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Abstract

Social interaction promotes the spread of values, attitudes, and behaviors. Here, we report on neural responses to ideas that are destined to spread. We scanned message communicators using functional MRI during their initial exposure to the to-be-communicated ideas. These message communicators then had the opportunity to spread the messages and their corresponding subjective evaluations to message recipients outside the scanner. Successful ideas were associated with neural responses in the communicators' mentalizing systems and reward systems when they first heard the messages, prior to spreading them. Similarly, individuals more able to spread their own views to others produced greater mentalizing-system activity during initial encoding. Unlike prior social-influence studies that focused on the individuals being influenced, this investigation focused on the brains of influencers. Successful social influence is reliably associated with an influencer-to-be's state of mind when first encoding ideas.

Keywords

social influence, mass media, social interaction, social behavior, neuroimaging

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What differentiates ideas that bomb from ideas that buzz? Although “buzz” began as an onomatopoeia for the sound a bee makes, since the 16th century it has had a variety of social meanings, including the act of calling someone on the phone, the sounds a crowd makes when roused, or the spreading of a rumor. Today, buzz most often refers to the excitement that spreads around an idea, person, or product. The generation of buzz requires not only a compelling idea but also people who are motivated and able to spread the idea effectively. Like all mental representations, however, these ideas live in the human brain and depend on effective social communication for their dissemination.

Research on the factors guiding the creation of this type of “buzz” has focused on processes that characterize the spread of information from person to person (Katz, 1957; Rogers, 1995), the relationship between message communicators and message recipients (Bangerter & Heath, 2004; Brown, Barry, Dacin, & Gunst, 2005; De Bruyn & Lilien, 2008), message characteristics (Berger & Milkman, 2012), and social-network characteristics

(Bakshy, Karrer, & Adamic, 2009; Hill, Provost, & Volinsky, 2006; Leskovec, Adamic, & Huberman, 2006). A large body of social-psychological literature focusing on persuasion and social influence from the perspective of message recipients also speaks to the processes through which people may be influenced to adopt new ideas or recommendations (Asch, 1955; Chaiken, Liberman, & Eagly, 1989; Cialdini & Goldstein, 2004; Hovland, Janis, & Kelley, 1953; Petty & Cacioppo, 1986). Yet there is less direct evidence about the underlying psychological mechanisms that precede message propagation from the perspective of the message communicator. This is

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perhaps due to individuals' notoriously imperfect ability to introspect on such processes (Nisbett & Wilson, 1977).

Despite having limitations of its own (Poldrack, 2008), functional MRI (fMRI) can measure neural responses in the moment when participants are initially processing messages, interrogating several neurocognitive networks simultaneously. It has been used successfully to study a number of different social-influence processes from the perspective of the message recipient, including conformity (Campbell-Meiklejohn, Bach, Roepstorff, Dolan, & Frith, 2010; Klucharev, Hytonen, Rijpkema, Smidts, & Fernandez, 2009; Klucharev, Munneke, Smidts, & Fernandez, 2011), responsiveness to social tagging of stimuli (Klucharev, Smidts, & Fernandez, 2008; Mason, Dyer, & Norton, 2009; Plassmann, O'Doherty, Shiv, & Rangel, 2008; Zaki, Schirmer, & Mitchell, 2011), and other persuasive inputs (Falk, Berkman, Mann, Harrison, & Lieberman, 2010; Falk, Berkman, Whalen, & Lieberman, 2011; Falk, Rameson, et al., 2010). However, little is known about the mechanisms that prompt communicators to share ideas in a persuasive manner to begin with. Are the processes from the perspective of message communicators distinct from those of the message recipient? As an initial step toward better understanding these processes, we used fMRI to investigate the neurocognitive processes in the minds of message communicators, which are set in motion by ideas destined to spread successfully to other individuals through positive recommendations on the part of the message communicator.

