7-2017

The Value of Sharing Information: A Neural Account of Information Transmission

Elisa C. Baek
University of Pennsylvania

Christin Scholz
University of Pennsylvania

Matthew B. O'Donnell
University of Pennsylvania

Emily B. Falk
University of Pennsylvania, falk@asc.upenn.edu

Recommended Citation

Baek, E. C., Scholz, C., O'Donnell, M. B., & Falk, E. B. (2017). The Value of Sharing Information: A Neural Account of Information Transmission. *Psychological Science, 28* (7), 851-861. https://doi.org/10.1177/0956797617695073

The Value of Sharing Information: A Neural Account of Information Transmission

Abstract

Humans routinely share information with one another. What drives this behavior? We used neuroimaging to test an account of information selection and sharing that emphasizes inherent reward in self-reflection and connecting with other people. Participants underwent functional MRI while they considered personally reading and sharing *New York Times* articles. Activity in neural regions involved in positive valuation, self-related processing, and taking the perspective of others was significantly associated with decisions to select and share articles, and scaled with preferences to do so. Activity in all three sets of regions was greater when participants considered sharing articles with other people rather than selecting articles to read themselves. The findings suggest that people may consider value not only to themselves but also to others even when selecting news articles to consume personally. Further, sharing heightens activity in these pathways, in line with our proposal that humans derive value from self-reflection and connecting to others via sharing.

Keywords

neuroimaging, cognitive processes, social interaction, social behavior, mass media, open materials

Disciplines

Cognition and Perception | Cognitive Psychology | Communication | Community Psychology | Interpersonal and Small Group Communication | Neurology | Neuroscience and Neurobiology | Neurosciences | Personality and Social Contexts | Social and Behavioral Sciences | Social Psychology

The Value of Sharing Information: A Neural Account of Information Transmission

*Elisa C. Baek[1], *Christin Scholz[1], Matthew B. O'Donnell[1], and Emily B. Falk[1]

[1]Annenberg School for Communication, University of Pennsylvania

[*]Joint First Author Contributions

Corresponding Authors:

Elisa C. Baek, Annenberg School for Communication, University of Pennsylvania

3620 Walnut St., Philadelphia, PA 19104

Email: elisa.baek@asc.upenn.edu

Emily B. Falk, Annenberg School for Communication, University of Pennsylvania

3620 Walnut St., Philadelphia, PA 19104

Email: falk@asc.upenn.edu

Abstract

Humans routinely share information with others. What drives us to do so? We used neuroimaging to test an account of information selection and sharing that emphasizes inherent reward in self-reflection and connecting with others. Participants underwent fMRI while they considered personally reading and sharing *New York Times* articles. Activity in hypothesized neural regions involved in positive valuation, self-related processing and taking the perspective of others was significantly associated with decisions to select and share articles, and scaled with preferences to do so. Activity in all three regions was greater when participants considered sharing with others versus selecting articles to read themselves. Findings suggest that people may consider value not only to self, but also to others even when selecting news articles to consume personally. Further, sharing heightens these pathways, in line with our proposed account of humans deriving value from self-reflection and connecting to others via sharing.

Introduction

Humans routinely share information with others. What drives us to do so? One account suggests that humans have evolved disproportionately large brains, in part to coordinate socially (Dunbar, 2008; Schoenemann, 2006). We learn better when we anticipate opportunities to share with others (Lieberman, 2012) and the brain's so-called 'default mode' facilitates efficient social judgments (Spunt, Meyer, & Lieberman, 2013). Thus, sharing may be inherently promoted by our biology (Tamir & Mitchell, 2012). Social network platforms also reflect our motivation to share, where users share billions of messages daily (Facebook, 2015; Twitter, 2012). In the current study, we test this account and present novel evidence emphasizing inherent reward in connecting with others through sharing, and highlight that sharing involves consideration of both social and self-relevance. We focus on online news as one form of sharing that has the potential for widespread impact (Pew Research Center, 2010).

Neural precursors of sharing

Studies of information selection and sharing have relied primarily on content characteristics or self-reported responses (Berger & Milkman, 2012; Botha & Reyneke, 2013; Kim, 2015; Lee & Ma, 2012). However, people may not have the ability or desire to objectively reflect upon their thoughts and emotions to explain their behavior (Dijksterhuis, 2004; Schmitz & Johnson, 2007). Furthermore, self-reports do not allow assessment of cognitive processes in real time, at the moment that individuals consider selecting or sharing news articles, thus limiting our understanding of cognitive underpinnings of selection and sharing.

To address these limitations, the current study uses neuroimaging (functional magnetic resonance imaging; fMRI) of activity in regions-of-interest (ROI) as participants considered selecting and sharing *New York Times* articles. We focused on three neural ROIs implicated in subjective value, self-related processing, and social cognition.

Subjective value. We first tested the idea that selecting and sharing information may carry inherent value. Regions of ventral striatum (VS) and ventromedial prefrontal cortex (VMPFC) were associated with positive valuation in a meta-analysis of 206 fMRI studies (Bartra, McGuire, & Kable, 2013). We examined whether these meta-analytically defined regions were preferentially activated as participants considered selecting and sharing news articles.

