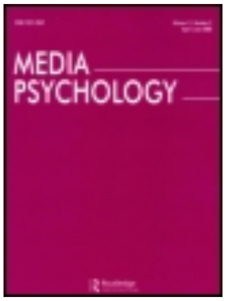

Media Psychology

ISSN: 1521-3269 (Print) 1532-785X (Online) Journal homepage: https://www.tandfonline.com/loi/hmep20

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MEDIA PSYCHOLOGY
https://doi.org/10.1080/15213269.2019.1572522

Decision-making about broad- and narrowcasting: a neuroscientific perspective

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ABSTRACT

What differentiates sharing with few, well-defined others (narrowcasting) from sharing with loosely defined crowds (broadcasting)? One possibility involves a trade-off where broadcasting is self-focused and self-serving, and narrowcasting is based on other-oriented, altruistic motives. We present neuroimaging data consistent with a second, parallel-processes perspective. According to this account, both narrow- and broadcasting simultaneously involve self-related and social motives since these concepts are strongly intertwined both on a psychological and neural level. We recorded brain activity within regions that are meta-analytically associated with self-related and social cognition while participants made decisions to narrow- or broadcast *New York Times* articles on social media. Results show increased involvement of brain regions associated with both self-related and social processing in narrow- and broadcasting, compared to a control condition. However, both processes were involved with higher intensity during narrowcasting, compared to broadcasting. These data help to disambiguate a theoretical discussion in communication science and clarify the neuropsychological mechanisms that drive sharing decisions in different contexts. Specifically, we highlight that narrow- and broadcasting afford differing intensities of two psychological processes that are crucial to persuasion and population-level content virality.

Information sharing is an inherently social process. As such, communicators who share information with others must consider the characteristics, preferences, and goals of their audience to effectively create messages that will resonate with receivers (Barasch & Berger, 2014; Bargh & Williams, 2006; Clark & Murphy, 1982; Magnifico, 2010). Thereby, communicators can fulfill central self-related and social motivations, such as to shape and present their own identity and to manage social relationships by making decisions about

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Data and R-code needed to reproduce the analyses presented in this manuscript are available on GitHub https://github.com/cnlab/narrowbroad

Color versions of one or more of the figures in the article can be found online at www.tandfonline.com/hmep.

whether, what, and how to share it (Berger, 2014; Cappella, Kim, & Albarracín, 2015; Cunningham, 2012; Meshi, Tamir, & Heekeren, 2015; Rosenberg & Egbert, 2011). Communicators regularly transmit information to one or few well-characterized others, for instance through private chat messages (narrowcasting), or large, often loosely defined audiences, for instance through social media status updates (broadcasting). The size of an audience may modify motivations and other decision factors that lead to information sharing and, consequently, sharing behavior (Barasch & Berger, 2014; Bazarova & Choi, 2014; Derlega & Grzelak, 1979; Omarzu, 2000) and downstream outcomes such as persuasion and information diffusion (Falk & Scholz, 2018). Whether and how audience size changes the role played by self-related and social concerns during sharing remains a matter of active discussion. We developed and tested two competing sets of hypotheses about this relationship based on recurring themes and (often implicitly made) assumptions in the literature. First, the *trade-off hypotheses* suggest a trade-off between self-related and social concerns wherein broadcasting is mainly associated with self-focused considerations, and narrowcasting is related to audience-directed, social thought processes. An alternative possibility, which we refer to as the *parallel-processes hypotheses*, is that narrow- and broad-casting simultaneously engage both self-related and social thinking and are, instead, differentiated by the intensity of these parallel processes. In a neuroimaging experiment, we empirically tested these two sets of competing hypotheses about the decision-making processes underlying narrow- and broadcasting.

Characteristics of broad- and narrowcasting

Broadcasting involves sharing with large, often ill-defined audiences, creating a certain psychological distance between sharer and audience (Trope & Liberman, 2010). Content shared through broadcasting is usually not private and messages composed by information sharers tend to be undirected, that is, not addressed towards a particular individual or group (Bazarova & Choi, 2014). Broadcasting allows sharers to efficiently reach many and diverse receivers through a single message. For instance, a Facebook status update might reach about 200 potential receivers for the median adult Facebook user (Smith, 2014). At the same time, broadcasters face significant risks and uncertainty regarding the appropriateness of the content they share due to the diversity of potential audience members. Broadcast audiences are often characterized by context collapse, that is a conglomeration of people from different contexts within a person's life (e.g., work and a sports team; Marwick & boyd, 2011) and broadcasters tend to hold biased representations of the size and characteristics of their audience (Bernstein, Bakshy, Burke, & Karrer, 2013; Marwick & boyd, 2011). The limited information available to accurately predict attitudes, preferences, and potential reactions to shared content (Krämer & Haferkamp, 2011; Marwick & boyd, 2011) might have implications for the extent to which sharers pursue self-related and social motivations.

In contrast, narrowcasting—or sharing with one, or few, well-defined others—affords more privacy and a reduced psychological distance between interaction partners (Trope & Liberman, 2010). This leads to messages that are more often directed at specific individuals or groups (Bazarova & Choi, 2014; Nguyen, Bin, & Campbell, 2012; Walther, 1996). Sharers retain greater control over who may receive their messages and can thus rely on more specific knowledge about a person or group as the basis for their sharing decisions. Dyadic interactions, especially in online contexts (Nguyen et al., 2012; Walther, 1996), increase the intimacy of shared content (Bazarova & Choi, 2014). In what follows, we discuss two competing sets of hypotheses about how these audience characteristics might relate to the psychological processes that underlie decisions about whether to share information when people are sharing in narrow- and broadcasting situations. Specifically, we focus on two thought processes that have previously been related to sharing decisions: self-related and social considerations (Baek, Scholz, O'Donnell, & Falk, 2017; Scholz et al., 2017).

Trade-off hypotheses

Arguing for a trade-off between self-related and social processing in broad- and narrowcasting, Barasch and Berger (2014) suggested that default egocentrism, a sharer's default focus on the self, motivates individuals to primarily share content that is related to their self-concept (e.g., by sharing content that reflects positively on themselves) when faced with loosely defined broadcasting audiences. Narrowcasting, on the other hand, is described by these authors as a special case of sharing where sharers are confronted with more prominent and concrete representations of their audience and thus motivated to abandon their egocentrism for a more sociocentric approach to sharing (e.g., by choosing content useful to the audience). In this view, ego- and sociocentrism are conceptualized and operationalized as extremes on a bipolar scale, suggesting that sharers focus primarily on one at a time and that increasing the focus on one, will decrease attention to the other.