Antecedents of Successful Message Propagation

When message communicators are first exposed to ideas that they will ultimately spread or recommend, two kinds of neurocognitive processes are likely to set this successful propagation in motion. First, for ideas that are destined to spread, communicators are likely to value the idea, either because they connect with the ideas or imagine that other people might. This process may recruit brain regions supporting reward and positive evaluations, such as ventral striatum and ventromedial prefrontal cortex. Second, successful message propagation "hinges on the ability of the recommender to accurately predict the recipient's interests and preferences" (Subramani & Rajagopalan, 2003, p. 303). This type of mentalizing most commonly recruits the dorsomedial prefrontal cortex (DMPFC) and the temporoparietal junction (TPJ). These regions have been implicated in successful communication between a speaker and listeners during narrative (Stephens, Silbert, & Hasson, 2010).

In this initial investigation of the neural bases of social influence from the perspective of the influencer, rather than the influenced, we focused on the *buzz effect*. This

effect reflects the increased neural activity present when message communicators are first encoding ideas that they are likely to spread successfully. Successful spreading of an idea was operationalized as a message communicator passing on an idea to a message recipient in such a way that the message recipient wanted to recommend the idea further to others.

We also examined two component processes that may contribute to successful message propagation. The *intention effect* reflects the neural activity present during the message communicator's initial encoding of an idea to the extent that the message communicator intends to recommend the idea. The *salesperson effect* reflects the neural activity present during message communicators' initial encoding of ideas that is higher in those message communicators who are better at persuading other people to evaluate ideas the same way they, the communicators, do. We hypothesized that the intention effect would be associated with brain regions associated with reward, whereas the salesperson effect would be associated with regions within the mentalizing network. Finally, we predicted that the buzz effect would be associated with both reward and mentalizing regions, as the motivation and the ability to propagate the message go hand in hand.

In this study, message communicators (who pretended to be interns at a television studio) viewed ideas for television pilots during an fMRI scanning session and considered whether they would pass the ideas on to message recipients (producers) for further consideration. After scanning, interns gave video interviews about each pilot-show idea. These interviews, but not the original pilot descriptions, were then shown to producers in a separate behavioral testing session. On the basis of only the videotaped interviews, producers indicated whether they would pass the idea on to other individuals.

Method

Participants

Interns. For the interns in our study, we recruited 20 participants from an undergraduate subject pool and through mass e-mails and posted fliers; 1 participant was dropped because of technical difficulties (final $N = 19$; 11 female, 8 male; mean age = 20.55 years, $SD = 6.17$). All participants were right-handed and spoke English fluently. Related to fMRI safety, participants were not claustrophobic, pregnant, or breast-feeding and were metal free. Potential participants were excluded if they were currently taking psychoactive medication.

Producers. For the producers in our study, we recruited 79 participants (57 female, 22 male; mean age = 20.54 years, $SD = 3.82$) from an undergraduate subject pool

and through mass e-mails and posted fliers. None of the producers knew the intern whose video they rated.

Materials and procedure

In our paradigm, an initial group of participants, referred to as “interns,” pretended to be working at a television studio and provided recommendations to their boss, the “producer,” about which shows should be considered for further development and production.

Television-pilot stimuli. Preliminary pilot-show ideas were generated by an independent group of undergraduates in response to a prompt in which they were asked to “Pretend you are pitching a new TV show idea to a network.” From this pool of show descriptions, 24 show ideas were selected as final stimuli based on further pilot testing and assessment by the research team; show ideas were selected to appeal to a wide range of audiences and to have comprehensible plots. The language of the pilot television show descriptions was then edited by the research team to standardize grammar, spelling, description length, and complexity (mean words per description = 56, $SD = 6$). An image representing the show was also paired with the description.