We also tested whether activity in these regions scaled with preference to select and share articles. Perceived utility of content influences people's choice of content (Botha & Reyneke, 2013; Kim, 2015), and neural regions implicated in subjective value processing are associated with higher enthusiasm in sharing messages (Falk, O'Donnell, & Lieberman, 2012) and disclosing information about the self (Tamir & Mitchell, 2012).

Self-related processing. We next tested whether brain regions implicated in self-relevance are associated with selecting and sharing information. Regions of the medial prefrontal cortex (MPFC) and posterior cingulate cortex (PCC) were engaged when participants made judgments about self-relevance in a meta-analysis of 25 studies (Murray, Schaer, & Debbané, 2012). We first tested whether these regions were engaged while participants considered selecting articles to read themselves. Individuals consider personal relevance when deciding to engage with content (Botha & Reyneke, 2013), with a bias toward content consistent with pre-existing beliefs (Cappella, Kim, & Albarracín, 2014). Secondly, we examined whether this ROI is activated while participants considered sharing articles. Self-enhancement is a key motivation for sharing information, and people find value in sharing self-relevant messages (Angelis, Bonezzi, Peluso, Rucker, & Costabile, 2012; Berger, 2014; Lee & Ma, 2012; Wien & Olsen, 2014).

We also tested whether activity in these regions scaled positively with preference to select and share articles. Activity in neural regions implicated in self-related processing is associated with higher enthusiasm to spread ideas (Falk et al., 2012), and articles that resonate personally are more likely to be selected and shared (Berger, 2014).

Social cognition. Finally, we examined brain activity associated with considering the mental states of others (‘social cognition’), consisting of portions of the ventral, middle, and dorsal medial prefrontal cortex (VMPFC, MMPFC, DMPFC), precuneus (PC), bilateral temporoparietal junction (TPJ), and right superior temporal sulcus (rSTS) (Dufour et al., 2013). These regions were engaged when large numbers of participants (N=462) considered others’ beliefs (Dufour et al., 2013). First, we tested whether these regions are engaged when people considered selecting information to read themselves. People regularly incorporate others’ recommendations when making decisions, and this process is reflected in brain regions similar to our ROIs (Cascio, O’Donnell, Bayer, Tinney, & Falk, 2015). Furthermore, social cognitive components within the brain’s default-mode network prime our minds for social judgments even at rest (Spunt et al., 2013), and anticipation of sharing may be a key motive for reading content.

Second, as sharing information is inherently social, and social interaction is a key driver to news sharing behavior (Angelis et al., 2012; Berger, 2014; Lee, Ma, & Goh, 2011), we examined whether this ROI is actively engaged while participants considered sharing articles.

We also tested whether activity in these regions scaled positively with preference to select and share articles. Exchange of useful information is a key motivation behind sharing (Lee et al., 2011). Sharing information may lead to social reward, such as interpersonal bonding (Berger, 2014).

Our approach allowed us to measure brain activity within subjective value, self-related, and social cognition regions of interest, while participants made judgments about selecting and sharing news articles, in real time. We use these data to advance an account of information selection and sharing that emphasizes inherent reward in connecting with others in combination with self and social relevance.

Methods

Participants

Forty-three participants (30 females) between the ages of 18 and 24 (M = 20.5, SD = 2.1) took part in the current study. We aimed to collect data from a total of 40 participants, with the sample size predetermined based on funding, but collected data from 3 additional participants due to concerns with data quality before any statistical analysis was performed. Data collection stopped when we reached the enrollment goal. Two participants were excluded from analysis due to data corruption, resulting in forty-one participants included for analysis. All participants gave informed consent in accordance with the procedures of the Institutional Review Board of the University of Pennsylvania. Participants also met standard fMRI eligibility criteria, including having no metal in their body, not currently taking any psychiatric medications, no history of psychiatric or neurological disorders, not currently being pregnant, and not suffering from claustrophobia. Participants were also required to be right-handed.

Procedure

Participants completed a baseline screening, as well as a neuroimaging appointment. During the neuroimaging appointment, participants completed a series of self-report surveys, and were scanned using BOLD fMRI while they completed two tasks. In the task of interest to the present investigation, participants read 80 news headlines and abstracts from the health section of the *New York Times* that were published online between July 2012 and February 2013. To control for reading speed, participants heard a recording of headlines and abstracts read aloud during each trial (*M* = 10.2s, range 8 - 12s, *SD* = 1.41s). Each headline and abstract was randomized into one of four conditions: 1) broadcast share condition ("*how likely would you be to share this article on your Facebook wall?"*) 2) narrowcast share condition (*"how likely would you be to share this article with Facebook Friend X," where X is the name of a specific friend*) 3) select to read for self condition ("*how likely would you be to read the article yourself?"*) and 4) content recall/control condition (*"is [age/nutrition/fitness/science/laws/well-being/cancer] the topic of this article?"*). Participants saw 20 news headlines and abstracts within each condition, which were randomly assigned within a randomization scheme that treated article length as a blocking factor (i.e., to balance the length of articles across conditions). Participants rated their responses on a 1 to 5 Likert scale, where 1 represented "*very unlikely"* and 5 represented "*very likely"* (in the content condition, 1 represented "*certainly not*" and 5 represented "*certainly yes"*), thereby indicating their select/share preferences or certainty of topic for each article.