Barasch and Berger (2014), for the first time, explicitly summarized propositions that led to our conceptualization of the trade-off hypotheses. However, their work is based on a broader literature on motivated reasoning in psychology (e.g., Dunbar, Marriott, & Duncan, 1997; Leary, 1996), and similar assumptions have been made implicitly or explicitly in the communication science literature on self-disclosure (Archer & Earle, 1983; Bazarova & Choi, 2014). Specifically, the idea of an egocentric default is grounded in psychological research that suggests a central role of self-perceptions when interacting with others. Holding a positive self-image is a central human motive that drives behavior across contexts (Leary, 1996; Mezulis, Abramson, Hyde, & Hankin, 2004). Research has demonstrated that sharing information about the self is intrinsically rewarding (Tamir & Mitchell, 2012), and that most conversations include self-related information (Dunbar et al., 1997; Emler, 1990; Landis & Burtt, 1924), particularly on social media (Naaman, Boase, & Lai, 2010). Reviews of the existing work on word-of-mouth and virality have confirmed the prominent role of self-presentational and self-enhancement concerns in the context of information sharing (Berger, 2014; Cappella et al., 2015). Even in social contexts, people tend to rely disproportionately on their own perspectives to predict those of their interaction partners (Dunning, Boven, & Loewenstein, 2001), perhaps because self-related information is more easily accessible (Ross & Sicoly, 1979). The trade-off hypotheses suggest that egocentrism is particularly prominent in broadcasting situations where audiences tend to be ill-defined and reactions to shared content are hard to predict (Bazarova & Choi, 2014; Krämer & Haferkamp, 2011; Marwick & boyd, 2011). In other words, when broadcasting, sharers might focus on themselves as the primary known variable in a complex social equation.

By contrast, when narrowcasting, a clearer definition of the audience make-up may lead sharers to abandon their egocentrism and adopt a greater other-focus. More reliable predictions about potential audience preferences and reactions might make it more feasible to specifically tailor content to audience needs (Barasch & Berger, 2014) and to more deeply address social motivations to associate positively with others in social groups (Baumeister & Leary, 1995; Lieberman, 2013) through information sharing.

There is some empirical evidence for the trade-off hypotheses in the literatures on information sharing and self-disclosure. In a study by Barasch and Berger (2014), broadcasters were more likely than narrowcasters to share information that made them look good and to report a stronger self, rather than other, focus. In contrast, participants reported stronger other than self focus during narrowcasting, compared to broadcasting, and tended to share information considered helpful to the audience. In parallel, Bazarova and Choi (2014) reported that participants identified self-related motivations, namely self-expression and social validation of self-related aspects, as the most common motivations for information sharing in broadcasting situations like Facebook status updates. Social motivations like the development of positive relationships were reported for a greater proportion of narrowcasted than broadcasted Facebook messages. Interestingly, other findings reported by Bazarova and Choi (2014) are more supportive of parallel processes hypotheses, which will be discussed shortly.

An additional, important element of the trade-off hypotheses is the idea that ego- and sociocentric states are negatively related to each other, so that a self focus in sharers decreases attention to the audience and an other focus decreases attention to the self (Barasch & Berger, 2014). A similar notion can be found in the self-disclosure literature, which describes an intrapersonal-interpersonal orientation continuum (Archer & Earle, 1983; Miller & Read, 1987). Characteristics of the self-disclosure context such as one's audience are thought to impact a sharer's position on this bipolar scale.

Existing evidence that led us to formulate the trade-off hypotheses is derived primarily from self-report scales, which operationalize pre-existing assumptions about a competing relationship between self and other focus during sharing (Barasch & Berger, 2014; Bazarova & Choi, 2014; Miller & Read, 1987). These operationalizations required the measurements to occur post-hoc, sequentially, and using predefined categories and descriptions of cognitions.

Parallel-processes hypotheses

Evidence from economics, social psychology, communication science, and social neuroscience (e.g., Gabriel, Valenti, & Young, 2016; Nowak, Page, & Sigmund, 2000; Schilbach, Eickhoff, Rotarska-Jagiela, Fink, & Vogeley, 2008; Utz, 2015) supports a set of competing hypotheses to the trade-off hypotheses, which we summarize here as the parallel-processes hypotheses. These hypotheses suggest that: (a) Self-related and social processing do not have a trade-off relationship where one process suppresses the other, but often co-occur and might interact; (b) both narrow- and broadcasting are based on both self-related and social considerations; and (c) differences between narrow- and broadcasting are likely due to differences in intensities of both self-related and social processing.

Neuroscientists who observe the brain's resting state, that is, spontaneous activity when study participants are not given specific instructions, routinely observe activity in the brain's so-called default mode network, which substantially overlaps with neural systems related to both self-related and social processing (Mars et al., 2012; Schilbach et al., 2008; Spreng, Mar, & Kim, 2008). These data provide a first hint at a default mode that may consider the self and others simultaneously. In further support of this idea, game theorists and economists frequently observe social behavior in study participants, even when selfish behavior is more rational and anonymity is guaranteed (Nowak et al., 2000), which is inconsistent with a purely egocentric default. In line with these findings, psychologists have advocated for the *social self*, arguing that a definition of self is, itself, developed based on inclusion and distinction from social groups and practices (Bretherton, 1991; Brewer, 1991; Gabriel et al., 2016).

Extending this argument to the realm of information sharing led us to the prediction that self-related and social sharing motives occur in parallel and interact with one another during narrow- and broadcasting. For instance, even though sharers motivated to present themselves in a positive light are labeled as self-focused in the trade-off hypotheses, they likely consider aspects of their audience to determine what a given individual or group may perceive as a positive characteristic. Similarly, when trying to understand others, for instance, to help somebody, information sharers may reference their own experiences and preferences (Dunning et al., 2001).