Intern procedure. Using fMRI, we monitored neural activity in each intern’s brain while the intern was presented with ideas to recommend to the producer, who was ostensibly too busy to review all of the proposals. Each participant viewed and heard 24 descriptions of television show ideas proposed by other undergraduate students. These descriptions were presented across three fMRI runs of 8 blocks each and 310 s per run (total = 465 volumes). Directly following exposure to each idea, interns rated how likely they would be to recommend the idea to the producer on a scale from 1 (*definitely would not*) to 4 (*definitely would*; the regressor used for the intention effect). Following the fMRI session, interns were videotaped separately discussing the merits of each idea as though responding to the producer’s inquiry and finally provided additional quantitative ratings, including whether they would watch each show themselves (full scale items were “I would watch this show”; “I would tell a friend about this show”; “If I were the producer in charge, I would produce this show”; “The description of this show is persuasive”; and “This concept is novel”; response options ranged from *strongly disagree* to *strongly agree*).

Producers’ materials and procedure. The videotaped interviews served as the stimuli for the producers. The structure of the procedure completed by producers was similar in many ways to the structure of the procedure

completed by interns. The primary difference was that instead of viewing a standardized set of written show idea descriptions, each producer was randomly assigned to view the videotapes of one intern who reviewed the different show ideas. All videos from the interns were cut into clips to allow the order of the ideas to be randomized across participants and to ensure that all videotaped discussions of each show were presented sequentially (i.e., if an intern discussed a particular show at more than one time point during videotaping, those clips were played sequentially to develop one continuous description of the show). Following each idea description by the intern, the producers rated their intentions to further recommend the show idea on a scale from 1 (*definitely would not*) to 5 (*definitely would*).

For each intern (i.e., the participants who completed the MRI portion of the study), we collected ratings from multiple producers (mean producers per intern = 4) to get an aggregate index of how successful each intern was in propagating interest about each show to a number of different individuals (the producers who watched that intern’s tape). Thus, we were able to individually track how influential interns were by correlating their idiosyncratic intentions to propagate each idea with the analogous preferences of their producers (the salesperson effect), as well as which ideas were successfully propagated across producers (the buzz effect), regardless of which intern’s interview was watched. After completion of data collection with the two groups of participants, we conducted a series of whole-brain analyses correlating neural activity during the interns’ initial exposure to the pilot-show ideas with relevant outcomes from both interns and producers.

fMRI data acquisition. Imaging data were acquired using a Trio 3 Tesla head-only MRI scanner at the University of California, Los Angeles Ahmanson-Lovelace Brain Mapping Center. Head motion was minimized using foam padding and surgical tape; goggles were fixed in place using surgical tape connected to the head coil and scanner bed. Three functional runs were recorded for each participant—echo-planar T2-weighted gradient-echo, repetition time (TR) = 2,000 ms, echo time (TE) = 30 ms, flip angle = 75°, matrix size = 64 × 64, 33 axial slices, field of view (FOV) = 220 mm, 4-mm thick, voxel size = 3.4 × 3.4 × 4.0 mm. A high-resolution T1-weighted magnetization-prepared rapid-acquisition gradient echo (MPRAGE) scan was also acquired in the coronal plane (TR = 2,300 ms, TE = 2.47 ms, FOV = 256 mm, slice thickness = 1.0 mm, 160 slices, voxel size = 1.3 × 1.3 × 1.0 mm, flip angle = 8°). The data were preprocessed and analyzed using Statistical Parametric Mapping (SPM) software (Version 5, Wellcome Department of Cognitive Neurology, Institute of Neurology, London, England).

Statistical analysis

fMRI preprocessing. Functional images were realigned to correct for motion and coregistered with the MPRAGE structural scan. The MPRAGE data were normalized into standard stereotactic space (Montreal Neurological Institute, or MNI, space), and these parameters were applied to the functional data. The resulting images were smoothed with an 8-mm Gaussian kernel, full width at half maximum.

Individual behavioral effects. We computed descriptive statistics of the length of the interns' postscan interviews, as well as whether some shows were systematically liked more than others according to the intraclass correlation coefficient (ICC), grouping by shows. ICCs were calculated using the `mult.icc` function from the multilevel package (Bliese, 2013) in R (R Development Core Team, 2011). Finally, the interns' intentions to propagate each idea were correlated with each intern's own show preferences, which were collected in a survey completed after the scan.

