SSM - Population Health 33 (2026) 101902

Contents lists available at ScienceDirect

SSM - Population Health

journal homepage: www.elsevier.com/locate/ssmph

Countering the forgetting of novel health information with 'social boosting'

Vaibhav Krishna *, Nicholas A. Christakis

Yale Institute of Network Science, Yale University, Suite 393A, 17 Hillhouse Avenue, New Haven, CT 06511, USA

A B S T R A C T

The prevalence of misleading information, especially with respect to health care practices, poses a threat. While studies have shown the effectiveness of various intervention techniques in mitigating the adverse effects of low-quality or false information, the effectiveness of such interventions can decay. Here, we investigate the role of the detailed social structure within which the intervened individuals live, which provides opportunities for the individuals to discuss and internalize new knowledge. We evaluated this with respect to information about maternal and child health care, delivered via a 22-month in-home intervention, among targeted individuals in 110 isolated Honduran villages. We hypothesize that individuals who receive specific knowledge can internalize and consolidate this information by engaging in social interactions where, for instance, they have an opportunity to discuss it with others. We found that well-connected individuals within a social network experience an enhanced effectiveness of knowledge interventions. These individuals may be more likely to internalize and retain the information and reinforce it in others, due to increased opportunities for social interaction where they teach or explain new knowledge, a mechanism we refer to as "social boosting". These findings underscore the role of social interactions in reinforcing health knowledge interventions.

1. Introduction

Despite the importance of people being well-informed, repeated exposure to low-quality or false information can lead to its acceptance, even if it is harmful—a phenomenon known as the "illusion of truth" (Cook et al., 2017; Hassan & Barber, 2021; Pennycook et al., 2018). Examples range from widespread doubt-sowing messages on global warming that affect the progress of policymakers (Lewandowsky et al., 2015), to viral conspiracy documentaries around the pandemic that have been linked to vaccine hesitancy (Loomba et al., 2021), to the disinformation related to new technologies like 5G resulting in vandalism (Ahmed et al., 2020).

To mitigate such adverse effects, researchers have proposed various intervention techniques – for instance, debunking (Chan et al., 2017), through post-hoc correction, or pre-bunking, based on inoculation theory, which serves both as a preemptive and therapeutic measure to enhance cognitive resilience (Compton & Pfau, 2005; Ivanov, 2017). While these intervention techniques have demonstrated efficacy, recent studies have highlighted a decay process (Banas & Rains, 2010; Ivanov et al., 2018) consistent with Ebbinghaus' well-known forgetting curves (Rubin & Wenzel, 1996). Though a general consensus on the duration of the intervention effectiveness varies, recent longitudinal studies have often reported a complete decay of many knowledge interventions after just a few weeks (Banas & Rains, 2010; Ivanov et al., 2018; Zerback et al., 2021). As a result, even after corrections are made, individuals may persist in believing false information due to the continued influence effect (CIE) (Ecker et al., 2010, 2014).

To address this decay, studies have suggested "booster" treatments that exploit insights into memory and the importance of rehearsal (Hardt et al., 2013; Murre & Dros, 2015). Drawing on the principles of biomedical inoculation, it is theorized that, analogous to vaccines that strengthen the biological immune system, for the "cognitive immune system," regular information boosters may be needed (Maertens et al., 2025). Thus, while some longitudinal studies have reported a decay starting after two weeks, studies administering booster messages have shown effectiveness of more than six weeks, with a general consensus that boosters work when administered in the right form at the right time (Ivanov et al., 2018). However, despite their effectiveness, the implementation of regular booster interventions would require substantial resources, posing significant scaling challenges.

In this study, we postulate that traditional intervention strategies could involve leveraging social network interactions as a mechanism for reinforcement to strengthen the retention of correct knowledge. Individuals who receive specific knowledge can internalize and consolidate this information by engaging in social interactions where, for instance, they at least had an *opportunity* to discuss it with others in the process. According to the cognitive theory of learning, generative processing occurs when individuals explain knowledge, facilitating deeper understanding (Fiorella & Mayer, 2013). Therefore, the act of explaining information to others (knowledge sharing) promotes deeper cognitive processing and elaborative encoding, which ultimately enhances memory retention (Cohen, 1986; King et al., 1998). Hence, we hypothesize

* Corresponding author.
E-mail addresses: vaibhav.krishna@yale.edu (V. Krishna), nicholas.christakis@yale.edu (N.A. Christakis).

https://doi.org/10.1016/j.ssmph.2026.101902
Received 14 August 2025; Received in revised form 10 December 2025; Accepted 23 January 2026
Available online 24 January 2026
2352-8273/© 2026 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

that individuals with a higher number of social ties will demonstrate significantly greater knowledge retention in the long term.

Using data from a randomized controlled trial in which individuals received counseling interventions related to pregnancy and early infancy, and in which knowledge outcomes were assessed approximately 22 months after the intervention commenced, we examine how the targeted individuals' positions within the social network—specifically, the number of alters they interact with—influence the long-term retention of accurate knowledge through what we term a "social booster" treatment.

2. Methods

2.1. Study design and population

Our primary analyses uses individual-level data from a randomized-controlled trial (RCT) study conducted in the Department of Copan in western Honduras, an area characterized by high rates of neonatal and maternal morbidity and mortality. The parent trial evaluated a novel social network targeting technique in 176 villages in the Copan region (Airoldi & Christakis, 2024); of these, 110 were included in the current assessment (specifically, we included only those villages in which participants were assigned to treatment based on randomized target selection within the villages or villages in which either none or all the households received treatment, see Fig. 1). All individuals living in the study village and aged 12 years or above were eligible to participate. All the participants provided informed consent before enrollment in the study and the university IRB and the Honduran Ministry of Health approved all the data collection procedures (Protocol #1506016012).

A total of 24,702 individuals living in 10,013 households in 176 villages (constituting 81·2 % of the total population) were enrolled and participated in the baseline social network and attributes survey. The targeted households and individuals within these villages received a 22-month educational intervention (between Nov 2016 to Aug 2018, involving monthly, in-home visits) and were surveyed periodically. We rely on survey data collected during two waves – wave 1 [Oct 2015–Jun 2016; (W1)] and wave 3 [Jan 2019–Dec 2019; (W3)]. Social networks within each village were mapped using the open-source Trellis software (Lungeanu et al., 2021) and various "name-generator" questions were used to capture different social relationships.

The primary relationships we examined here used three key name-generator questions (*"Who do you spend your free time with?", "Who is your closest friend?",* and *"Who do you discuss personal matters with?"*). These generators capture relational contexts in which interpersonal communication and informal discussion are likely to occur, making them relevant for examining knowledge retention through interactions. We defined a tie if an ego nominated the alter on at least one of these generators. As our focus is on opportunities for interpersonal interaction rather than on directional influence, the social network obtained was symmetrized (i.e., we counted a tie either when an ego nominated an alter, or vice versa). To complement these social networks, we additionally examined ties derived from other key name generators, namely the alters an ego identified as those to whom they gave or from whom they got health advice. These networks are likely to capture informational interactions related to the intervention content and were used to assess the robustness of our findings.

A two-stage factorial design was used in the parent trial; in the first stage, villages were randomly assigned a dosage level, or the proportion of households targeted for intervention per village (0, 0·05, 0·1, 0·2, 0·3, 0·5, 0·75, 1); and, in the second stage, households were randomly assigned to the intervention. The current randomized assessment focuses on the 88 villages of which 66 villages were assigned to a proportion of randomly targeted households greater than 0 and less than 1 in a village (the proportions were 0.05, 0.1, 0.2, 0.3, 0.5, and 0.75), and 22 villages where all the households received the intervention. In addition, 22 further villages where no household received the intervention—i.e., villages with a dosage proportion equal to 0—were included and served as a control group for certain analyses.