Each trial began with a 1.5s orientation screen that informed the participant which condition they were about to undertake. The participants then saw (and heard via headphones) an article headline and abstract that ranged from 8-12 seconds in length, followed by a randomly jittered fixation screen (*M* = 2s, range 0.5 - 4.7s, *SD* = 0.97s). Participants then had 3s to record their response on a 5-point rating scale as described above, which was followed by a fixation with a jittered inter-trial interval (*M* = 1.5s, range 0.5 - 4.7s, *SD* = 0.96s). In order to avoid issues of collinearity between trials, we used Optseq (Optseq2, 2006) to maximize design efficiency. We ran the Optseq simulation twice per run, each 100,000 times, to determine the optimal jitter times 1) between trials and 2) between the read and rate screens within trials. See Figure 1 for an illustration of the task design.

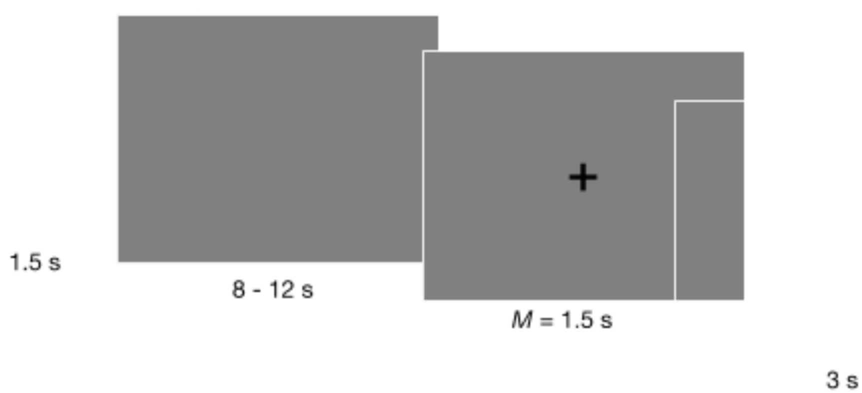

Fig. 1.
Article task design (reading condition example). Participants were first reminded of the condition of the trial. Then, they saw and heard an audio recording of an article headline and abstract. This was followed by a jittered ITI (*M* = 1.5 seconds). Finally, they were given 3 seconds to indicate their preference to select or share the article. In the content condition, they were asked to indicate their certainty that the article content was about a topic (e.g. fitness).

fMRI Image Acquisition

Neuroimaging data were acquired using Tesla Siemens scanners[1]. Two functional runs were acquired for each participant (500 volumes per run). Functional images were recorded using a reverse spiral sequence (TR = 1500 ms, TE = 25ms, flip angle = 70°, -30° tilt relative to AC-PC line, 54 axial slices[2], FOV = 200 mm, slice thickness = 3mm; voxel size = 3.0 x 3.0 x 3.0 mm) and high-resolution T1-weighted images (MPRAGE; 160 slices; slice thickness = 0.9 x 0.9 x 1 mm) and T2-weighted images in-place with the BOLD images for use in coregistration and normalization.

Imaging Data Analysis

Functional data were pre-processed and analyzed using Statistical Parametric Mapping (SPM8, Wellcome Department of Cognitive Neurology, Institute of Neurology, London, UK). To allow for the stabilization of the BOLD signal, the first five volumes (7.5 seconds) of each run were not collected. Functional images were despiked using the 3dDespike program as implemented in the AFNI toolbox (Cox, 1996). Next, data were corrected for differences in the time of slice acquisition using sinc interpolation; the first slice served as the reference slice. Data were then spatially realigned to the first functional image. We then co-registered the functional and structural images using a two-stage procedure, each stage being 6 parameter affine. First, in-plane T1 images were registered to the mean functional image. Next, high-resolution T1 images were registered to the in-plane image (12 parameter affine). After coregistration, high-resolution structural images were segmented into gray matter, white matter and cerebral

[1] Due to technical issues, 41 participants were acquired on TIM Trio scanner, and remaining 2 on Prisma scanner, per pre-specified target enrollment goals.
[2] 52 axial slices for 2 participants scanned on Prisma scanner

spinal fluid (CSF) to create a whole brain mask for use in modeling. T1 images were normalized to the skull-stripped MNI template provided by FSL ("MNI152_T1_1mm_brain.nii"). Finally, functional images were smoothed using a Gaussian kernel (8 mm FWHM).

Task Analysis

Data were modeled using the general linear model as implemented in SPM8. Three conditions were modeled. The first condition ('share') combined the two share trial types, broadcast (share on Facebook wall) and narrowcast (share with a friend), for analysis[3]. The second condition ('select') consisted of trials where participants considered whether to select the full articles to read themselves. Lastly, the third condition ('content') modeled the trials when participants were asked to recall the content of the article and served as a control condition. Low-frequency noise was removed using a high-pass filter (128 s). Contrasts were created for share > content, share > select and select > content. Percent signal change scores were extracted from the select > content; share > content; and share > select contrasts for each participant using the MarsBar toolkit for SPM (Brett, Anton, Valabregue, & Poline, 2002). Next, a random effects model was computed for each contrast, averaging across participants. Two sets of additional, parallel models were run: 1) controlling for reaction time on each trial, and 2) using only a subset of trials that were matched on reaction time across conditions.