Some existing data supports this view. For instance, empirical work has shown effects of broadcasts about characteristics of the self on social relationships and enhanced relationship management both online and offline (Greene, Derlega, & Mathews, 2006; Valkenburg & Peter, 2009). In one study (Steijn & Schouten, 2013) participants were most likely to identify public status updates (i.e., broadcasts) as the most common causes for changes in their social relationships (e.g., uptake of new relationships or changes in trust), compared to other types of narrow- and broadcasting. Similarly, Utz (2015) found a positive relationship between certain characteristics of broadcasted self-disclosures on Facebook and the perceived connection to the communicator experienced by message receivers.

Although these findings call into question whether broadcasting is primarily egocentric, they merely speak to the outcomes of sharing, not the thought processes driving it in different contexts. Addressing motivational underpinnings, other researchers have suggested that information sharers use heuristics to engage in social processing by making predictions about the preferences and characteristics even of large, ill-defined broadcasting audiences (Bernstein et al., 2013; Litt, 2012; Marwick & boyd, 2011). For instance, in a largest common denominator approach, communicators might attempt to identify content believed to be suitable for all possible audience members. Alternatively, according to the strongest audience effect, a sharer might focus more on a concrete subset of audience members than the entire group (Hogan, 2010; Litt, 2012; Marder, Joinson, Shankar, & Thirlaway, 2016; Vitak, 2012).

With regards to narrowcasting, information about the self also remains a prominent topic for sharers, even in dyads, the most extreme form of narrowcasting (Nguyen et al., 2012), and the exemplar of narrowcasting we focus on in this investigation. One important way of enhancing the intimacy of a social relationship is to disclose increasingly intimate information about the self (Collins & Miller, 1994; Jiang, Bazarova, & Hancock, 2011; Kashian, Jang, Shin, Dai, & Walther, 2017) and this self-disclosure intimacy is both more expected (Bazarova, 2012) and practiced (Bazarova & Choi, 2014) in sharing situations that are more private. Narrowcasting, in turn, affords more privacy than broadcasting (Bazarova & Choi, 2014). In this way, self-disclosure, which requires a self-focus, might help to achieve relationship maintenance goals and might occur more frequently in narrowcasting. This stands in contrast to the trade-off hypothesis that narrowcasting is inherently sociocentric, and not self-focused.

Although the parallel-processes hypotheses suggest that narrow- and broadcasting involve similar types of cognitions, differences are hypothesized in the intensity of both types of thought processes. Compared to narrow-casters, broadcasters' thoughts are guided by a more abstract, and loosely defined conception of audience (e.g., the entire Facebook network or a general interest group). Cognitions driving broadcasting are thus likely to be based on heuristics such as the ones described previously, rather than person-specific knowledge. According to construal-level theory, this psychological distance between broadcasters and their audience may impact both sharer's cognitions and actions (Trope, Liberman, & Wakslak, 2008). As a result, social and self-related cognitions might be more vivid and intensive during narrowcasting. Table 1 summarizes the trade-off and parallel-processes hypotheses.

Measuring self-related and social processes using neuroimaging

The hypotheses outlined in Table 1 require the measurement of basic psychological processes, namely self-related and social processing. This implies several measurement issues. First, these broad categories of thought processes may be expressed as a number of different motivations depending on the context (Berger, 2014; Cappella et al., 2015; Scholz et al., 2017). For instance, self-related processing may manifest as self-presentational concern or self-enhancement. Social processing might be associated with the wish to help somebody or to start a funny, relationship-building conversation. Second, each of these motivations might impact sharing within or outside of conscious awareness. Third, given the possibility of the co-occurrence and interactions between self-related and social processes, sequential, post-hoc

Table 1. Trade-off and parallel-processes hypotheses (H) of narrow- and broadcasting.

Trade-Off		Parallel-Processes	Data Supports
H1: Broadcasting involves more self-related, but not more social, cognitions than the control condition.	*versus*	*H5*: Broadcasting involves more self-related and more social cognitions than the control condition.	*H5 Parallel Processes*
H2: Narrowcasting involves more social, but not more self-related, cognitions than the control condition.	*versus*	*H6*: Narrowcasting involves more social and more self-related cognitions than the control condition.	*H6 Parallel Processes*
H3: Narrowcasting engages more social cognitions than broadcasting. *H4*: Broadcasting engages more self-related cognitions than narrowcasting.	*versus*	*H7*: Self-related and social cognitions are stronger during narrowcasting than during broadcasting.	*H3 (Trade-Off and Parallel Processes) & H7 (Parallel Processes)*

measurement might be vulnerable to memory bias and introduce unintended order effects. Consequently, well-known consequences of self-report measures (e.g., Nisbett & Wilson, 1977; Wilson & Nisbett, 1978) limit our ability to distinguish between the trade-off and parallel-processes hypotheses about narrow- and broadcasting through this method alone.

Neuroimaging methods such as functional magnetic resonance imaging (fMRI) can provide additional, unique information about sharing decisions that can ultimately help to triangulate the underlying mechanisms of sharing (Baek et al., 2017; Meshi et al., 2015; Scholz et al., 2017; Tamir & Mitchell, 2012). Specifically, fMRI provides an estimate of neural activity in real-time and across the entire brain while participants consider sharing content with others. This allows simultaneous, unobtrusive measurement of multiple processes as they unfold.

We rely on large existing literatures of hundreds of brain mapping studies that have identified neural substrates of self-related and social thought. The results of these studies are meta-analytically summarized on the open-access database Neurosynth (Yarkoni, Poldrack, Nichols, Van Essen, & Wager, 2011). Using this database, we identified region of interest (ROI) masks consisting of voxels implicated in self-related and social processing. We then analyzed the intensity of neural activity during narrow- and broadcasting within each ROI (compared to a control condition and compared to each other) as a proxy of the extent to which participants engaged in social- and self-related processing when we specifically prompted them to consider either narrow- or broadcasting. The self-related processing mask consists of clusters of brain voxels located mainly within medial prefrontal cortex (MPFC) and precuneus/posterior cingulate cortex (PC/PCC) and thus converges with other meta-analyses of the neural correlates of various types of self-related processing (Murray, Schaer, & Debbané, 2012). In addition to clusters within ventral and dorsal MPFC, social processing regions include the temporal poles bilaterally, as well as bilateral temporo-parietal junction (TPJ). These regions conform to other large-scale studies of social processing (Dufour et al., 2013). Given the diversity of self-related and social tasks that have been found to activate similar underlying neural regions, neural activity in these brain areas might constitute the greatest common denominator of various specific motivations relevant to sharing (Scholz et al., 2017).