The intervention assessment reported here establishes the correct knowledge response among the targeted individuals in the 88 villages at the endline survey (W3) collected 2 years after the baseline survey (W1). To identify key knowledge outcomes for evaluation, we compared responses at the endline survey for participants in the 22 fully treated villages (where everyone got the educational intervention) to the responses at the baseline survey. This comparison enabled the shortlisting of outcomes that demonstrated meaningful improvements in knowledge following the intervention, for use in the analysis in all the focal 88 villages.

While both the participants and the Community Change Agents (CCAs) who delivered the intervention were blinded to the criteria used for selecting the intervention households, complete masking of participants and CCAs was not feasible due to the nature of the intervention; however, ascertainment of outcomes in all villages was blinded as to treatment assignment.

2.2. Procedures

The RCT in this study was conducted with extensive local engagement, involving introducing the project to village leaders, securing local approvals, and managing local implementation of the study and intervention. CCAs, who were trained, compensated, and managed by World Vision, delivered the intervention – named *Proyecto Redes: Con Amor y Cuidados Madres y Bebés Sanos* (With Love and Care, Healthy Moms and Babies) – across two years (November 2016–August 2018). Each targeted household received up to 22 sessions, typically lasting 1–2 h and delivered monthly. These sessions covered 15 thematic modules based on a modified version of the globally recognized Timed and Targeted Counseling (ttC) framework (World Vision International. Timed and targeted counseling (ttC), 2016).

The interventions were tailored to the family's current circumstances and, accordingly, CCAs spoke to families regarding several health topics during every house visit. The educational content was designed to enhance knowledge about critical health topics including pregnancy preparedness, safe childbirth practices, newborn care, maternal nutrition, diarrheal and respiratory illness, and early childhood development. Furthermore, content delivery incorporated a behavior-change communication strategy based on the P Process tool, which uses narrative and negotiation techniques to foster engagement and agreement on health-promoting behaviors (Health Communication Capacity Collaborative. The P Process: Five Steps to Strategic Communication, 2013). An important part of the visits involved designing sessions that included discussing relevant regional practices that are potentially dangerous to newborns. The modules were thus tailored to correct these prevailing health malpractices and misbeliefs.

CCAs used tablets during the visits, which supported standardized delivery through multimedia aids—where families access educational materials through videos, songs, and riddles—that facilitate better understanding and retention. Importantly, unlike many community-based health interventions, this program was not limited to expectant mothers but included households irrespective of composition, allowing a broader diffusion of knowledge within social networks. The intervention also did not rely on mass media or community mobilize groups, focusing instead on intensive, individualized home visits.

Two different and independent teams of people delivered the interventions and conducted the outcomes assessment. The survey instrument was designed to capture target outcomes and demographic information. Baseline data, including a photographic census and network mapping, were collected from June 2015 to June 2016 using the open-source Trellis platform (Lungeanu et al., 2021). Endline data collection, including a follow-up census and survey, occurred from January 2019 to December 2019 (W3)—approximately 4 months after the conclusion of the intervention.

2.3. Outcomes

The primary outcomes are responses to knowledge queries at the endline survey (W3) related to maternal and neo-natal healthcare practices, which can be grouped into the following: (1) prenatal care and pregnancy danger signs; (2) care of the mother during childbirth and the postpartum period; (3) newborn care and danger signs; (4) infant care (caring for children 1–6 months); (4) danger signs and seeking medical attention for acute respiratory infections and diarrheal illnesses; (5) reproductive health including life plan and importance of preventing teen pregnancy; and (6) importance of folic acid for mother and baby. All outcomes were measured via a standard endline survey instrument. Participants' responses were recorded for a total of 60 knowledge outcomes, each mapped to one or more of the 15 counseling modules delivered during the intervention.

To shortlist the key outcomes for analysis in the focal 88 villages, we assessed the improvement in knowledge response at the endline survey (W3) in the 22 villages where 100 % of the residents got the intervention compared to responses that were recorded during the baseline survey (W1). Based on the foregoing, we filtered out the outcomes where the health knowledge was already high at the baseline. For example, 99 % of the participants at the baseline acknowledge that fathers should help care for their sick children while 96 % of the participants acknowledge that women ideally should wait to have their first baby at 18 years of age or older. We further filtered out the outcomes where the health knowledge was very low at baseline and very low at the endline survey. For example, only 1–2 % of participants at the baseline and endline know that difficulty in urinating is a prenatal danger sign, while only 1 % of participants at the baseline and endline know that retained placenta is a postpartum danger sign. Following this, we shortlisted 31 knowledge outcomes; this included two previously unheard riddles. Then, we analyzed the outcome responses of the *targeted* individuals from the 88 randomized targeted villages at the endline survey. The outcomes were coded as 1 for correct responses and 0 otherwise.

2.4. Statistical analysis

Given that our focus here is to estimate the knowledge outcomes of intervention at the endline survey (W3) for the *treated* individuals (who got the educational intervention), we used multivariate logistic regression fitted to individual-level data and binary outcome (correct response). We estimated the main effect of social interactions on the treated individuals based on the number of ties they have (i.e., we computed an "egocentric reduction" whereby information collected sociocentrically was assigned to each villager) corresponding to the social network built using three name generators based on the individual subjects identified as those with whom they (i) "spent free time", (ii) discussed "personal or private" matters, or (iii) were "close friends." Furthermore, to help account for the between-targeted-participants interference within villages, we included the proportion of each ego's ties who *also* received the specific intervention module. We assume that a respondent's outcome can be affected more by interactions with treated individuals compared to untreated individuals.

In addition, we account for the variability of intervention visits individuals received. In particular, some targeted individuals receive counseling sessions for intervention modules several times. The multiple counseling sessions might act as a direct booster treatment, and we control for this in our model.

We control for a range of demographic variables that may influence knowledge retention and outcomes, including age, sex, marital status, education level, and economic status. Existing research on cognitive aging indicates that memory performance tends to decline from early to late adulthood (Grady, 2000), largely due to a general slowing of cognitive processes and a reduction in attentional resources (Craik & Byrd, 1982; Craik et al., 1990; Naveh-Benjamin, 2000). Early research on sex differences in memory tasks has suggested that while neither sex can be said to have better memory per se, the two sexes differ in terms of what type of information they remember best (Loftus et al., 1987). Women outperform men on memory tasks that require remembering verbally encoded items owing to their advantage in verbal ability, while men's advantage in visuospatial ability favors them in the visual episodic memory performance (Pauls et al., 2013). These differences have been suggested to stem from sex-specific physiological capabilities, interests, expectations, or some complex interactions of these factors (Loftus et al., 1987). Females tend to remember information better which tapped their specific interests (e.g., i child care) to a greater extent (Pauls et al., 2013). We also account for marital status since married individuals might have a more vested interest in the information related to mother and child health care practices.

The influence of schooling on cognitive ability is well documented, showing a significant association of low schooling level with lower performance on attention, learning and episodic memory, reaction time, and spatial working memory (Bento-Torres et al., 2017). Recent studies have shown the influence of formal schooling, particularly literacy acquisition, on the growth of memory abilities, specifically on verbal memory (Kolinsky et al., 2020). This is theorized to be due to improvements in processing and temporary encoding of spoken language through phoneme awareness (Demoulin & Kolinsky, 2016).

Finally, socioeconomic disparities are associated with individual differences in cognitive development. Studies have found family income is associated with brain surface area in children and adolescents (Noble et al., 2015). Another line of research has suggested that individuals in low-income families are exposed to chronic stress (food anxiety, neighborhood disadvantages, and parental stress), which is known to have an impact across the brain, specifically on frontal areas, impairing both working memory and long-term memory (Shields, Doty, et al., 2017). Lower income is also associated with greater inflammatory activity (poor diet, fewer healthy behaviors, exposure to pathogens) which in turn impairs cognitive functioning (Shields, Moons, & Slavich, 2017).