In addition, we examined the relationship between brain activity in the select and share conditions and participants' preference ratings to select and share, respectively. These models

[3] See Scholz, Baek, O'Donnell & Falk (in submission) for details comparing narrow and broadcasting trials.

used the participants' preference ratings as a parametric modulator of neural activity during each trial, for each participant, in a fixed effects model implemented in SPM8. Next, a random effects model was computed for each analysis at the group level, averaging across participants.

Regions of Interests Analysis

To investigate the relationship between neural activity during the consideration of selecting and sharing news articles, we conducted a series of analyses using neural activity extracted from three sets of *a priori* regions-of-interest (ROIs) defined by three separate meta-analyses of subjective value processing [VS + VMPFC] (Bartra et al., 2013); self-related processing [MPFC + PCC] (Murray et al., 2012). and social cognition [VMPFC, MMPFC, DMPFC, PC/PCC, PC, bilateral TPJ, and rSTS] (Dufour et al., 2013). Parameter estimates representing percent signal change for each of the contrasts defined above were extracted and averaged across participants. See Figure 2 for a description of these regions.

Whole Brain Analysis

In addition, following our planned ROI analyses, we conducted exploratory whole brain analyses to examine whether neural regions outside of our ROIs were associated with the main contrasts of interest (select > content; share > content; share > select) as well as the select and share conditions modulated by the subsequent ratings. All analyses are reported with a threshold of $p < .05$, K > 20, corrected for familywise error using SPM8.

Results

Neural Correlates of Selecting and Sharing Articles

Decisions to select. We first examined brain activity associated with making decisions to select an article (vs. content judgments) in our *a priori* hypothesized ROIs (select > content). All three hypothesized ROIs were more strongly activated when participants were thinking about selecting an article for themselves than when they were asked to recall the main content of the article. This included activity in the hypothesized subjective value (t (40) = 7.22, $p < .001$, mean parameter estimate = 0.118, 95% CI [0.085, 0.151]), self-related processing (t (40) = 7.26, $p < .001$, mean parameter estimate = 0.143, 95% CI [0.103, 0.183]), and social cognition (t (40) = 4.99, $p < .001$, mean parameter estimate = 0.067, 95% CI [0.040, 0.095]) ROIs (Table 1; Figure 3)[4].

Decisions to share. Next, we examined brain activity associated with making decisions

[4]Additional analyses were performed removing the regions of social cognition ROI that overlap with subjective valuation and self-related processing ROIs. We report these results in Tables S1 and S2 in Supplementary Materials. All results remained robust with overlapping regions removed.

to share an article (vs. content judgments) in our *a priori* hypothesized ROIs (share > content). All three hypothesized ROIs were more strongly activated when participants were thinking about sharing an article with others than when they were focusing on the content of the article. This included activity in the hypothesized subjective value (t (40) = 12.69, p < .001, mean parameter estimate = 0.158, 95% CI [0.133, 0.184]), self-related processing (t (40) = 15.25, p < .001, mean parameter estimate = 0.225, 95% CI [0.195, 0.255]), and social cognition (t (40) = 9.41, p < .001, mean parameter estimate = 0.104, 95% CI [0.082, 0.127]) ROIs (Table 1; Figure 3).

Effects of sharing versus selecting. Although both decisions to select and share articles were associated with activity in subjective value, self, and social cognition ROIs, relative to the control condition, we next directly compared these conditions (share > select) to determine whether activation was stronger in either condition. We observed greater activation in all three ROIs during sharing than selecting to read conditions (Table 1). There was a stronger activation in the subjective value regions (t (40) = 3.09, p = .004, mean parameter estimate = 0.040, 95% CI [0.014, 0.067]), self-related processing (t (40) = 5.02, p < .001, mean parameter estimate = 0.082, 95% CI [0.049, 0.115]) as well as the social cognition ROIs (t (40) = 3.12, p = .003, mean parameter estimate = 0.037, 95% CI [0.013, 0.061]) during sharing than selecting (Table 1).

Table 1.
Neural Correlates of Selecting and Sharing News Articles

ROIs	Select > Content			Share > Content			Share > Select		
	t (40)	*p*	*Mean parameter estimate [95% CI]*	*t* (40)	*p*	*Mean parameter estimate [95% CI]*	*t* (40)	*p*	*Mean parameter estimate [95% CI]*
Subjective Valuation	7.22	<.001	0.118 [0.085, 0.151]	12.69	<.001	0.158 [0.133, 0.184]	3.09	.004	0.040 [0.014,0.067]

Self-Related Processing	7.26	<.001	0.143 [0.103, 0.183]	15.25	<.001	0.225 [0.195, 0.255]	5.02	<.001	0.082 [0.049, 0.115]
Social Cognition	4.99	<.001	0.067 [0.040, 0.095]	9.41	<.001	0.104 [0.082, 0.127]	3.12	.003	0.037 [0.013, 0.061]

Note: A table consisting of activations in the sub-regions of each ROI system can be found in Table S3 in the Supplemental Material available online.

Fig. 3.
Percent signal change estimates for activity in the subjective valuation, self-related processing, and social cognition regions-of-interest are graphed separately for selection and sharing conditions. Activation was measured in contrast to the content trials. Activity in each contrast (select > content; share > content; select > share) was significant at $p < .001$. Sagittal and axial cuts of the brain represent the regions-of-interest.