Individual-level fMRI effects. Three separate design matrices were then created for each intern. These matrices modeled activity that was greater during the task (while encoding the show descriptions in the scanner) than during rest and correlated this task-related activity with each of the constructs of interest. We conducted a random-effects analysis for each effect, averaging across participants at the group level.

The buzz effect. The interns' task-related activity (activity during exposure to show ideas compared with activity during rest) was correlated with the ultimate success of each show idea, as indicated by the average idea preferences of all producers. This analysis was conducted for each intern at the single-subject level.

The intention effect. For each intern, we correlated task-related activity with that intern's specific preferences as indicated by intentions to recommend each idea (modeled as a parametric modulator at the single-subject level).

The salesperson effect. The correlations between each intern's intentions and the preferences of the producers within the respective intern's sphere of influence were entered as regressors in a group-level random-effects model of the neural activity associated with the intention effect. Higher correlations indicated greater success convincing the producers of the merits of the intern's preferred ideas.

All whole-brain results are reported at a threshold of $p < .005$, with a voxel extent of $k = 60$,¹ which corresponds to a corrected value of $p < .005$ based on a Monte Carlo simulation implemented using AlphaSim in the software package AFNI (Ward, 2000). All coordinates are reported in MNI space.

Results

Participant behavior

Interns varied in the average amount of time they spent discussing shows ($M = 40$ s, $SD = 12$ s) and, correspondingly, in the number of words contained within each of their show descriptions ($M = 72$ words per show, $SD = 19$); however, this variation was not systematically associated with other individual differences in influence (e.g., the salesperson effect). We also examined whether some shows were systematically liked more than others according to the ICC, grouping by shows. The ICC for intern intentions was relatively low (.139), as was successful propagation across producers (the buzz effect; .158), which indicates that different interns and the different groups of producers, respectively, expressed interest in propagating different shows. This suggests that the effects observed captured influence processes beyond everyone merely liking the same shows. Similarly, interns' liking for shows accounted for only 12% of the variance of producers' intentions to propagate the message further.

The buzz effect

The ultimate success of an idea being recommended in such a way that it reached from message communicators to message recipients (i.e., beyond interns to producers) was computed by averaging across the ratings of all producers in our study to determine which ideas were successful (i.e., re-recommended) regardless of the message communicator. This index was used as a parametric modulator of the neural response to each pilot idea for each intern. This analysis allowed us to examine which brain regions were increasingly active as each intern was exposed to ideas that were ultimately successful in being propagated across the group of producers as a whole. As predicted, this buzz effect was associated with increased activity in neural regions previously associated with reward processing (i.e., ventral striatum, or VS) and with mentalizing (TPJ and DMPFC; Table 1; Fig. 1a).

The intention effect

The intention effect was assessed by using each intern's stated intention to propagate each idea as a parametric

Table 1. Associations Between Neural Activity in the Interns' Brains and Effects of Interest

Effect and region	Local maximum MNI coordinates			<i>k</i>	<i>t</i> (18)
	<i>x</i>	<i>y</i>	<i>z</i>		
Intention effect					
Medial prefrontal cortex	-3	51	-3	106	3.34
Precuneus-posterior cingulate cortex	-3	-57	21	71	3.56
Superior frontal gyrus	-21	33	48	98	4.71
Precentral gyrus	-39	-18	66	154	3.87
Salesperson effect					
Temporoparietal junction	-54	-51	30	135	5.34
Temporoparietal junction	45	-57	27	127	5.28
Buzz effect					
Temporoparietal junction	-48	-51	15	350	3.33
Temporoparietal junction	51	-60	18	582	4.65
Dorsomedial prefrontal cortex	6	54	36	196	4.03
Precuneus-posterior cingulate cortex	3	-60	48	411	6.26
Ventral-dorsal striatum	-3	9	3	459	6.31
Brainstem	3	-36	-27	91	4.82

Note: The intention effect reflects the interns' individual intentions to propagate ideas, the salesperson effect indexes the interns' success at convincing producers within their sphere of influence of the merits of their intended ideas, and the buzz effect indexes the ultimate success of idea propagation across producers. Results were assessed at a corrected significance level ($p < .005$; whole brain: $k = 60$). MNI = Montreal Neurological Institute.