Last, we accounted for the time gap, estimated as the number of months between the last intervention visit and the endline survey start date to account for forgetting in line with Ebbinghaus' forgetting curves (Rubin & Wenzel, 1996).

Significance was defined as $p < 0{\cdot}05$. Multicollinearity checks using variance inflation factors indicated no covariates exceeded accepted thresholds. All analyses were performed using R V.4.2.2.

3. Results

Participants aged 12 and older were recruited and completed the baseline survey between June 2015 and July 2016. A total of 66 of 176 villages were randomized to the random targeting strategy, in which 11 villages were randomly assigned to treatment dosages (or proportion of households targeted), of between 5 % and 75 %; 22 villages were randomized to 100 % targeting; and 22 villages were randomized to the control arm with 0 % treated households. Among the treatment arms, a total of 15177 individuals across 5416 households were randomized, 12353 of whom from 5033 households completed the baseline surveys (see Fig. 1).

Following the 22 months of counseling intervention that began in November 2016, 8250 individuals across 4229 households completed the endline survey (W3) between January 2019 and December 2019, approximately 26 months after intervention delivery began. A total of 1103 individuals out of our sample of treated individuals (30 %) were lost at the endline. Of the individuals lost by the endline, 46 % moved out of the village, 31 % could not be reached, 13 % refused to continue in the study, 5 % were lost to death, and 5 % to other reasons. Participants lost to the endline survey were more likely to be younger, male, single, and have at least a primary level of education. Retention among targeted households was 84 % (Table S6). Although some demographic differences were observed, the analytic sample remained broadly comparable on key variables central to the study mechanisms, particularly measures

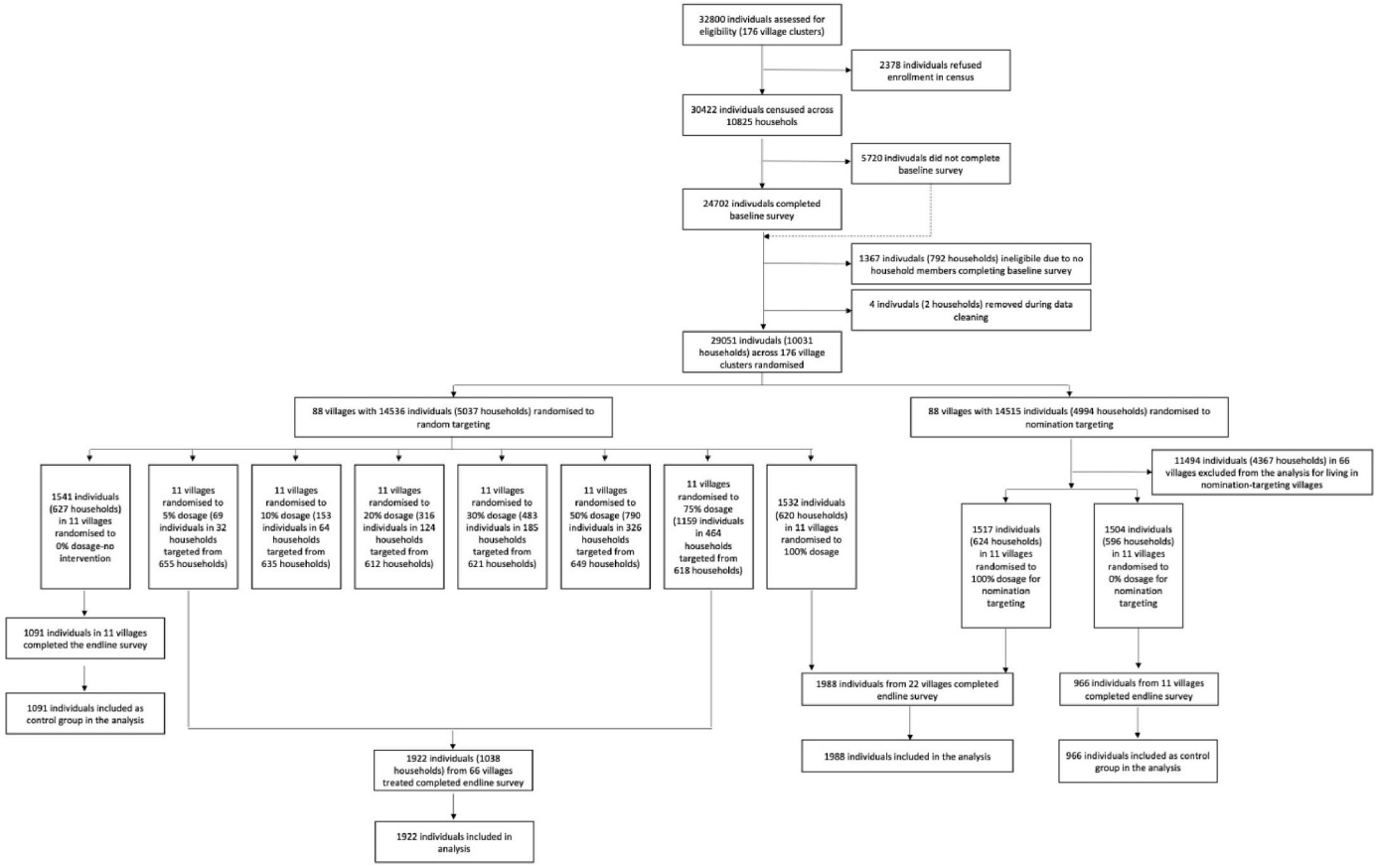

Fig. 1. A population-level cluster randomized controlled trial of maternal and child health intervention.

of social connectedness (Table S6).

Across all the 66 villages assigned to random targeting strategy and the 22 villages assigned to 100 % households targeting, the number of participant households varied between 12 and 193, and the number of individual participants varied between 15 and 315 each. In the randomized targeting villages and the 100 % targeted villages, a total of 3698 individuals in 1822 households received knowledge intervention visits between November 2016 and August 2018.

In the targeted villages, at baseline, 7108 (58 %) participants were women. The mean age of the participants was 32·8 years (SD 17·2); 7154 (58 %) of the respondents were married or in a civil union. At the endline survey, among the randomized targeted individuals, the mean age was 37·6 (SD 17·7); 1780 (69 %) participants were women; and 1738 (67 %) of the individuals were married or in a civil union. Descriptive statistics of the randomized targeted villages are reported in Table 1.

The number of social ties that individual egos had (an indicator of social interactions) is associated with improvements in the correct knowledge response related to intervention even 20 months after its delivery. We modeled the heterogenous treatment effects of social interaction opportunities by comparing individuals with varying degrees of social ties at the endline survey for the treated (from the 88 villages) and the control group (22 villages where no household received any intervention).

Fig. 2 shows four illustrative outcomes corresponding to intervention modules related to pregnancy and postnatal mother care, postnatal newborns care, and knowledge about proper diarrhea treatment among the targeted participants, compared to the control group at the endline survey. While the intervention resulted in higher probability of correct response among the targeted individuals, this improvement is significantly higher for individuals with a higher number of social ties.

For example, while the intervention improved the correct response of knowing the use of folic acid before pregnancy by ~6 % for individuals having fewer social ties (low opportunity of social interactions), it improves by up to ~15 % for individuals having more social ties (high opportunity of social interactions) (Fig. 2A). Similarly, the intervention improved the understanding of proper treatment of diarrhea in children five and under by ~11 % for individuals having low social ties, it improves by up to ~21 % for individuals having the highest number of social ties (Fig. 2D).