Reaction time (RT) robustness analyses. Finally, we compared differences in reaction time between all conditions of interest. Although participants were slower to make decisions during the content trials than during selecting and sharing, all results remained robust when controlling for RT and in analyses subsetting to match reaction times across conditions (see

Tables S5, S6, S7, and S8 in Supplementary Materials online), thereby suggesting that our results were not driven by difficulty across conditions.

Whole brain analysis. Next, whole-brain analyses were conducted that examined whether regions outside of our hypothesized ROIs were more active during the contrasts of interest, select > content, share > content, and share > select. The results of the whole brain analyses confirm that the activity observed during these contrasts were robust in the three regions identified in our ROI analyses (see Table 2 and Figure 4).

Table 2.
Whole Brain Associations of Selecting and Sharing Articles

Region	MNI coordinates			Number of voxels (*k*)	*t* (41)
	x	*y*	*z*		
Select > Content					
MPFC/ VMPFC (bilateral)	-9	59	4	1363	9.63
DMPFC	-18	38	43	92	6.75
Temporoparietal Junction (L)	-51	-64	34	180	7.69
Precuneus (L)	-9	-55	19	81	6.65
Inferior Temporal Gyrus	66	-10	-14	52	6.30
Middle Temporal Gyrus	-60	-10	-17	141	7.48
Share > Content					
MPFC (bilateral)	-6	53	10	3263	15.58
Precuneus (R)	-6	-55	25	935	12.56
Temporoparietal Junction (R)	51	-61	25	233	8.52
Temporoparietal Junction (L)	-54	-67	43	336	8.20
Middle Temporal Gyrus	-63	-7	-14	202	8.47
Insula (L)	-30	17	-14	34	7.74
Inferior Temporal Gyrus	63	-7	-17	129	7.61
Hippocampus	-27	-34	-11	23	6.10
Share > Select					
Precuneus (bilateral)	9	-61	28	385	8.50

Note: The table reports significant activations ($p < .05$, corrected for familywise error) of clusters with a minimum size of 20 voxels. The *t* tests were conducted at peak coordinates. MNI = Montreal Neurological Institute.

Fig. 4.
Whole brain associations of selecting and sharing articles. This figure reports significant activations ($p < .05$, corrected for family-wise error) of clusters with a minimum size of 20 voxels. See Table 2 for a detailed breakdown of each cluster and Supplementary Materials for complete sagittal slices of the whole brain results. Colored scales indicate t values.

Neural Correlates of Preference to Select and Share Articles

Next, we examined whether the neural regions in question scale with participants' degree of preference to select and share articles, respectively. To do this, we examined the relationship between activity in our hypothesized ROIs during the select and share trials and participants' subsequent ratings of likelihood to select and share each article, respectively.

Preference ratings. Participants varied in their ratings of likelihood to select and share articles. On average, participants indicated higher likelihood to select (M = 3.17, SD = 1.40) than likelihood to share (M = 2.12, SD = 1.26). Intra-class correlation analyses revealed higher within-subject than between-subject variance in preference ratings, indicating that individuals' likelihood to select ([ICC1] = 0.18) and share ([ICC1] = 0.20) varied across articles; in other words, participants expressed a range of preferences and did not show strong individual differences in rating all articles positively or negatively. Likewise, higher within-article than between-article variance in preference ratings indicated that articles varied in their popularity to be selected ([ICC1] = 0.11) and shared ([ICC1] = 0.07) across participants; thus different participants preferred different articles, suggesting that the effects observed are not merely a function of article-specific features or some articles being universally preferred.

Neural correlates of likelihood to select and share. Activity in all three ROIs, the subjective value, self-related processing, and social cognition regions, was positively associated with higher preference ratings in both select and share conditions (See Table 3). We also conducted whole-brain analyses to more precisely identify neural sub-regions within our ROIs and outside of our ROIs that were associated with higher preference to select and share ratings. The results of the whole-brain analyses support the ROI analyses and suggest the relative specificity of our results (we did not observe widespread activity outside of our main ROIs).

Of particular note, our whole-brain search suggests that a sub-portion of VMPFC that is largely associated with self-related processing, was associated with greater preference ratings for selection, but not sharing, of articles. In contrast, a sub-portion of DMPFC and TPJ that are largely associated with social cognition, was found to be associated with greater preference ratings for sharing, but not selection, of articles. These results support the ventral-dorsal gradient of self and other-related processing in the MPFC (Denny, Kober, Wager, & Ochsner, 2012) and suggest that although there is overlap of self-related and social cognition activity in the selection and sharing of information, some specificity may also be involved when people consider how much they prefer selecting articles to read personally versus sharing with others (Figure 5). Full results of the whole brain search can be found in Table 4.

Table 3.
Neural Activity Modulated by Preference Ratings Measuring Likelihood to Select to Read or Share

ROIs	Conditions

	Select x Rating			Share x Rating		
	t (40)	*p*	*Mean parameter estimate [95% CI]*	*t* (40)	*p*	*Mean parameter estimate [95% CI]*
Subjective Valuation	6.01	<.001	0.046 [0.030, 0.061]	3.66	<.001	0.039 [0.174, 0.061]
Self-Related Processing	5.28	<.001	0.053 [0.033, 0.073]	3.36	.002	0.058 [0.023, 0.093]
Social Cognition	3.47	.001	0.027 [0.011, 0.043]	3.20	.003	0.036 [0.133, 0.059]

Note: A table consisting of activations in the sub-regions of each ROI can be found in Table S4 in the Supplemental Material available online.