Methods

To distinguish between the trade-off and parallel-processes hypotheses (Table 1), we conducted a within-subject experiment in which participants were exposed to 80 *New York Times* (*NYTimes*) articles in different conditions, which asked participants to consider either broad- or narrowcasting with others, while we monitored their neural activity using fMRI. We have reported on orthogonal analyses of the same neural data elsewhere to understand the neural correlates of individual (Baek, Scholz, O'Donnell, & Falk, 2017) and population-level sharing (Scholz et al., 2017; Doré et al., 2018), averaging across (and thereby ignoring differences between) narrow- and broadcasting situations. Here, for the first time, we distinguish between the processes involved in decisions to share when offered the opportunity to narrow- and broadcast.

Article task

Inside the fMRI scanner, participants completed two task runs of the article task, which consisted of 40 trials each (Figure 1). In the current analysis, we focus on three within-subject conditions (20 trials each) in which participants were asked to consider: (a) whether to share each article with a specific, close friend via a private Facebook message (narrowcasting), (b) whether to use a Facebook status update to post the article (broadcasting), or (c) whether a word shown on the screen (cancer/age/laws/fitness/science/nutrition/well-being) represented the article's main topic (control condition). In a fourth condition that is not analyzed here, participants decided whether they wanted to read the full text of the article after the scan. In an online survey prior to scanning, participants identified six Facebook friends who they had interacted with recently, and who they thought were interested in the general subject matter of the articles used here (physical activity and healthy living). In each narrowcasting trial, participants were asked to consider sharing with one randomly chosen individual from this list. Note that this procedure may produce some recipient-content matches that are suboptimal for the estimation of the true likelihood of a given participant sharing a given article (e.g., a decision

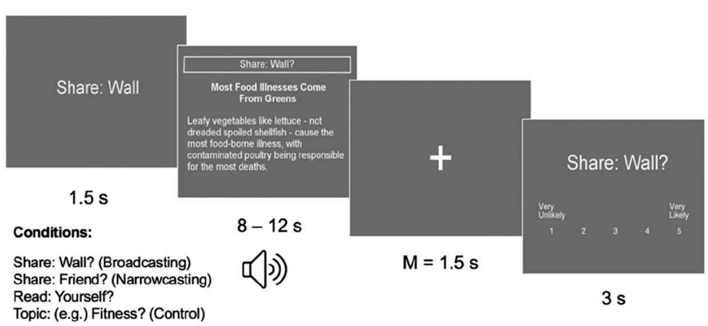

Figure 1. Article sharing task (example trial in broadcasting condition).

about whether to narrowcast an article about leafy greens to a friend known as a strong carnivore). However, we are interested in what thought processes motivate/suppress sharing in narrow- or broadcasting situations. This makes variation in the content-recipient matching a useful design feature that allows us to observe thought processes that increase or decrease the likelihood of sharing. The control condition was designed to subtract neural processes associated with exposure to the visual stimuli, reading *NYTimes* articles about health, and being in the fMRI environment. Comparing each sharing condition to the control condition thus isolates neural activity associated with the specific processes of interest.

Each trial lasted an average of 14.7 s, excluding fixation periods. The first screen informed participants about the trial condition and was visible for 1.5 s. Next, participants read the article's title and abstract while considering a question corresponding to the current condition (e.g., whether to narrowcast the article). Reading speed was controlled through additional auditory presentation of the articles by a female voice through MRI compatible headphones. The reading screens were presented for 8 (N = 16 trials), 10 (N = 40 trials), or 12 (N = 24 trials) s, depending on the word count of the text and the length of the corresponding audio file. For each participant, article length was counterbalanced across task runs and conditions. An, on average, 1.5 s (range 0.5–4.7 s) fixation period followed the reading screen. Afterward, depending on the trial condition, participants had 3 s to rate their likelihood to narrowcast, broadcast, to read the article's full text, or their certainty that the word presented on the screen represented the article's main topic (control trials). Ratings were made on 5-point Likert-type scales and followed by a second fixation period with an average length of 2 s (range 1–4.7 s). Optimized fixation time distributions were obtained using Optseq2 (Dale, Greve, & Burock, 1999). All analyses are based on neural activity extracted from task screens, which presented article headlines and abstracts only. Prior (orthogonal) analyses of the dataset discussed here show that activity during this task phase within regions of interest that overlap with those studied here correlates with self-reported sharing likelihood (Baek et al., 2017). This suggests that the variance in our neural measures is partially explained by thought processes that inform decisions to share (i.e., motivations and other decision-relevant processes).

New York Times articles

The 80 headlines and abstracts used in the article task were originally published in the health section of the *NYTimes* website (www.nytimes.com). All articles were sampled from a census (excluding certain article categories to preserve homogeneity in article format) of articles (N = 760) published between July 11, 2012 and February 28, 2013 and described in detail by Kim

(2015). Inclusion criteria were comparability regarding word count and topic. To this end, we conducted a keyword search to identify articles that discuss healthy living and exercise. Keywords included: *physical activity, exercise, running, fitness, swimming, soccer, skiing, food* (excluding "Food and Drug Administration"), *walking, eating, nutrient, nutrition, diet, gluten, calcium, vitamin, caffeine, carbohydrates, obesity, cholesterol*, and *weight*. Four irrelevant articles were excluded before we subselected 80 articles from the resulting sample (N = 139) to meet fMRI time constraints. This final selection was made based on word count comparability (range: 21–35 words).

Participants

Forty-three participants were sampled from respondents of an online survey that was part of a project about social influence and information diffusion.[1] In addition to completing this online screening, selected participants attended a lab session including a 60-min fMRI scan. Screening criteria included conventional fMRI eligibility criteria, namely no history of neurological or psychiatric disorders, right-handedness, having no metal in their body, no current pregnancy or breast feeding, and currently not taking psychiatric medication or illicit drugs.