We estimated the effect size of the social ties on the likelihood of correct response for the treated individuals in the focal 88 villages at the endline survey. During the intervention visits, aimed at increasing awareness of health practices among families, community health workers also introduced and taught two previously unheard riddles. These riddles were developed in consultation with community members at the outset of the trail and drew on familiar cultural references. For example, wrapping *fejaros* (umbilical cord belly bands) around newborns belly is a common practice in these villages, and zinc and aluminuim sheets are widely used as roofing materials. The first riddle (riddle 1) asks, "*Dry, dry without a fajero, it falls off quicker, you will see it. What is it?*" (umbilical cord), and the second (riddle 2) states, "*It seems like it is for the roof, but it's not—it's for diarrhea, you tell me, what is it?*" (zinc). We modeled the outcomes of two riddles at the endline survey (W3) for the targeted individuals to observe how social ties are associated with the likelihood of correct answer retention to this exogenously introduced and novel information. Our findings, shown in Table 2, indicate that the number of social ties is positively associated with the likelihood of providing accurate responses to the riddles. In particular, each additional social tie is associated with an average of 30 % increase in the probability of a correct response. Moreover, the accuracy of responses to riddles also improves when a higher proportion of an ego's connections

Table 1
Characteristics of the population in 88 villages (random-targeting and 100 % targeted villages).

Respondent characteristics	Baseline	Endline	Treated individuals at endline
Individuals	12353	8250	2595
Sex			
Female	7108 (58 %)	5321 (65 %)	1780 (69 %)
Male	5245 (42 %)	2929 (35 %)	815 (31 %)
Age at baseline	32·8 (17·2)	35·0 (17·5)	37·6 (17·7)
Education			
Less than primary	2616 (21 %)	1954 (24 %)	674 (26 %)
Primary	8488 (69 %)	5360 (65 %)	1670 (64 %)
Secondary or greater	1249 (10 %)	936 (11 %)	251 (10 %)
Marital status			
Single	4392 (36 %)	2494 (30 %)	655 (25 %)
Married or civil union	7154 (58 %)	5133 (62 %)	1738 (67 %)
Separated/divorced/ widowed	807 (6 %)	623 (8 %)	202 (8 %)
Intervention visit count	–	–	1.4 (0.6)
Number of social ties	5.8 (3.6)	5.2 (3.4)	5.4 (3.6)
Percent of alters intervene	–	27.2 (31)	45.1 (33)
Household characteristics			
Households	5033	4229	1529
Wealth index			
Quintile 1	2052 (17 %)	1271 (15 %)	427 (17 %)
Quintile 2	2335 (19 %)	1598 (19 %)	505 (20 %)
Quintile 3	2480 (21 %)	1617 (20 %)	490 (19 %)
Quintile 4	2602 (21 %)	1878 (23 %)	603 (23 %)
Quintile 5	2735 (22 %)	1880 (23 %)	554 (21 %)

(alters) also received the intervention.

Analyzing responses across multiple outcomes, we found that the number of alters that targeted individuals have – a proxy for increased opportunities for social interactions – shows a consistent and significant effect on their likelihood of retaining accurate knowledge at the endline survey related to prenatal care, postnatal mother, and newborn care (see Fig. 3).

Specifically, for maternal care knowledge before and during pregnancy, each additional social tie was associated with notable improvements in key indicators. Targeted individuals with stronger social ties were 38 % more likely per social tie to correctly recall the importance of taking folic acid before pregnancy for women (95 % CI: 18·8 %-61·8 %, $p < 0·000$). The effect was even more pronounced for timely prenatal care, where an additional social tie translated into an 84 % increase in the likelihood of identifying that prenatal checkups should begin by 12 weeks of pregnancy (95 % CI: 42·2 %-136·6 %, $p < 0·000$). Social ties also associated with strengthened knowledge retention of pregnancy danger sighs; for instance, knowledge that headaches during pregnancy signal risk increased by 19 % for each additional social tie (95 % CI: 6·2 %-32·7 %, $p = 0·007$). Similarly, understanding that having a saving plans is essential for birth preparation rose by 54 % per social tie (95 % CI: 20·4 %–98.1 %, $p = 0·005$).

A similar pattern emerges for knowledge related to proper care during postnatal period, where social ties are associated with enhanced ability to retain critical health information. Each additional tie increased the likelihood of identifying that mothers should receive a postnatal checkup within three days by 19 % (95 % CI: 5·7 %-33·6 %, $p = 0·011$) and within seven days by 26 % (95 % CI: 13·2 %-40·6 %, $p < 0·000$). Recognition of postnatal danger signs also improved: awareness that severe headache is a warning sign rose by 20 % per additional social tie (95 % CI: 6·9 %-34·2 %, $p = 0·005$), and that heavy vaginal bleeding indicates postpartum danger increased by 24 % (95 % CI: 10·0 %-39·0 %, $p = 0·002$). Knowledge retention related to newborn care also showed similar strong association with social ties. Individuals with each additional social tie were 29 % more likely to know that infants should be exclusively breastfed for the first six months (95 % CI: 11·9 %-50·7 %, $p = 0·004$). Awareness of neonatal danger signs also increased substantially, including difficulty breathing (29 % increase, 95 % CI: 12·7 %-46·6 %, $p = 0·001$) and pneumonia (22 % increase, 95 % CI 7·5 %-38·8 %, $p = 0·015$) per extra social tie. Furthermore, we found a significant association of social ties with the effectiveness of intervention for knowledge related to proper treatment of diarrhea in children five and under.

In addition to the observed association of social ties, we also found that the *proportion of an ego's alters who were randomly selected to also received the same intervention* also positively influenced knowledge retention for several important outcomes. For instance, individuals whose network members were also exposed to the intervention were 15 % more likely to correctly identify that folic acid should be taken before pregnancy (95 % CI: 2·7 %-28·1 %, $p = 0·032$). Shared intervention within the network similarly strengthened recognition of pregnancy danger sign: the likelihood of identifying severe headache as a risk indicator increased by 16 % (95 % CI: 4·7 %-29·3 % $p = 0·037$). Parallel effects were observed in enhanced knowledge retention related to newborn care. A greater proportion of treated alters was associated with a 19 % increase in the probability of recognizing fever as a neonatal danger sign (95 % CI: 7·3 %-31·0 %, $p = 0·003$). Likewise, knowing zinc as the appropriate treatment for childhood diarrhea treatment riddle rose by 18 % (95 % CI 5·2 %-31·5 %, $p = 0·009$).

We found no significant association of social ties with knowledge response outcomes related to attitudes towards helping women with housework during pregnancy; awareness of fever as a prenatal danger sign; awareness of feeling pain and weakness as a postpartum danger sign; and acknowledging accompanying woman to prenatal care as support during pregnancy (see online supplementary appendix Table S1).

We performed several additional analyses to evaluate the robustness of our results. First, as our hypothesis posits that increased opportunities of social interactions are likely to improve knowledge retention among targeted individuals, we expanded the network to include two additional name generators. In particular, we included ties corresponding to: (1) whom the respondent gets health advice from, and (2) whom the respondent gives health advice to, alongside the three name generators used in the primary analysis (see online supplementary appendix Table S2 and Table S3). Second, to account for the hierarchical structure of the data – individuals nested within villages - we estimated multilevel models with village-level random intercepts (see online supplementary appendix Table S4). Finally, for some outcomes where we have baseline knowledge measures, we estimated models controlling for baseline knowledge (see online supplementary appendix Table S5).

Across all robustness checks, we find consistent significant positive association between individuals' number of social connections and their likelihood of retaining and correctly responding to the intervention-related knowledge outcomes.