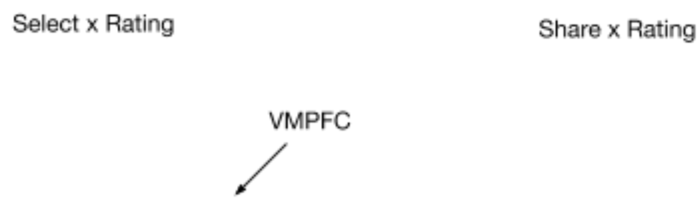

Fig. 5.
Whole brain associations of neural activity modulated by preference ratings to select or share. Preferences to read articles oneself scaled positively with activity within VMPFC, whereas preferences to share articles scaled positively with activity in DMPFC.

Table 4.
Whole brain associations of neural activity modulated by preference ratings of likelihood to select to read or share

Region	MNI Coordinates			Number of voxels *(k)*	*t* (41)
	x	*y*	*z*		
Select x Rating					
VMPFC (bilateral)	-6	38	-8	417	7.50
Cerebellum (R)	36	-61	-41	24	6.54
Middle Temporal Gyrus	-54	2	-23	47	6.54
Middle Temporal Gyrus	-63	-22	-14	50	6.31
Inferior Frontal Gyrus	-42	29	-2	41	6.07
Share x Rating					
DMPFC	-12	53	34	48	6.31
Temporoparietal Junction (L)	-48	-64	34	35	6.03
Middle Frontal Gyrus	-45	8	52	55	6.36

Caudate (R)	9	8	4	24	6.27
Caudate (L)	-9	14	7	29	5.91

Note: The table reports significant activations ($p < .05$, corrected for familywise error) of clusters with a minimum size of 20 voxels. The t tests were conducted at peak coordinates. MNI = Montreal Neurological Institute.

Discussion

We advance an account of information selection and sharing that emphasizes positive valuation, self, and social relevance as drivers. Neural activity within positive valuation, self-related processing, and social cognition ROIs was associated with deciding to select and share news articles, and scaled with preferences to do so. We observed substantial overlap in the processes underpinning selection and sharing decisions, with heightened activity during sharing. Scholars have suggested that similar psychological processes may underpin the selection and sharing of information (Cappella et al., 2014; Kim, 2015) and that representations of the self and other often overlap (Brewer, 1991; Platek, Keenan, Gallup, & Mohamed, 2004). Our data advance this theory by demonstrating neural overlap in the processes engaged.

Information selection. Examining selection and sharing separately, our data highlight that information selection involves brain activity in regions of interest implicated in self-related and value processes, but also engages brain regions chosen for their role in social cognition. These data are consistent with a value-based account of information selection; VS and VMPFC are robustly associated with computing subjective values of different stimuli (Bartra et al., 2013). One source of value for personal consumption of information may be an article's self-relevance. We observed greater activity within self-related ROIs (MPFC + PCC) during decisions to select articles, relative to recalling the content. Activity in these regions was further associated with the degree of preference to select the article for oneself. These findings are consistent with previous literature on persuasion and influence (Cascio et al., 2015; Falk et al., 2012), suggesting that self-related processing may be a key factor in being influenced to act in accordance with a message (in this case, to select the article).

We also observed greater activity within the social cognition ROIs (VMPFC, MMPFC, DMPFC, TPJ, PC, rSTS) during decisions to select articles, relative to judging the articles' contents. Activity within these regions was further associated with preference to select the article. These data are consistent with the idea that even when selecting information for personal consumption, people may consider broader social factors (Cialdini & Trost, 1998). This finding also converges with evidence that the 'default mode network' in the brain primes us to readily consider others' mental states (Spunt et al., 2013). Thus, social considerations may be important in selecting information, as the knowledge gained can translate into social value.

Information sharing. We also observed greater activity within all three regions of interest during sharing, both relative to decisions to select for self and relative to the control condition (content recall). Activity in all three ROIs also scaled with preference to share the articles. These data are consistent with a value-based account of information sharing, in accordance with evidence that informing others (Tamir, Zaki, & Mitchell, 2015) and sharing about oneself activates reward pathways (Tamir & Mitchell, 2012). We extend these findings to the domain of sharing more broadly, and also examine two possible additional sources of value: self and social relevance.

Indeed, activity in meta-analytically defined self-related processing regions of MPFC and PCC was greater during sharing, even when compared to making selections for oneself. These findings align with previous research demonstrating that MPFC activity scales with intentions to recommend ideas (Falk, Morelli, Welborn, Dambacher, & Lieberman, 2013). We extend these findings to show that merely considering sharing information activates this ROI, and the activity scales with preference.

These findings also highlight how the social act of sharing may be self-reflective, converging with accounts of self-presentation motives in sharing (Barasch & Berger, 2014). Desires to enhance one's reputation and social status are suggested as key motivators behind news sharing (Angelis et al., 2012; Berger, 2014; Lee & Ma, 2012; Wien & Olsen, 2014). Further, people are more likely to engage with messages that promote their values (Berger, 2014; Botha & Reyneke, 2013). Critically, our findings provide neural evidence that self-related processing is engaged not only when people consider selecting messages, but also in sharing them with others.

