus, to understand the impact of such influences and to acknowledge the fact that selective presentation of information can have serious deleterious consequences for the public, from the acquisition of health relevant information (Coman & Berry, 2015) to the propagation and maintenance of stereotypes (Lyons & Kashima, 2003). Programmatic investigations of these phenomena, we claim, could prove critically important in public policy contexts. The current study is the first to show that the attitudinal societal climate in which conversations happen (e.g., generalized support or opposition towards a particular policy) influence the propagation of information in communities of individuals. These findings hint at the possibility that in polarized societies the sensitivity to social influence could give rise to information bubbles (Pariser, 2011).

4 Acknowledgements

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