4. Discussion

An increasing number of real-world interventions are being offered to preemptively or therapeutically protect people against prevailing misbeliefs or malpractices (Lewandowsky & Van Der Linden, 2021). These interventions have demonstrated positive effects on individuals in fostering correct beliefs or knowledge when measured immediately after treatment. However recent studies have highlighted that such

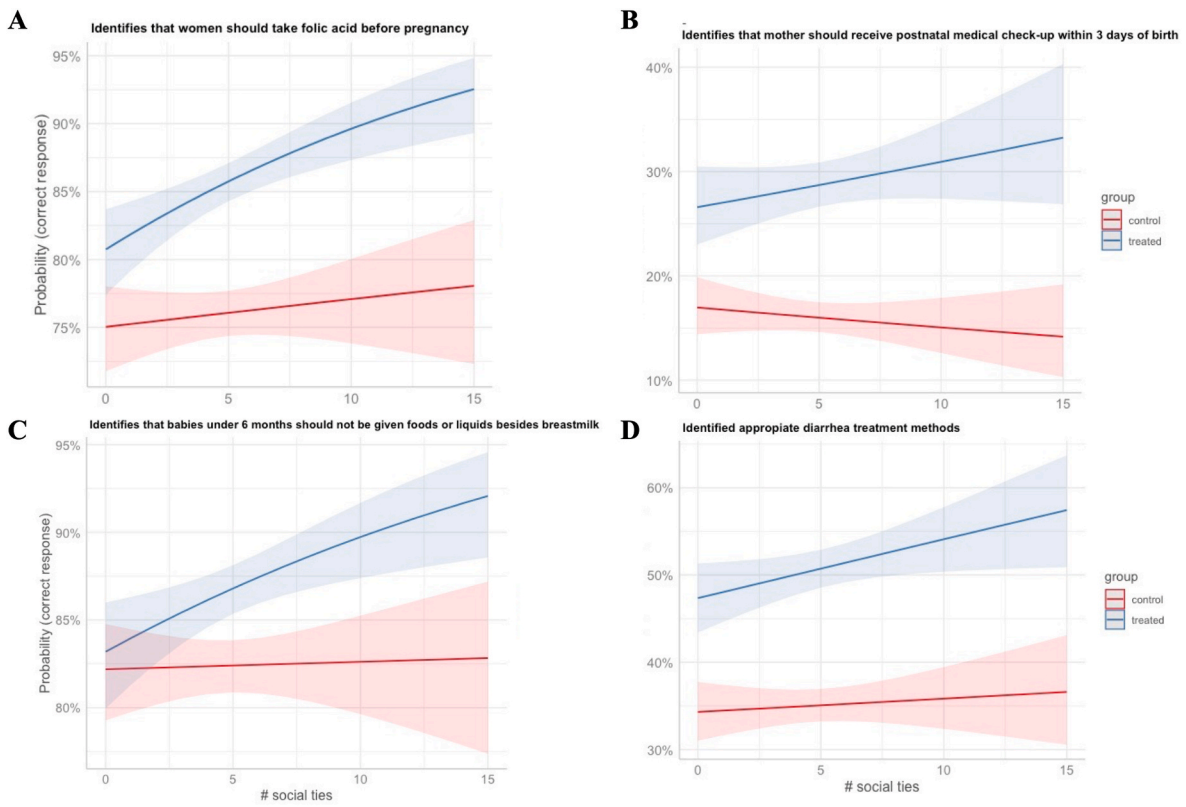

Fig. 2. Association of the number of social ties with knowledge outcomes in treated vs control group.

Table 2
Association of social ties with riddle knowledge outcomes at endline survey.

	Riddle 1		Riddle 2	
	effect	p-value♠	effect	p-value♠
age at survey	−0.741	<0·000***	−0.672	<0·000***
sex (male)	−0.802	<0·000***	−1.330	<0·000***
education level (Primary)	0.509	<0·000***	0.431	0·003**
education level (Secondary)	0.914	0·007**	1.040	0·003**
marital status (Married)	0.865	<0·000***	0.766	<0·000***
marital status (Divorced)	0.410	0·239	0.270	0·428
household wealth index (Q2)	0.205	0·386	0.156	0·516
household wealth index (Q3)	0.268	0·248	−0.058	0·813
household wealth index (Q4)	0.062	0·755	0.235	0·333
household wealth index (Q5)	0.410	0·097(.)	0.460	0·047*
months since intervention	−0.052	0·433	0.014	0·835
Intervention visit counts	−0.078	0·248	0.045	0·583
Number of social ties	0.245	<0·000***	0.290	<0·000***
Percent of alters got intervention	0.044	0·491	0.163	0·009**
	*Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1*			
AIC	1799		1924	
BIC	1879		2005	

♠ - False discovery rate (FDR) adjusted p-value.

interventions are often only effective for a month before the decay process starts (Ivanov et al., 2018). To counter such decay, memory-enhancing booster interventions have been suggested (Maertens et al., 2025). However, the scalability of these booster interventions poses challenges, especially under resource-constraint settings.

In this study, we found that being well-connected within a social network might enhance the effectiveness of knowledge interventions. These individuals may be more likely to internalize and retain the information, due to increased opportunities for social interaction where they teach others or learn from them, a mechanism we refer to as "social boosting."

Using data from a randomized controlled trial conducted across 110 villages in Honduras, aimed at delivering knowledge-based interventions on maternal and neonatal health practices, we evaluated the association of having social connections with knowledge retention among targeted individuals, 26 months after the educational intervention began. This study's extended follow-up period enables a robust examination of sustained knowledge retention over time. Our findings indicate a significant positive association between the number of social ties an ego has and improved knowledge retention across several key health outcomes.

Individuals with more social ties were substantially more likely to retain knowledge from interventions across multiple maternal and newborn health domains, ranging from folic acid use before pregnancy to the timing of prenatal care, breastfeeding, and recognizing neonatal danger signs such as pneumonia. These patterns indicate that social interactions may provide opportunities for repeated discussion, rehearsals, and reinforcement of newly acquired knowledge. Moreover, the benefits of social connectedness were amplified when a larger share of individual's social ties also received the intervention. In such networks, targeted individuals showed greater retention of knowledge, including stronger recognition of the recommended timing of prenatal care and the importance of accompanying pregnant women to clinic visits.

These findings underscore the role of social interactions in reinforcing health knowledge interventions over the long term. From a theoretical standpoint, these results are consistent with the generative learning theory and the social presence hypothesis which holds that deeper cognitive processing occurs when learners engage in generative processing leading to improved learning outcomes (although, to be clear, here we only observed *opportunities* to engage, not actual conversations). In particular, possibly by explaining newly acquired knowledge to others, learners can engage in the cognitive processes of