Relatedly, we observed the greatest activity in our social cognition ROIs, relative to selecting articles for oneself and relative to the control condition, and this activity scaled with preferences to share. Humans have an inherent motivation to socialize through sharing information (Baumeister & Leary, 1995; Berger, 2014; Tamir & Mitchell, 2012). Prior research has shown that activity within sub-regions of the social cognition ROIs is associated with successful retransmission (Falk et al., 2013) and enthusiastic recommendations (Falk et al., 2012).

Although there is substantial neural overlap in the selection and sharing of information, we found preliminary support for some distinctions. Our whole-brain results show that VMPFC, an area previously implicated in self-related processing and value to self, was robustly associated with greater preference for selection of articles. In contrast, DMPFC and TPJ, areas previously implicated in social cognition, were associated with greater preference for sharing of articles. These results support the ventral-dorsal gradient of self and other-related processing in the MPFC (Denny et al., 2012) and suggest that while there is largely an overlap of self-related and social cognition activity in the selection and sharing of information, some specificity may also be involved when people consider how much they prefer information for themselves versus others.

In summary, we advance a novel account of the neurocognitive mechanisms behind selection and retransmission processes as participants were actively considering selecting and sharing news. Increased activity in hypothesized subjective value, self-related, and social cognition ROIs was associated with decisions to select and share information, as well as with preferences to do so. These results highlight fundamental dimensions of our motivation to communicate and highlight more generally the overlap in considering information for personal and social purposes.

Author Contributions

All authors contributed to the design of the study. E.C.B, C.S., and M.B.O. collected the neural data. E.C.B. conducted the data analysis in close correspondence with C.S. and E.B.F. E.C.B. drafted the manuscript in collaboration with E.B.F. All authors approved the final version of the manuscript for submission.

Acknowledgements

The authors thank Elizabeth Beard, Lynda Lin, and staff of the University of Pennsylvania fMRI Center for support with data acquisition; Hyun Suk Kim, Rosie Bae, Erin Maloney, and Joseph Cappella for assistance with stimulus materials. This work was supported by The Defense Advanced Research Projects Agency (D14AP00048; PI Falk) and NIH (1DP2DA03515601; PI Falk). The views, opinions, and 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, DoD or NIH.

References

Angelis, M. De, Bonezzi, A., Peluso, A. M., Rucker, D. D., & Costabile, M. (2012). On braggarts and gossips: A self-enhancement account of word-of-mouth generation and transmission. *Journal of Marketing Research*, *49*(4), 551–563. http://doi.org/10.1509/jmr.11.0136

Barasch, A., & Berger, J. (2014). Broadcasting and narrowcasting: How audience size affects what people share. *Journal of Marketing Research*, *51*(3), 286–299. http://doi.org/10.1509/jmr.13.0238

Bartra, O., McGuire, J. T., & Kable, J. W. (2013). The valuation system: A coordinate-based meta-analysis of BOLD fMRI experiments examining neural correlates of subjective value. *NeuroImage*, *76*, 412–427. http://doi.org/10.1016/j.neuroimage.2013.02.063

Baumeister, R. F., & Leary, M. R. (1995). The need to belong: Desire for interpersonal attachments as a fundamental human motivation. *Psychological Bulletin*, *117*(3), 497–529. http://doi.org/10.1037/0033-2909.117.3.497

Berger, J. (2014). Word of mouth and interpersonal communication: A review and directions for future research. *Journal of Consumer Psychology*, *24*(4), 586–607. http://doi.org/10.1016/j.jcps.2014.05.002

Berger, J., & Milkman, K. L. (2012). What makes online content viral? *Journal of Marketing Research*, *49*(2), 192–205. http://doi.org/10.1509/jmr.10.0353

Botha, E., & Reyneke, M. (2013). To share or not to share: The role of content and emotion in viral marketing. *Journal of Public Affairs*, *13*(2), 160–171. http://doi.org/10.1002/pa.1471

Brett, M., Anton, J. L., Valabregue, R., & Poline, J. B. (2002). Region of interest analysis using an SPM toolbox. *NeuroImage*, *16*(2), 497. http://doi.org/http://dx.doi.org/10.1016/S1053-8119(02)90010-8

Brewer, M. B. (1991). The social self: On being the same and different at the same time. *Personality and Social Psychology Bulletin*, *17*(5), 475–482. http://doi.org/10.1177/0146167291175001

Cappella, J. N., Kim, H. S., & Albarracín, D. (2014). Selection and transmission processes for information in the emerging media environment: Psychological motives and message characteristics. *Media Psychology*, *3269*(June 2015), 1–29. http://doi.org/10.1080/15213269.2014.941112

Cascio, C. N., O'Donnell, M. B., Bayer, J., Tinney, F. J., & Falk, E. B. (2015). Neural correlates of susceptibility to group opinions in online word-of-mouth recommendations. *Journal of Marketing Research*, *52*(4), 559–575. http://doi.org/10.1509/jmr.13.0611

Cialdini, R., & Trost, M. (1998). Social influence: Social norms, conformity and compliance. In D. T. Gilbert, S. T. Fiske, & G. Lindzey (Eds.), *The Handbook of Social Psychology, Vol. 2* (pp. 151–192). New York, NY: McGraw-Hill.