Two participants were excluded from all analyses. One of them was only presented with three out of four conditions of the article task and the second showed poor normalization to the template brain. For four additional participants, we analyzed a subset of trials due to data loss affecting one task run (N = 1), excessive head movement affecting one task run (N = 2), and technical issues leading to 23 articles being shown to one participant twice. For this latter person, 57 trials represent initial article exposures and are thus included in the analyses. The final sample of 41 participants (29 women) was aged between 18 and 24 ($\bar{M}$ = 20.6, SD = 2.1). The Institutional Review Board at our institution reviewed and approved all study procedures.

MRI data acquisition

Thirty-nine participants underwent fMRI scanning using a 3-Tesla Siemens Magnetom TrioTim scanner (32-channel head coil). Two participants were scanned using a Siemens Prisma 3 Tesla whole-body MRI (64-channel head/neck array). Both scanners were operated using identical specifications (described in the following), except for slice numbers acquired for functional T2*-weighted images (54 at the TrioTim and 52 at the Prisma scanner) which we took into account during slicetime correction.

T1-weighted anatomical images were acquired using an MPRAGE (magnetization-prepared rapid-acquisition gradient echo) sequence (160 axial slices, slice thickness = 1 mm, TI = 1110 ms, FOV = 240 mm, voxel size = 0.9 × 0.9 × 1). A structural, in plane, T2-weighted image (176 axial slices, slice thickness = 1 mm, voxel size = 1 × 1 × 1) was collected for the purpose of two-stage coregistration. Although participants completed the article task, we collected 500 volumes of functional images per run using a T2*-weighted reverse spiral sequence (TR = 1.5 s, – 30 degree tilt relative to AC-PC line, flip angle = 70°, TE = 25 ms, voxel size = 3 × 3 × 3 mm, slice thickness = 3 mm, FOV = 200 mm, multiband acceleration factor = 2, interleaved slice order).

A priori regions of interest (ROIs)

Two ROI masks were extracted from the Neurosynth *reverse inference*[2] meta-analysis tool: a self-related processing ROI based on 903 studies using the search term *self*, and a social processing ROI based on 104 studies using the search term *mentalizing*. Mentalizing refers to thoughts about others' mental states (Frith & Frith, 2006), a highly relevant type of social processing for information sharing and social interactions (Baek et al., 2017; Dietvorst et al., 2009; Falk, Morelli, Welborn, Dambacher, & Lieberman, 2013; Meshi et al., 2015; Scholz et al., 2017). Both region of interest maps include overlapping and nonoverlapping clusters within large portions of MPFC, PCC/PC, and bilateral TPJ. The social processing ROI additionally includes regions within bilateral temporal cortex and cerebellum. We intersected these ROIs to create two additional masks representing regions sensitive to self-related, but not social processing and vice versa (see Figure 2a).

Imaging data analysis

Statistical Parametric Mapping (SPM8, Wellcome Department of Cognitive Neurology, Institute of Neurology, London, UK) was used for all data-preprocessing steps described in the following except those that are explicitly identified as using tools from AFNI (Cox, 1996) or FSL (S. M. Smith et al., 2004). The initial five volumes of each functional run were not recorded to allow the BOLD signal to stabilize. AFNI's 3dDespike tool was used to despike functional images. Subsequently, FSL sinc interpolation was used for slice time correction, before images were realigned spatially to the first image in SPM8 and coregistered to structural and functional images in two stages, each of which was six-parameter affine. Thereby, the in-plane T2-weighted image was registered to the mean functional image before the high-resolution T1 image was registered to the in-plane image. To select voxels to be included in statistical modeling, high-resolution structural images were then segmented into cerebral spinal fluid, white and gray matter. These masked structural images were normalized in SPM8 to the skull-stripped

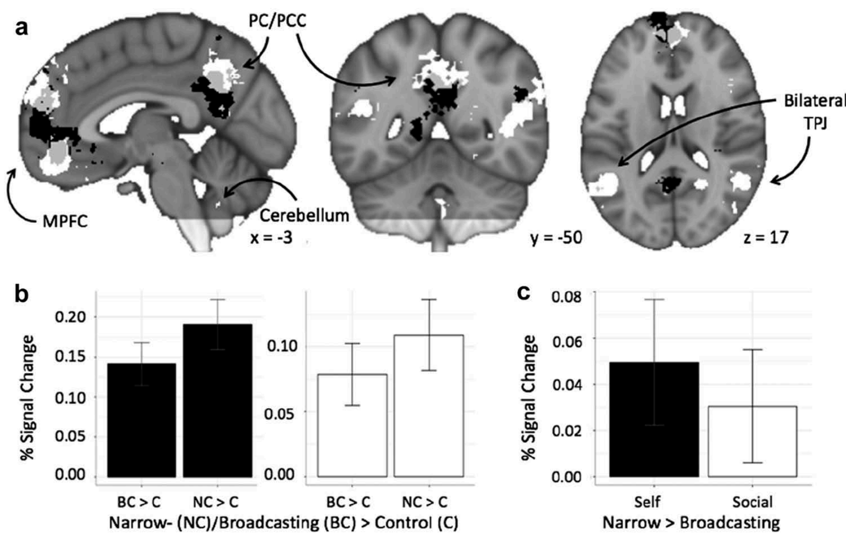

Figure 2. (a) Regions of interest (ROIs). ROIs are based on reverse inference maps extracted from www.neurosynth.org. Black: Voxels that are exclusively part of the self-related processing ROI. White: Voxels that are exclusively part of the social processing ROI. Grey: Overlap; Coordinates correspond to the Montreal Neurological Institute (MNI) standard space. MPFC = medial prefrontal cortex, PC/PCC = precuneus/posterior cingulate cortex, TPJ = temporo-parietal junction; The social processing ROI also includes regions within the bilateral temporal cortex, not pictured here.; (b) Percent signal change in self-(black columns) and social-processing (white columns) ROIs for the broadcasting (BC) > control (C), and the narrowcasting (NC) > control contrasts.; (c) Percent signal change in self- and social processing ROIs for the narrowcasting > broadcasting contrast.; Error bars represent 95% confidence intervals; N = 41.