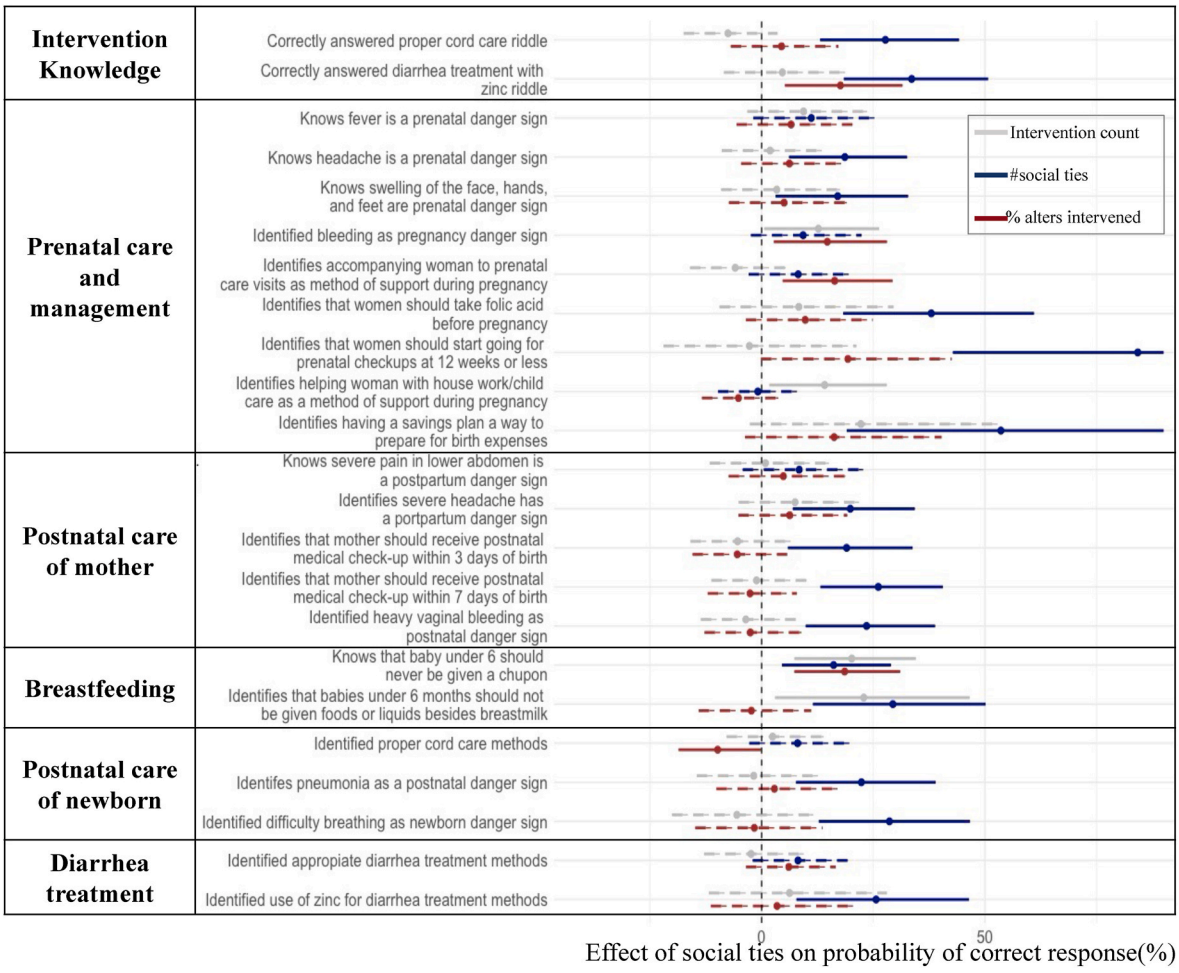

Fig. 3. Significant positive effects of social ties on knowledge outcomes at endline survey (solid lines represent significant effect at 95 % CI).

selecting relevant information, organizing it in a coherent structure, and integrating it with prior knowledge. This process promotes the formation of both internal cognitive connections and external communicative linkages, enhancing learning and long-term knowledge retention (Fiorella & Mayer, 2013). Furthermore, the social presence hypothesis posits that heightened perceptions of social presence—such as those experienced when explaining information to others—enhance motivation and elicit physiological arousal (Hoogerheide et al., 2016). These factors foster the consolidation of working memory and stimulate more intensive cognitive processing, thereby promoting deeper learning outcomes (Fiorella & Mayer, 2016).

Alternatively, insights from cognitive neuroscience studies that measure brain activity during cognitive and social processing offer a potential mechanism through which social interactions may enhance cognitive functioning. These studies highlight that regions of the brains that are activated during social interactions such as explaining to others, are also associated with long-term memory and integrating information from learning materials (Decety & Lamm, 2007; Jakobs et al., 2012). Extant fNIRS study showed that groups involved in both social and cognitive processing have enhanced activated brain regions compared to groups that are engaged in only cognitive tasks. Thus, the simultaneous cognitive and social processing that activates while explaining to others facilitates stronger brain patterns, leading to deeper learning and memory outcomes (Zhu et al., 2024).

The enhanced effect of intervened alters on egos' learning that we observe can also be understood through the lens of active and collaborative learning theories (Van Blankenstein et al., 2011). Research on active learning underscores the value of peer discussions in promoting knowledge retention. These discussions, a facet of active learning, promote critical thinking and higher-order, deep learning (Pollock et al., 2011). When learners acquire new knowledge, they benefit significantly from interactive exchanges with their peers, in which they elaborate, defend, and extend their positions, opinions and beliefs(Garside, 1996). Such processes promote the resolution of any inconsistencies, stimulate new ideas, and enhance elaboration of more coherent mental models (Webb, 1989). This deeper cognitive processing not only strengthens knowledge structures, but also counteracts forgetting, thereby facilitating long-term retention of newly acquired information (Reder, 1980). Together, these findings underscore the important role that social connectedness plays in reinforcing the long-term effectiveness of health knowledge intervention.

Furthermore, these findings also complement the work on opportunity structures in social networks, including insights on role-sets (Merton, 1957) and frameworks of cross-cutting social circles (Blau et al., 2018), which emphasizes individuals' social environments shape their opportunities to encounter varied perspectives. The opportunity structures could thus provide the settings through which people rehearse, refine, and internalize new knowledge. These findings also intersect with the perspectives from social learning theory (SLT) (Bandura & Walters, 1977), which emphasizes that individuals acquire knowledge and behaviors by observing, modeling, and interacting with others. However, whereas SLT focuses primarily on learning through imitation, the 'social boosting' mechanism proposed in this study stresses internalization through repeated rehearsals and explanation of learned content during social interactions. This distinction underscores the value of generative processes, rather than passive observation within

social contexts.

It is noteworthy that while we observed a generally positive association of social ties with knowledge outcomes across several outcomes, the extent and nature of this association may vary depending on the knowledge possibly being transmitted – such as the complexity of the knowledge or the prevalence of the long-standing beliefs. For instance, in the case of the outcome assessing whether individuals recognize providing support to pregnant women (such as assisting with household work or childcare) as an appropriate form of help, our analysis revealed a non-significant negative association with the number of social ties. This finding suggests that normative beliefs, particularly those tied to entrenched sex roles, may be resistant to change either due to reduced interpersonal dissemination by targetted individuals or the reinforcement of prevailing norms through social feedback. This pattern aligns with SLT's principle that peer reinforcement (praise, or criticism) shapes likelihood of adopting or rejecting new behaviors (Jones et al., 2011). Interestingly, for this same outcome, we found a significant positive effect of intervention visits by health agents, indicating that repeated exposure (direct booster treatment) to targeted messaging may be able to overcome normative resistance more effectively than informal social interactions alone. Taken together, these results highlight the importance of individuals' exposure to diverse social influences, consistent with work on cross-cutting social circles and norm heterogeneity (Centola, 2015).

This work has limitations. First, the data used in this study is collected through RCT that focuses on one country and an intervention specific to maternal and child health. Future studies could study the social booster effects of correcting misbeliefs (misinformation) with respect to political conspiracy theories, scientific myths around epidemics, or climate change perspectives. Second, the current study used name generator questions to capture social network interactions. It will be interesting to analyze more granular social interactions, e.g., by asking how many times targeted individuals actually discussed the new knowledge they acquired with their social ties, who they discussed with, and so on. These will help establish more causal relationships of the underlying mechanism. Third, the current work studies information flow in a face-to-face network, which might differ for information flow in online social networks. Lastly, while the current work examines the association of opportunity of social interactions on targeted individuals, it will be interesting to examine how targeted well-connected individuals reinforce health knowledge on non-targetted individuals. In this aspect, future studies could draw insights from social contagion (Christakis & Fowler, 2013; Airoldi & Christakis, 2024), social learning (Bandura & Walters, 1977), and innovation diffusion (Young, 2009) theories to illuminate broader network-level dynamics. Together, these perspectives reflect to classic work on foci in Homans' theorization of human groups, emphasizing how shared settings generate repeated interactions that foster group cohesion and facilitate learning (Feld, 1981; Homans, 2013).