Cox, R. W. (1996). AFNI: Software for analysis and visualization of functional magnetic resonance neuroimages. *Computers and Biomedical Research, an International Journal*, *29*(3), 162–173. http://doi.org/10.1006/cbmr.1996.0014

Denny, B. T., Kober, H., Wager, T. D., & Ochsner, K. N. (2012). A meta-analysis of functional neuroimaging studies of self- and other judgments reveals a spatial gradient for mentalizing in medial prefrontal cortex. *Journal of Cognitive Neuroscience*, *24*(8), 1742–52. http://doi.org/10.1162/jocn_a_00233

Dijksterhuis, A. (2004). Think different: The merits of unconscious thought in preference development and decision making. *Journal of Personality and Social Psychology*, *87*(5), 586–598. http://doi.org/10.1037/0022-3514.87.5.586

Dufour, N., Redcay, E., Young, L., Mavros, P. L., Moran, J. M., Triantafyllou, C., … Saxe, R. (2013). Similar brain activation during false belief tasks in a large sample of adults with and without autism. *PLoS ONE*, *8*(9). http://doi.org/10.1371/journal.pone.0075468

Dunbar, R. I. M. (2008). Why humans aren't just Great Apes. *Issues in Ethnology and Anthropology*, *3*(3), 15–33.

Facebook. (2015). Facebook: Company Info. Retrieved June 5, 2015, from http://newsroom.fb.com/company-info/

Falk, E. B., Morelli, S. A., Welborn, B. L., Dambacher, K., & Lieberman, M. D. (2013). Creating buzz: The neural correlates of effective message propagation. *Psychological Science*, *24*(7), 1234–42. http://doi.org/10.1177/0956797612474670

Falk, E. B., O'Donnell, M., & Lieberman, M. (2012). Getting the word out: Neural correlates of enthusiastic message propagation. *Frontiers in Human Neuroscience*, *6*(November). http://doi.org/10.3389/fnhum.2012.00313

Kim, H. S. (2015). Attracting views and going viral: How message features and news-sharing channels affect health news diffusion. *Journal of Communication*, *65*, 512–534. http://doi.org/10.1111/jcom.12160

Lee, C. S., & Ma, L. (2012). News sharing in social media: The effect of gratifications and prior experience. *Computers in Human Behavior*, *28*(2), 331–339. http://doi.org/10.1016/j.chb.2011.10.002

Lee, C. S., Ma, L., & Goh, D. H. L. (2011). Why do people share news in social media? *Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, *6890 LNCS*, 129–140. http://doi.org/10.1007/978-3-642-23620-4_17

Lieberman, M. (2012). Education and the social brain. *Trends in Neuroscience and Education*, *1*, 3–9. http://doi.org/10.1016/j.tine.2012.07.003

Murray, R. J., Schaer, M., & Debbané, M. (2012). Degrees of separation: A quantitative neuroimaging meta-analysis investigating self-specificity and shared neural activation between self- and other-reflection. *Neuroscience and Biobehavioral Reviews*. http://doi.org/10.1016/j.neubiorev.2011.12.013

Optseq2. (2006). Optseq Home Page. Retrieved from https://surfer.nmr.mgh.harvard.edu/optseq/

Pew Research Center. (2010). *Understanding the participatory news consumer : How internet and cell phone users have turned news into a social experience*. Retrieved from http://www.pewinternet.org/2010/03/01/understanding-the-participatory-news-consumer/

Platek, S. M., Keenan, J. P., Gallup, G. G., & Mohamed, F. B. (2004). Where am I? The neurological correlates of self and other. *Cognitive Brain Research*, *19*(2), 114–122. http://doi.org/10.1016/j.cogbrainres.2003.11.014

Schmitz, T. W., & Johnson, S. C. (2007). Relevance to self: A brief review and framework of neural systems underlying appraisal. *Neuroscience & Biobehavioral Reviews*, *31*(4), 585–596. http://doi.org/10.1016/j.neubiorev.2006.12.003

Schoenemann, P. T. (2006). Evolution of the size and functional areas of the human brain. *Annual Review of Anthropology*, *35*(1), 379–406. http://doi.org/10.1146/annurev.anthro.35.081705.123210

Spunt, R. P., Meyer, M. L., & Lieberman, M. D. (2013). The default mode of human brain function primes the intentional stance. *Journal of Cognitive Neuroscience*, *25*, 719–729. http://doi.org/10.1162/jocn_a_00352

Tamir, D. I., & Mitchell, J. P. (2012). Disclosing information about the self is intrinsically rewarding. *Proceedings of the National Academy of Sciences*, *109*(21), 8038–8043. http://doi.org/10.1073/pnas.1202129109

Tamir, D. I., Zaki, J., & Mitchell, J. P. (2015). Informing others is associated with behavioral and neural signatures of value. *Journal of Experimental Psychology: General*, *144*(6), 1114–1123.

Twitter. (2012). Twitter turns six. Retrieved June 8, 2015, from https://blog.twitter.com/2012/twitter-turns-six

Wien, A. H., & Olsen, S. O. (2014). Understanding the relationship between individualism and word of mouth: A self-enhancement explanation. *Psychology & Marketing*, *31*(6), 416–425. http://doi.org/10.1002/mar