modulator of that intern's neural response to each pilot idea. This allowed us to examine which brain regions were increasingly active to ideas that interns explicitly expressed increased interest in propagating directly following exposure to each idea. Although this analysis did not produce activity within the reward system, it did produce activations in medial prefrontal cortex (MPFC) and precuneus/posterior cingulate cortex (PC/PCC) commonly associated with self-relevance processing (Lieberman, 2010; Table 1; Fig. 1b). We also examined the extent to which intentions to recommend shows were correlated with each intern's own show preferences ("I would watch this show"; preferences were collected after the scan). We found that these metrics were highly correlated² (average $r = .68$), $t(18) = 21.03$, $p < .001$.

The salesperson effect

As a measure of how successful interns were in cultivating the same preferences in their particular producers as they themselves held, we calculated a *salesperson index*, defined as the correlation between each intern's set of intention ratings and the intention ratings made by the producers after viewing that intern's video. There was substantial variability in the salesperson index ($M = .31$,

$SD = .27$, average $r_s = -.31$ – $.61$), which indicates that interns varied widely in their ability to persuade their producers to share their views. A group-level analysis using the salesperson index as the primary regressor identified neural regions that were increasingly active in the interns who were most successful at propagating their intended ideas. The salesperson effect was exclusively associated with activity in the interns' bilateral TPJ, a primary component of the mentalizing network (Saxe, 2010; Table 1; Fig. 1c).

Discussion

In this study—the first to examine the brains of people doing the persuading, rather than of those being persuaded—we found that responses in the brains of initial idea recipients forecast an idea's success beyond the initial recipients to others whose brains are never examined and whose eyes are never exposed to the original information. Neural regions associated with successful message propagation overlap with the brain's reward system. Activity in this system is often associated with influence in studies in which the participant is being influenced during the scan (Ariely & Berns, 2010; Falk, Way, & Jasinska, 2012). Neural regions associated with successful