The social reinforcement of learning is a key means by which learning transpires in the first place, and a key means by which forgetting is avoided. When a subject is surrounded by others with whom they might discuss novel information, they may be more likely to retain, and not just spread, that information themselves.

CRediT authorship contribution statement

Vaibhav Krishna: Writing – review & editing, Writing – original draft, Investigation, Funding acquisition, Formal analysis, Conceptualization. **Nicholas A. Christakis:** Writing – review & editing, Supervision, Resources, Investigation, Funding acquisition, Data curation.

Data sharing and availability

Compliant with our privacy and confidentiality assurances to our research participants and with other legal obligations, data may be made available on our secure server, subject to data release provisions in force at Yale and the Yale Institute for Network Science (or successor entities) at the time of release. Access to data requires proof of IRB approval and human participants certification. Contact nicholas.christakis@yale.edu for inquiries regarding the data.

Ethics approval

This study involves human participants and all participants provided informed consent at the time of data collection before randomisation. Ethics approval was obtained from the Institutional Review Board (Protocol #1506016012) at Yale University in New Haven, Connecticut, USA and the Ministry of Health of Honduras.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

We acknowledge support from Grant OPP1098684 from the Bill and Melinda Gates Foundation. VK acknowledges support from Grant No. P500PS_217720 from Swiss National Science Foundation (SNSF).

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ssmph.2026.101902.

References

Ahmed, W., Vidal-Alaball, J., Downing, J., & López Seguí, F. (2020). COVID-19 and the 5G conspiracy theory: Social network analysis of Twitter data. *Journal of Medical Internet Research, 22*, Article e19458. https://doi.org/10.2196/19458

Airoldi, E. M., & Christakis, N. A. (2024). Induction of social contagion for diverse outcomes in structured experiments in isolated villages. *Science, 384*(6695), Article eadi5147.

Banas, J. A., & Rains, S. A. (2010). A meta-analysis of research on inoculation theory. *Communication Monographs, 77*, 281–311. https://doi.org/10.1080/03637751003758193

Bandura, A., & Walters, R. H. (1977). *Social learning theory*. Englewood Cliffs, NJ: Prentice hall.

Bento-Torres, N. V. O., Bento-Torres, J., Tomás, A. M., Costa, V. O., Corrêa, P. G. R., Costa, C. N. M., Jardim, N. Y. V., & Picanço-Diniz, C. W. (2017). Influence of schooling and age on cognitive performance in healthy older adults. *Brazilian Journal of Medical and Biological Research, 50*, Article e5892. https://doi.org/10.1590/1414-431x20165892

Blau, P. M., Schwartz, J. E., & Blau, P. M. (2018). *Crosscutting social circles: Testing a macrostructural theory of Intergroup relations* (1st ed.). Routledge. https://doi.org/10.4324/9781351313049

Centola, D. (2015). The social origins of networks and diffusion. *American Journal of Sociology, 120*, 1295–1338. https://doi.org/10.1086/681275

Chan, M. S., Jones, C. R., Hall Jamieson, K., & Albarracín, D. (2017). Debunking: A meta-analysis of the psychological efficacy of messages countering misinformation. *Psychological Science, 28*, 1531–1546. https://doi.org/10.1177/0956797617714579

Christakis, N. A., & Fowler, J. H. (2013). Social contagion theory: Examining dynamic social networks and human behavior. *Statistics in Medicine, 32*, 556–577. https://doi.org/10.1002/sim.5408

Cohen, J. (1986). Theoretical considerations of peer tutoring. *Psychol. Schs., 23*, 175–186. https://doi.org/10.1002/1520-6807(198604)23:2%253C175::AID-PITS2310230211%253E3.0.CO;2-H

Compton, J. A., & Pfau, M. (2005). Inoculation theory of resistance to influence at maturity: Recent progress in theory development and application and suggestions for future research. *Annals of the International Communication Association, 29*, 97–146. https://doi.org/10.1080/23808985.2005.11679045

Cook, J., Lewandowsky, S., & Ecker, U. K. H. (2017). Neutralizing misinformation through inoculation: Exposing misleading argumentation techniques reduces their influence. *PLoS One, 12*, Article e0175799. https://doi.org/10.1371/journal.pone.0175799

Craik, F. I. M., & Byrd, M. (1982). Aging and cognitive deficits. In F. I. M. Craik, & S. Trehub (Eds.), *Aging and cognitive processes* (pp. 191–211). US, Boston, MA: Springer. https://doi.org/10.1007/978-1-4684-4178-9_11.

Craik, F. I. M., Morris, L. W., Morris, R. G., & Loewen, E. R. (1990). Relations between source amnesia and frontal lobe functioning in older adults. *Psychology and Aging, 5*, 148–151. https://doi.org/10.1037/0882-7974.5.1.148

Decety, J., & Lamm, C. (2007). The role of the right temporoparietal junction in social interaction: How low-level computational processes contribute to meta-cognition. *The Neuroscientist, 13*, 580–593. https://doi.org/10.1177/1073858407304654

Demoulin, C., & Kolinsky, R. (2016). Does learning to read shape verbal working memory? *Psychonomic Bulletin & Review, 23*, 703–722. https://doi.org/10.3758/s13423-015-0956-7

Ecker, U. K. H., Lewandowsky, S., Fenton, O., & Martin, K. (2014). Do people keep believing because they want to? Preexisting attitudes and the continued influence of misinformation. *Mem Cogn, 42*, 292–304. https://doi.org/10.3758/s13421-013-0358-x

Ecker, U. K. H., Lewandowsky, S., & Tang, D. T. W. (2010). Explicit warnings reduce but do not eliminate the continued influence of misinformation. *Mem Cogn, 38*, 1087–1100. https://doi.org/10.3758/MC.38.8.1087

Feld, S. L. (1981). The focused Organization of Social Ties. *American Journal of Sociology, 86*, 1015–1035. https://doi.org/10.1086/227352

Fiorella, L., & Mayer, R. E. (2013). The relative benefits of learning by teaching and teaching expectancy. *Contemporary Educational Psychology, 38*, 281–288. https://doi.org/10.1016/j.cedpsych.2013.06.001

Fiorella, L., & Mayer, R. E. (2016). Eight ways to promote generative learning. *Educational Psychology Review, 28*, 717–741. https://doi.org/10.1007/s10648-015-9348-9

Garside, C. (1996). Look who's talking: A comparison of lecture and group discussion teaching strategies in developing critical thinking skills. *Communication Education, 45*, 212–227. https://doi.org/10.1080/03634529609379050

Grady, C. (2000). Changes in memory processing with age. *Current Opinion in Neurobiology, 10*, 224–231. https://doi.org/10.1016/S0959-4388(00)00073-8

Hardt, O., Nader, K., & Nadel, L. (2013). Decay happens: The role of active forgetting in memory. *Trends in Cognitive Sciences, 17*, 111–120. https://doi.org/10.1016/j.tics.2013.01.001

Hassan, A., & Barber, S. J. (2021). The effects of repetition frequency on the illusory truth effect. *Cogn. Research, 6*, 38. https://doi.org/10.1186/s41235-021-00301-5

Health Communication Capacity Collaborative. (2013). *The P process: Five steps to strategic communication*.

Homans, G. C. (2013). *The Human Group* (0 ed.). Routledge. https://doi.org/10.4324/9780203709009

Hoogerheide, V., Deijkers, L., Loyens, S. M. M., Heijltjes, A., & Van Gog, T. (2016). Gaining from explaining: Learning improves from explaining to fictitious others on video, not from writing to them. *Contemporary Educational Psychology, 44–45*, 95–106. https://doi.org/10.1016/j.cedpsych.2016.02.005

Ivanov, B. (2017). Inoculation theory applied in health and risk messaging. In *Oxford research encyclopedia of communication*. Oxford University Press. https://doi.org/10.1093/acrefore/9780190228613.013.254.