Montreal Neurological Institute (MNI) template available in FSL ("MNI152_T1_1mm_brain.nii"). Functional images were finally smoothed using a Gaussian kernel (8 mm FWHM). For each participant, we modeled functional neuroimaging data using fixed effects models within the general linear model in SPM8, using SPM's canonical difference of gammas HRF. Six rigid-body translation and rotation parameters derived from spatial realignment were included in first-level models as nuisance regressors. Data were further high-pass filtered with a 128 s cutoff. Finally, random effects models were implemented in SPM8.

Neural model of the article task

We modeled the article task using the following boxcar functions: one function describing all condition screen periods, four functions describing reading screen periods pooled by task condition, four functions describing each rating screen period up until a rating was entered by the participant separately pooled by task condition, a function representing all rating screen period after participant had entered a rating, and afunction describing entire trials in which participants failed to provide a rating. Fixation periods were pooled into a baseline rest regressor. For the participant who was exposed to several articles twice, repeated exposure trials were pooled into a separate regressor of no interest. The contrasts of interest for this analysis are: (a) reading screens during narrowcasting versus control trials, (b) reading screens during broadcasting versus control trials, and (c) reading screens during narrowcasting versus broadcasting trials.

On average, reaction times for providing ratings in control trials ($\bar{M}$ = 0.94 s, *SD* = 0.26) were significantly slower than those in narrowcasting ($\bar{M}$ = 0.74 s, *SD* = 0.18), $T(40) = 7.09$, $p < .001$, and broadcasting trials ($\bar{M}$ = 0.82, *SD* = 0.23), $T(40) = 2.88$, $p = .006$. Reaction times in broadcasting trials were further significantly slower than those in narrowcasting trials, $T(40) = 3.23$, $p = .002$. This may indicate differing demands on processing resources. Consequently, a second model was constructed to test the robustness of our results. In this model, four additional regressors represented reading screen periods for all four task conditions modulated by a parametric modulator of reaction time (i.e., allowing us to control for reaction time).

ROI and whole brain analyses

Average parameter estimates of neural activity across all voxels were extracted for each participant, contrast, and ROI using MarsBaR (Brett, Anton, & Valabregue, 2002). These values were divided by the constant to convert them to percent signal change. One-sample *t*-tests were computed in R to test for significant percent signal change in each contrast (R Team, 2015). All tests were two-tailed to account for competing hypotheses. As a robustness check, we tested the effects of individual differences in Facebook friend counts, and hence size of each participant's potential broadcast audience, on these results by computing bivariate correlations between percent signal change in each of the contrasts and each of the regions and friend count. None of these correlations was significant. Whole brain-analyses combined contrast images using random effects models in SPM8. False discovery rate (FDR) correction at $p < .05$ assured multiple comparison correction.

Results

First, we separately examined the role played by self-related and social processing in narrow- and broadcasting by comparing each sharing condition to control. Figure 2b shows increased activity within both hypothesized self-related and social cognition ROIs during both types of sharing relative to control judgments. Parallel results were obtained using the *self exclusive of social*—narrowcasting > control: $\bar{M}$ = 0.18, $T(40)$ = 11.81, $p < .001$, broadcasting > control: $\bar{M}$ = 0.14, $T(40)$ = 10.73, $p < .001$—and *social exclusive of self*—narrowcasting > control: $\bar{M}$ = 0.09, $T(40)$ = 6.64, $p < .001$, broadcasting > control: $\bar{M}$ = 0.07, $T(40)$ = 5.57, $p < .001$—ROIs, and all results remained highly significant when controlling for reaction time. In sum, we find direct overlap between the neural processes involved in the two sharing contexts, which is consistent with the parallel-processes (H5 and 6), but not trade-off hypotheses (H1&2; Table 1).

Figure 2c shows the results of one sample, two-sided *t*-tests assessing percent signal change during narrow- compared to broadcasting trials. Results show significantly stronger activation in both the self-related, $\bar{M}$ = 0.05, $T(40)$ = 3.56, p = .001, and social cognition, $\bar{M}$ = 0.03, $T(40)$ = 2.43, p = .02, ROIs during narrowcasting trials, supporting H3, which is implicated in both the trade-off and parallel processes hypotheses but not trade-off H4. In addition, parallel processes H7 is supported (see Table 1). These results are replicated in the *self exclusive of social*, $\bar{M}$ = 0.04, $T(40)$ = 3.16, p = .003, and the *social exclusive of self*, $\bar{M}$ = 0.02, $T(40)$ = 2.02, p = .05, ROIs and all results remain significant in the neural model that controls for reaction time, except the test for percent signal change in the *social exclusive of self* ROI, which becomes marginal, $\bar{M}$ = 0.02, $T(40)$ = 1.65, p = .10. Again, our data lend stronger support to hypotheses about differences between broad- and narrowcasting that focus on the intensity of parallel-processes rather than the type of process.

After completing our planned ROI analyses, we conducted exploratory whole-brain analyses to identify clusters of significant activity outside of the ROI masks differentiating narrow- and broadcasting from the control condition, respectively, and clusters of significant activity differentiating narrow- from broadcasting (Figure 3; Table 2). Whole-brain results show large clusters overlapping with regions within both the self-related and social ROIs that are more involved in both narrow- and broadcasting, compared to control. In addition, consistent with the finding of longer reaction times during the control condition, control trials compared to narrow- and broadcasting trials showed stronger involvement in areas such as the dorsolateral prefrontal cortex, which is thought to be involved in effortful processing, among others. Analyses comparing narrow- to broadcasting confirm the heightened intensity of neural activity in regions associated with self-related and social processing during narrowcasting which was shown in the ROI analyses. In addition, we identified several regions outside of our a priori ROIs, which showed heightened activity