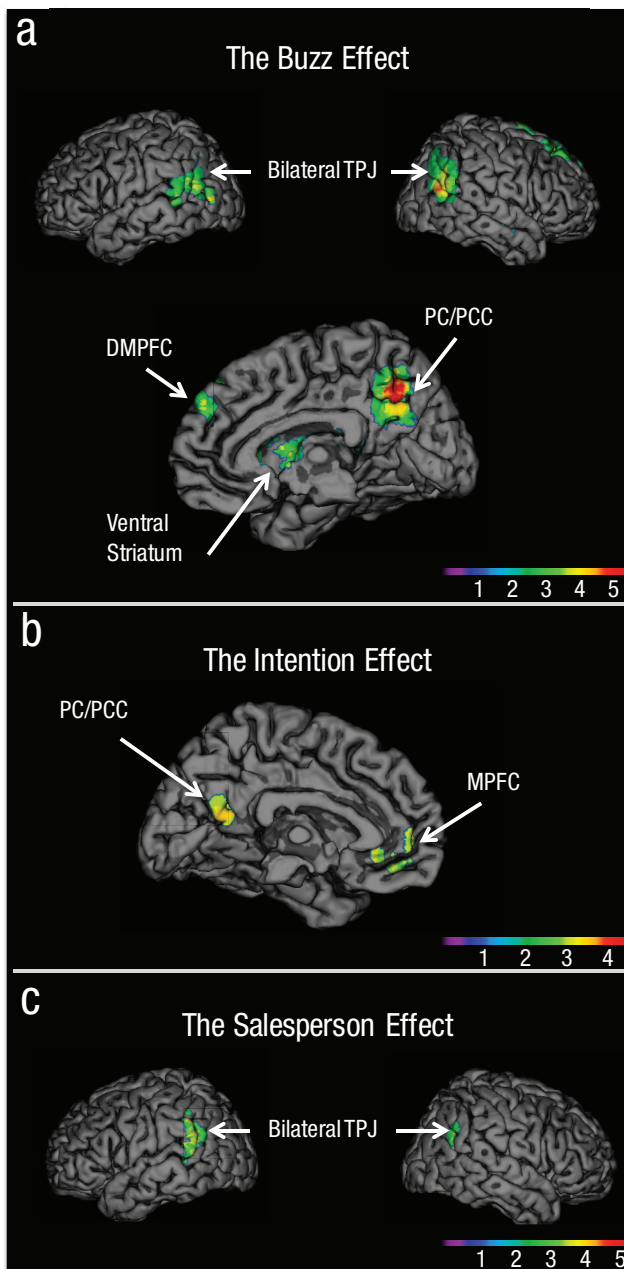


Fig. 1. Neural regions associated with (a) the buzz effect (indexed by the average preferences of producers irrespective of the interns they observed), (b) the intention effect (indexed by interns' intentions to propagate messages), and (c) the salesperson effect (indexed by the success of interns in promoting their valenced evaluations to a set of producers). Results were assessed at a corrected significance level ($p < .005$; whole brain: $k = 60$). Color bars represent t statistics. DMPFC = dorsomedial prefrontal cortex; MPFC = medial prefrontal cortex; PC/PCC = precuneus/posterior cingulate cortex; TPJ = temporoparietal junction.

message propagation also overlap with the brain's mentalizing system, a finding that suggests additional computations that may position individuals to become effective

message communicators and to eventually propagate ideas.

More specifically, in examining neural activity associated with the ideas that the interns most successfully spread to producers (such that the producers also had the intention to spread the ideas further; i.e., facilitating the buzz effect), we observed activation of the regions most commonly associated with mentalizing (DMPFC, TPJ), as well as VS in the reward system. Activity in VS may implicitly index the appeal of ideas—an index of an idea's overall buzzworthiness or social value—and may also implicitly reflect anticipated reward in sharing the idea with other people. Activity in the mentalizing system, by contrast, may position the message communicator to be able to share effectively.

In examining the component processes that preceded successful message propagation, the initial intentions of interns to recommend the shows to producers, and the interns' own liking of the shows, were highly correlated; this finding suggests that interns may have relied on their own preferences when indicating their intentions to share the pilot ideas. Consistent with this account, results showed that the intentions to propagate ideas (intention effects) were associated with midline regions commonly associated with self-relevance and valuation (MPFC, PC/PCC). These regions have also been associated with being persuaded to act while encoding health messages (Falk, Berkman, et al., 2010; Falk et al., 2011). However, actual success in propagating ideas was only modestly correlated with interns' personal preferences, and there was a high degree of heterogeneity in participants' ratings of the shows. This evidence indicates that processes beyond consensus in preferences across participants are necessary to explain the successful message-propagation effects observed.

To this end, TPJ was the only region in which activity differentiated the interns who were more successful at propagating their preferred ideas from those who were less successful at this (the salesperson effect). It is possible that better message communicators were already thinking about how to make the information useful and interesting to other individuals at encoding, rather than simply taking in the information for their own sake. Such perspective-taking processes would be brought online to the extent that one considered ways in which the incoming message would be relevant to others. Increased processing of this type could position the message to spread more successfully to other people.

As such, these findings may have implications for the spread of ideas, norms, values, or culture itself. Our results are consistent with research demonstrating that the spread of preferences may depend more on the message communicator's social-cognitive abilities and motivations, and less on factors such as deliberative reasoning

(Salganik, Dodds, & Watts, 2006). In no analysis did any regions commonly associated with reasoning and related central executive processing emerge for any of the examined effects (Table 1), though the absence of such effects does not rule out the possibility that effective ideas may have resulted in an alternative form of deeper or more elaborative encoding. Instead, our results are consistent with a prominent role of socioaffective processes in producing social influence and, in particular, suggest that activity in the mentalizing network may augment transmission of ideas.