Ivanov, B., Parker, K. A., & Dillingham, L. L. (2018). Testing the limits of inoculation-generated resistance. *Western Journal of Communication, 82*, 648–665. https://doi.org/10.1080/10570314.2018.1454600

Jakobs, O., Langner, R., Caspers, S., Roski, C., Cieslik, E. C., Zilles, K., Laird, A. R., Fox, P. T., & Eickhoff, S. B. (2012). Across-study and within-subject functional connectivity of a right temporo-parietal junction subregion involved in stimulus–context integration. *NeuroImage, 60*, 2389–2398. https://doi.org/10.1016/j.neuroimage.2012.02.037

Jones, R. M., Somerville, L. H., Li, J., Ruberry, E. J., Libby, V., Glover, G., Voss, H. U., Ballon, D. J., & Casey, B. J. (2011). Behavioral and neural properties of social reinforcement learning. *Journal of Neuroscience, 31*, 13039–13045. https://doi.org/10.1523/JNEUROSCI.2972-11.2011

King, A., Staffieri, A., & Adelgais, A. (1998). Mutual peer tutoring: Effects of structuring tutorial interaction to scaffold peer learning. *Journal of Educational Psychology, 90*, 134–152. https://doi.org/10.1037/0022-0663.90.1.134

Kolinsky, R., Gabriel, R., Demoulin, C., Gregory, M. M., De Carvalho, K. S., & Morais, J. (2020). The influence of age, schooling, literacy, and socioeconomic status on serial-order memory. *J Cult Cogn Sci, 4*, 343–365. https://doi.org/10.1007/s41809-020-00056-3

Lewandowsky, S., Oreskes, N., Risbey, J. S., Newell, B. R., & Smithson, M. (2015). Seepage: Climate change denial and its effect on the scientific community. *Global Environmental Change, 33*, 1–13. https://doi.org/10.1016/j.gloenvcha.2015.02.013

Lewandowsky, S., & Van Der Linden, S. (2021). Countering misinformation and fake news through inoculation and prebunking. *European Review of Social Psychology, 32*, 348–384. https://doi.org/10.1080/10463283.2021.1876983

Loftus, E. F., Banaji, M. R., Schooler, J. W., & Foster, R. (1987). Who remembers what?: Gender differences in memory. *Michigan Quarterly Review, 26*, 64–85.

Loomba, S., De Figueiredo, A., Piatek, S. J., De Graaf, K., & Larson, H. J. (2021). Measuring the impact of COVID-19 vaccine misinformation on vaccination intent in the UK and USA. *Nature Human Behaviour, 5*, 337–348. https://doi.org/10.1038/s41562-021-01056-1

Lungeanu, A., McKnight, M., Negron, R., Munar, W., Christakis, N. A., & Contractor, N. S. (2021). Using Trellis software to enhance high-quality large-scale network data collection in the field. *Social Networks, 66*, 171–184. https://doi.org/10.1016/j.socnet.2021.02.007

Maertens, R., Roozenbeek, J., Simons, J. S., Lewandowsky, S., Maturo, V., Goldberg, B., Xu, R., & Van Der Linden, S. (2025). Psychological booster shots targeting memory increase long-term resistance against misinformation. *Nature Communications, 16*, 2062. https://doi.org/10.1038/s41467-025-57205-x

Merton, R. K. (1957). The Role-Set: Problems in sociological theory. *British Journal of Sociology, 8*, 106. https://doi.org/10.2307/587363

Murre, J. M. J., & Dros, J. (2015). Replication and analysis of ebbinghaus' forgetting curve. *PLoS One, 10*, Article e0120644. https://doi.org/10.1371/journal.pone.0120644

Naveh-Benjamin, M. (2000). Adult age differences in memory performance: Tests of an associative deficit hypothesis. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 26*, 1170–1187. https://doi.org/10.1037/0278-7393.26.5.1170

Noble, K. G., Houston, S. M., Brito, N. H., Bartsch, H., Kan, E., Kuperman, J. M., Akshoomoff, N., Amaral, D. G., Bloss, C. S., Libiger, O., Schork, N. J., Murray, S. S., Casey, B. J., Chang, L., Ernst, T. M., Frazier, J. A., Gruen, J. R., Kennedy, D. N., Van Zijl, P., … Sowell, E. R. (2015). Family income, parental education and brain structure in children and adolescents. *Nature Neuroscience, 18*, 773–778. https://doi.org/10.1038/nn.3983

Pauls, F., Petermann, F., & Lepach, A. C. (2013). Gender differences in episodic memory and visual working memory including the effects of age. *Memory, 21*, 857–874. https://doi.org/10.1080/09658211.2013.765892

Pennycook, G., Cannon, T. D., & Rand, D. G. (2018). Prior exposure increases perceived accuracy of fake news. *Journal of Experimental Psychology: General, 147*, 1865–1880. https://doi.org/10.1037/xge0000465

Pollock, P. H., Hamann, K., & Wilson, B. M. (2011). Learning through discussions: Comparing the benefits of small-group and large-class settings. *Journal of Political Science Education, 7*, 48–64. https://doi.org/10.1080/15512169.2011.539913

Reder, L. M. (1980). The role of elaboration in the comprehension and retention of prose: A critical review. *Review of Educational Research, 50*, 5–53. https://doi.org/10.3102/00346543050001005

Rubin, D. C., & Wenzel, A. E. (1996). One hundred years of forgetting: A quantitative description of retention. *Psychological Review, 103*, 734–760. https://doi.org/10.1037/0033-295X.103.4.734

Shields, G. S., Doty, D., Shields, R. H., Gower, G., Slavich, G. M., & Yonelinas, A. P. (2017). Recent life stress exposure is associated with poorer long-term memory, working memory, and self-reported memory. *Stress: The International Journal on the Biology of Stress, 20*, 598–607. https://doi.org/10.1080/10253890.2017.1380620

Shields, G. S., Moons, W. G., & Slavich, G. M. (2017). Inflammation, Self-Regulation, and health: An immunologic model of self-regulatory failure. *Perspectives on Psychological Science, 12*, 588–612. https://doi.org/10.1177/1745691616689091

Van Blankenstein, F. M., Dolmans, D. H. J. M., Van Der Vleuten, C. P. M., & Schmidt, H. G. (2011). Which cognitive processes support learning during small-group discussion? The role of providing explanations and listening to others. *Instructional Science, 39*, 189–204. https://doi.org/10.1007/s11251-009-9124-7

Webb, N. M. (1989). Peer interaction and learning in small groups. *International Journal of Educational Research, 13*, 21–39. https://doi.org/10.1016/0883-0355(89)90014-1

World Vision International. (2016). *Timed and targeted counseling (ttC)*.

Young, H. P. (2009). Innovation diffusion in heterogeneous populations: Contagion, social influence, and social learning. *The American Economic Review, 99*, 1899–1924. https://doi.org/10.1257/aer.99.5.1899

Zerback, T., Töpfl, F., & Knöpfle, M. (2021). The disconcerting potential of online disinformation: Persuasive effects of astroturfing comments and three strategies for inoculation against them. *New Media & Society, 23*, 1080–1098. https://doi.org/10.1177/1461444820908530

Zhu, W., Wang, F., Mayer, R. E., & Liu, T. (2024). Effects of explaining a science lesson to others or to oneself: A cognitive neuroscience approach. *Learning and Instruction, 91*, Article 101897. https://doi.org/10.1016/j.learninstruc.2024.101897