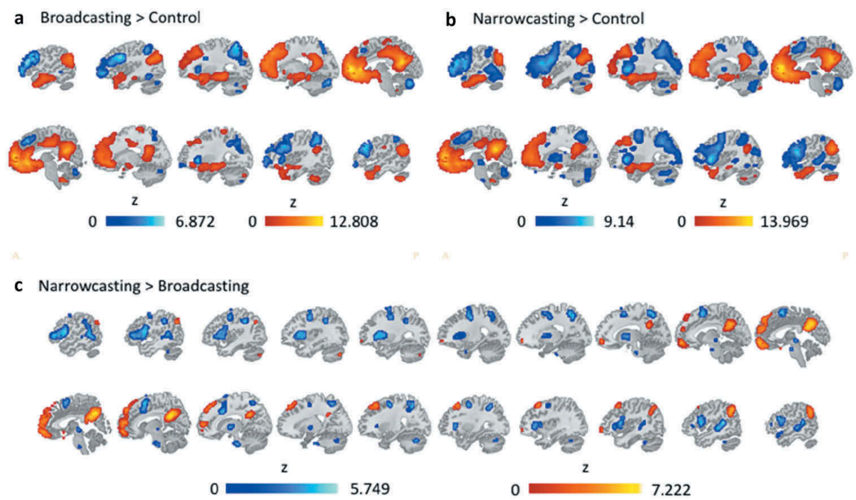

Figure 3. Exploratory whole brain results showing voxels positively (warm colors) or negatively (cold colors) associated with the following contrasts: (a) narrowcasting greater than control, (b) broadcasting greater than control, and (c) narrowcasting greater than broadcasting; Whole brain maps are FDR corrected at $p < .05$. Coordinates refer to the Montreal Neurological Institute (MNI) standard space. In each sequence, the first slice of the first row is located at x = −52.5, and the first slice of the second row at x = 5 (2.5 in panel C).

during broadcasting compared to narrowcasting, including the lateral prefrontal cortex and anterior cingulate cortex.

Discussion

Information sharers confronted with an audience of few, well-defined others (narrowcasting), or a large, loosely defined crowd (broadcasting) may arrive at their sharing decisions through different psychological processes. Research has shown strong links between such thought processes underlying sharing decisions and important downstream outcomes such as persuasion and virality (Falk & Scholz, 2018). We have outlined two competing sets of hypotheses about the psychological antecedents of broad- and narrowcasting. The trade-off hypotheses suggest that, when broadcasting, sharers are primarily focused on presenting themselves in a positive light; smaller, well-defined audiences in narrowcasting situations demand greater attention and lead to greater other-focus (e.g., Barasch & Berger, 2014). The parallel-processes hypotheses, on the other hand, suggest that both self-related and social processing are key to sharing with small and large audiences, and that narrow- and broadcasting are differentiated instead by the intensity of these processes. We used fMRI to test these two competing sets of hypotheses about differences in the psychological drivers of broad- and narrowcasting.

Table 2. Whole brain analysis comparing narrow- and broadcasting to the control condition, and narrow- to broadcasting.

Regions	R/L	X	Y	Z	T	K
Narrow- > Broadcasting						
Precuneus	R	3	−52	25	7.22	579
Precuneus	R	3	−61	34	7.11	
Ventro-medial prefrontal cortex	R	3	59	−8	5.93	943
Middle medial prefrontal cortex	R	6	56	13	4.73	
Dorso-medial prefrontal cortex	R	6	53	40	4.19	
Right temporo-parietal junction	R	48	−61	43	5.48	195
Left temporo-parietal junction	L	−51	−70	40	4.10	52
Left temporal lobe	L	−69	−22	−14	4.90	99
Right temporal lobe	R	63	−7	−20	4.38	39
Narrow- < Broadcasting						
Right temporal lobe	R	48	−40	13	5.75	141
Lateral frontal cortex	L	−51	8	16	5.26	700
Lateral frontal cortex	L	−51	35	7	4.74	
Insula	L	−30	20	7	4.27	
Lateral frontal cortex	R	45	11	13	5.00	267
Insula	R	33	29	10	3.84	
Supplemental motor area	R	6	8	58	4.76	514
Anterior cingulate cortex	R	12	11	43	4.41	
Superior frontal cortex	L	−24	−10	49	4.14	
Parietal lobe	L	−18	−61	55	4.67	129
Supra marginal gyrus	L	−57	−43	28	3.72	
Parietal lobe	R	24	−58	55	4.57	112
Inferior parietal lobe	L	−42	−40	40	4.52	292
Temporal lobe	L	−51	−46	10	4.49	
Precentral gyrus	R	27	−4	55	4.23	52
Brain stem	R	12	−19	−35	4.16	62
Brain stem	M	0	−25	−2	4.09	24

Note. BA = Brodmann area, R = right, L = Left, M = Medial, K = number of voxels within cluster, X, Y, and Z coordinates correspond to the Montreal Neurological Institute (MNI) standard brain. Clusters are separated by horizontal lines. The first row within each cluster shows the peak voxel. Whole brain maps were False Discovery Rate (FDR) corrected at $p < .05$, K > 20. All coordinates (except peaks) were chosen to represent cluster extends.

Our data are consistent with parallel-processes hypotheses showing higher activity in both brain regions associated with self-related and social cognition when participants were considering either narrow- or broadcasting relative to a control condition. In addition, neural activity during narrow- and broadcasting differed in intensity, such that both processes showed stronger involvement during narrow- compared to broadcasting.

These results are consistent with the idea that sharing decisions are made on the basis of both social and self-related considerations irrespective of audience size and that the two types of thought processes are not necessarily mutually exclusive or negatively correlated. Neural activity within self-related and social processing systems in the brain might originate in sharers' considerations of the consequences of sharing for themselves and their self-image and for their social interactions and relationships (Scholz et al., 2017). Holding a positive self-image and social belonging are two central human motives that are relevant to behaviors and cognitions across domains (Baumeister & Leary, 1995; Mezulis et al., 2004) and these core motives are strongly interconnected. For instance, psychologists have argued that a person's self-concept is often defined in terms of inclusion and exclusion from certain social groups and practices (Bretherton, 1991; Brewer, 1991; Gabriel et al., 2016). In the context of sharing information with others, researchers have demonstrated relationships between self-focused actions (e.g., disclosure of self-related information) and social motivations and outcomes (e.g., relationship management and changes in trust; Steijn & Schouten, 2013; Utz, 2015). Adding to these insights about sharing outcomes, our data suggest that self-related and social sharing thought processes tend to co-occur during sharing decisions in both narrow- and broadcasting situations.