Our data may also be relevant to social cognition more broadly. It has been suggested that the growth of the prefrontal cortex over primate evolution has been driven by virtual aspects of social cognition (Barrett, Henzi, & Dunbar, 2003). The mental states of other people are virtual because they are unseen and inferred from a variety of cues, such as context and facial expressions. Many studies have focused on the role of the mentalizing network in decoding mental states from contextual and facial cues (Amodio & Frith, 2006). In our study, we examined a different kind of virtuality: individuals preparing for social encounters that have not yet occurred. Success in such preparation (i.e., successfully preparing to recount show ideas to the producer in a way that the producer would find compelling) was associated with activity in the mentalizing network, further affirming and extending the understanding of the network's role in virtual aspects of social life. Future research is needed to assess whether this hypothesized role of the mentalizing network is specific to the spread of the type of ideas targeted in our paradigm or generalizes to other related tasks (e.g., the spread of technical, religious, or fashion ideas).

Our findings also contribute to a small but growing number of studies identifying mentalizing activity with more accurate or effective behavior. Activity within the mentalizing network, under the alternate label *default-mode network*, has frequently been associated with decreased performance and low-effort cognition (Mason et al., 2007; McKiernan, Kaufman, Kucera-Thompson, & Binder, 2003; Weissman, Roberts, Visscher, & Woldorff, 2006). In contrast, greater speaker-listener coupling in these same brain regions has been associated with better communication between speakers and listeners (Stephens et al., 2010). These mentalizing regions also increase with greater working memory effort when the content of working memory is social (Meyer, Spunt, Berkman, Taylor, & Lieberman, 2012). The current study also found that greater activity in mentalizing regions is associated with more desirable outcomes. Message communicators who produced greater mentalizing activity while encoding the pilot television show ideas were more likely to pass on the information in such a way that message

recipients were motivated to pass it on further. In future investigations, it will be of interest to determine the extent to which these same regions might forecast the accuracy of message propagation, as well as propagation of neutral information or disliked ideas. In addition, the relatively small sample size in the current investigation limited our analysis possibilities (e.g., for testing interactions), and replication will increase confidence in the robustness of our effects.

Finally, our results suggest that in the initial process of taking in information, people may consider the social currency of being the person who spreads a particular piece of information and plan for ways to successfully share the information with others accordingly. Being seen as the source of good ideas (whether or not they are one's own) has always had great social value and status benefits, and it has been widely recognized that there are individual differences in the extent to which individuals take on the role of information brokers or idea salesmen (Katz, 1957; Rogers, 1995). New media outlets have made the process of recommendation and idea propagation even more visible and explicit and have highlighted the importance of understanding how and why ideas spread (e.g., social-networking sites such as Facebook and Twitter promote individuals as "information DJs"). The current research lays the groundwork for future studies that might inform the ability to construct more compelling, "stickier" messages and identify the mechanisms that lead individuals to be better messengers. More specifically, the activations identified in this research might serve as regions of interest in future work using neural activity to prospectively predict the success of messages and message communicators. Ultimately, this work also expands the understanding of the role of the mentalizing network in preparing for social interactions, and it may help researchers understand how the ability to spread information relates to social identity, builds social status, and strengthens social ties.

Author Contributions

E. B. Falk and M. D. Lieberman developed the study concept. All authors contributed to the study design. Recruitment, testing, and data collection were performed by E. B. Falk, S. A. Morelli, B. L. Welborn, and K. Dambacher. The data analysis was performed by E. B. Falk in consultation with M. D. Lieberman and with support from S. A. Morelli and B. L. Welborn. The manuscript was written by E. B. Falk and M. D. Lieberman, and all authors provided critical revisions. All authors approved the final version of the manuscript for submission.

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Declaration of Conflicting Interests

The authors declared that they had no conflicts of interest with respect to their authorship or the publication of this article.

Notes

1. This threshold ($k = 60$) could filter out small but relevant brain activations. Therefore, an exploratory analysis was conducted within limbic regions (striatum and amygdala) using a lower threshold ($k = 20$), but no relevant activations were found.

2. Intention scores were also highly correlated with other proxies for participant liking.

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