Although self-related and social processes both played some role in narrow- and broadcasting, both types of neural activity were significantly stronger during narrow- compared to broadcasting. This finding further supports parallel-processes hypotheses that posit that narrow- and broadcasting are differentiated by the intensity, rather than the involvement, of two parallel-processes. Again, this difference might be due to the affordances of each sharing mode like differences in the psychological distance between sharer and audience which, according to construal-level theory (Trope & Liberman, 2010) may cause differences in thought processes and sharing behavior. Small, well-defined narrowcasting audiences might be associated with higher certainty regarding the knowledge, opinions or past behavior of one's audience. Increased neural activity in regions associated with self-related and social processing during narrowcasting might thus reflect the greater tendency to integrate and translate this knowledge into expectations regarding the self-related and social consequences of sharing. A useful future endeavor is to test construal-level as a mediator of audience size effects on sharing.

Finally, expanding on both the trade-off and parallel processes hypotheses, our exploratory whole brain analysis identified clusters within lateral prefrontal cortex and anterior cingulate cortex, which were activated more strongly during broadcasting compared to narrowcasting. Similar regions have been implicated in cognitive control, effortful processing, and emotion regulation (Buhle et al., 2014, www.neurosynth.org). For instance, these areas are active when participants reappraise their reactions to emotionally evocative stimuli by imagining that the depicted events are not relevant to them or happened a long time ago (i.e., through psychological distancing). In the context of broadcasting, these processes might indicate the greater psychological distance between broadcasters and their audience, which may be due to uncertainty about the composition and potential reactions of ill-defined broadcasting audiences (Krämer & Haferkamp, 2011; Marwick & boyd, 2011). The cognitive control network is also involved in broader effortful processes to adapt and react appropriately in situations that are not highly automatized (Wager, Jonides, & Reading, 2004). Thus, another possible interpretation is that broadcasting requires more neural activity associated with executive functions and cognitive control, possibly because shared content is judged and seen by more individuals and sharing might thus be perceived as more consequential. Future research aimed at exploring psychological differences between narrow- and broadcasting next to those identified with regards to self-related and social processing will complement the theoretical account presented here.

Additionally, it will be important to understand the effects of differences in psychological antecedents of sharing decisions on downstream behaviors. Barasch and Berger (2014) found that participants were more likely to share information deemed useful to the audience when narrowcasting and more likely to share information which made the sharer look good during broadcasting. Prior work shows that sharing behavior is correlated with thought processes measured while sharing decisions are being made (Baek et al., 2017; Scholz et al., 2017). To better understand these effects, it will be crucial to examine whether differences in the intensity of social and self-related processing in narrow- and broadcasters are related to differences in sharing behavior. Next, identifying the source of differences in underlying thought processes identified here will be informative for interventional approaches. Another future direction concerns moderating effects of the communication context on the role played by self-related and social processing in narrow- and broadcasters. The parallel-processes hypotheses do not posit that all instances of narrow- and broadcasting are necessarily driven to an equal extent by social and self-related thoughts. Instead, relative contributions may vary across contexts (e.g., different media).

Limitations and generalizability

It is important to note inherent limitations of inferences about psychological processes based on observations made using fMRI (Poldrack, 2006), for instance, because more than one thought process may engage activity in the same brain region. In this project, we strengthened these reverse inferences by examining activity in regions in which activity is meta-analytically associated with self-related and social processing across hundreds of neuroimaging studies. Further, the involvement of these processes was hypothesized a priori based on theoretical reasoning. Finally, the results presented here demonstrate shared processes across narrow and broadcasting, regardless of specific psychological labels ascribed to the brain activation.

The generalizability of our findings is determined by our experimental design. Our naturalistic, diverse stimuli increase the relevance of our results to the greater category of health news about healthy living and physical activity. In addition, the theoretical assumptions and conclusions we draw here are based on general human motivations that guide behavior across contexts, namely to hold a positive self-image and relate positively to others. Although these predictions are, in theory, applicable to a wide range of other sharing contexts (e.g., on different media) and content (e.g., topics outside health), this assumption needs to be confirmed empirically. Finally, we investigated dyads, the most extreme form of narrowcasting. Interestingly, despite the resulting large differences in audience size between conditions, similar self-related and social thought processes were identified for broad- and narrowcasting. It will be crucial to confirm our results and to define boundary conditions in the future, for instance in the context of other content topics and different sizes of narrow- and broadcasting audiences.

Relatedly, to maximize experimental control, we provided participants with content they were asked to share with a predetermined audience. The fixed audience may impact the saliency and relevance of certain thought processes, which then impact sharing. In real-life, a given motivation (e.g., presenting oneself in a positive light) may, instead, guide the choice of an audience that best supports the motivation. Note that, here too, considerations of potential consequences of sharing with each available audience (i.e., the thought process manipulated here) are necessary.

Conclusion

In sum, the size of the audience attending to a communicator who is considering to share information has specific effects on the psychological processes underlying sharing decisions. Our data show that both self-related and social processing occurs when communicators consider sharing via narrow- and broadcasting. However, both types of processing occur more intensively during narrowcasting. That is, narrow- and broadcasting afford different intensities of two processes known to be highly relevant for downstream outcomes concerning the diffusion of information, namely persuasion and virality (Falk & Scholz, 2018).

Acknowledgments

The views, opinions, and/or findings contained in this article are those of the authors and should not be interpreted as representing the official views or policies, either expressed or implied, of DARPA or the Department of Defense. Additionally, we received support from the National Institutes of Health in form of a New Innovator Award (NIH 1DP2DA03515601; PI Falk). We gratefully acknowledge Alixandra Barasch and Jonah Berger for fruitful discussions during earlier stages of this work and the Communication Science Laboratory for research assistance during data collection and analysis.

Notes

1. Note that a larger sample of participants was screened for participation in this study. Forty-three participants were chosen based on the ego-betweenness centrality of their Facebook networks in order to answer a research question that is orthogonal to the analyses discussed here (see the online pre-registration document for details; authors redacted, 2015).
2. As noted on neurosynth.org: "Reverse inference map: z-scores corresponding to the likelihood that a term is used in a study given the presence of reported activation (i.e., P (Term|Activation))", in other words reverse inference maps illustrate brain regions where activation is associated with the specified function.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

This work was supported by the Defense Advanced Research Projects Agency [D14AP00048]; National Cancer Institute [1DP2DA03515601]; ARL [Cooperative Agreement Number W911NF-10-2-0022; Subcontract Number APX02-0006] and Hopelab.

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