BEING THE GATEKEEPER: HOW THINKING ABOUT SHARING AFFECTS NEURAL ENCODING OF INFORMATION

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Abstract

Information transmission in a society depends on individuals' intention to share or not. Yet, little is known about whether being the gatekeeper shapes the brain's processing of incoming information. Here, we examine how thinking about sharing affects neural encoding of information, and whether this effect is moderated by the person's real-life social network position. In an fMRI study, participants rated abstracts of news articles on how much they wanted to read for themselves (read) or – as information gatekeepers – to share with a specific other (narrowcast) or to post on their social media feed (broadcast). In all conditions, consistent spatial BOLD patterns associated with news articles were observed across participants in brain regions involved in perceptual and language processing as well as higher-order processes. However, when thinking about sharing, encoding consistency decreased in higher-order processing areas (e.g., default mode network), suggesting that the gatekeeper role involves more individualized processing in the brain that is person- and context-specific. Moreover, participants whose social networks had high ego-betweenness centrality (i.e., more likely to be information gatekeeper in real life) showed more individualized encoding when thinking about broadcasting. This study reveals how gatekeeping shapes our brain's processing of incoming information.

Keywords: neural consistency, information sharing, social network analysis

Introduction

Information sharing is a key building block of societal cohesion, and whether information spreads in a society depends on people's decisions to share it or not. This is especially true given the emergence of digital platforms that allow users to connect and distribute information more efficiently (Barzilai-Nahon 2009; Coddington and Holton 2014). While people are inherently motivated to share information with others (Tamir and Mitchell 2012; Tamir et al. 2015), little is known about how the brain may process information differently when thinking about whether to share or not, i.e., taking on the role of an information gatekeeper instead of a passive recipient. In the present study, we examine the neural processing of information when individuals think about sharing or not, compared to the control condition of thinking about whether to read the information themselves or not. We then explore whether the ego-betweenness centrality of a person's real-life social network – an indicator of the person's capacity for information brokerage – affects how sensitive their brain is to this gatekeeper role. Ego-betweenness centrality is a measure of how much they could connect otherwise unconnected others in their social network (Borgatti and Everett 2006; Burt et al. 2013). It has been argued that this measure reflects a person's information brokerage capacity, i.e., to function as a gatekeeper of information among different social groups (Prell 2012).

In past functional magnetic resonance imaging (fMRI) studies, individuals processing the same incoming information exhibit consistent spatial patterns of blood oxygenation level dependent (BOLD) signals (Kriegeskorte and Bandettini 2007; Hasson et al. 2012; Haxby et al. 2014). These neural patterns are similar across people, as shown in multiple studies involving simple percepts such as words and objects (Bruffaerts et al. 2013; Devereux et al. 2013) and complex, naturalistic stimuli such as movies and spoken stories (Hasson 2004;

Hasson et al. 2008, 2010; Nastase et al. 2019). Some evidence further suggests that attention and context shape the neural encoding process (Regev et al. 2013; Yeshurun et al. 2017).

These extant studies required participants to process information either with the implicit goal of understanding the content presented, or with the explicit task to later communicate the content to another person. In everyday life, however, people often take on the role of a gatekeeper instead, thinking about whether to pass on certain information to – or withhold it from – a friend or group of friends. Does taking on the gatekeeper role, instead of that of a passive recipient, change the neural encoding of the same information? In addition, it has long been known that people's social network positions vary their abilities to broker and share information with others (Borgatti and Everett 2006; Burt et al. 2013). Do individuals whose social network positions provide greater capacity for information brokerage (i.e., with higher ego-betweenness centrality) encode information differently, especially when they have to think about whether to share with others?

Neural encoding of information in non-sharing contexts

Multiple studies have found that different individuals display similar neural representations of complex information, such as movies and spoken stories, not only in visual and auditory cortices, but also in brain regions implicated in self and social cognition within the default mode network (Spreng and Andrews-Hanna 2015), including precuneus, angular gyri, temporal poles, and medial prefrontal cortices (Hasson 2004; Hasson et al. 2010; Regev et al. 2013; Chen et al. 2017; Pollick et al. 2018; Nguyen et al. 2019). The consistency of neural encoding – that is, the extent to which different individuals produce similar neural patterns when exposed to the same content – is modulated not only by the nature and quality of the information (Nummenmaa et al. 2012; Schmälzle et al. 2015; Jääskeläinen et al. 2016; Chan et al. 2019), but also by the context in which the message recipients process the information. For example, participants in one study (Yeshurun et al. 2017) listened to an ambiguous story after being told different prior contexts that would lead to different interpretations. Brain regions such as temporoparietal junction, precuneus, and ventromedial prefrontal cortex (vmPFC) displayed contextual effects, i.e., distinct patterns between different conditions were observed in those areas. These findings suggest that different motivations and contexts can affect the way information is encoded, especially in brain areas involving higher-order mental processes such as regions within the default mode network.

Neural encoding of information in sharing contexts

Successful (vs unsuccessful) transmission of information, both from one individual to another (Stephens et al. 2010) and from a common source to multiple recipients (Nguyen et al. 2019), is associated with more similar neural patterns. For example, in a free-form storytelling task (Stephens et al. 2010), a speaker told an unrehearsed story during fMRI scanning while a listener heard the recordings afterwards. Synchronized temporal neural patterns between the two individuals were found not only in the auditory cortex, but also in precuneus and medial prefrontal cortex (MPFC). This interpersonal transfer of neural encodings has been suggested as a mechanism for transmitting information between individuals (Hasson et al. 2012).

Before transmission takes place, however, an individual has to determine whether the information is relevant to potential recipients. If people need to take on the gatekeeper role and determine the relevance of a piece of information to a potential audience instead of focusing on themselves, do they also process the information itself differently? Previous studies have shown that both thinking about the self and thinking about others' mental states increase brain activity in regions of the default mode network (Lombardo et al. 2010), and that making sharing decisions intensifies the activations of these brain areas (Baek et al. 2017; Scholz et al. 2020). In terms of neural encoding, however, does taking on the gatekeeper role affect the way the incoming information is actually represented in the brain?

Ego-betweenness centrality and information sharing

While many people share ideas and content within their social networks, individuals have different social network configurations, which affect their opportunities to serve as information brokers (Burt et al. 2013). A person's position within this configuration shapes their everyday social experience; for example, a person's social network position is related to personality traits and information sharing behaviour (Staiano et al. 2012; Miller et al. 2015; Cobb et al. 2016), and is related to brain activity during social tasks (Zerubavel et al. 2015; O'Donnell et al. 2017; Schmälzle et al. 2017). Of particular relevance to the current investigation is the ego-betweenness centrality of a person in their social network. Ego-betweenness centrality refers to the extent to which a person connects many individuals in their social network that otherwise would be disconnected (Figure 1; Freeman 1978; Borgatti and Everett 2006; Baek et al. 2020). Individuals with high ego-betweenness centrality, considered to be gatekeepers of information (Prell 2012), exhibit higher activation in regions of the brain's default mode network when they think about whether to share information with others (O'Donnell et al. 2017), suggesting that they may show greater sensitivity to the gatekeeper role. Given their experience in information brokerage, do these gatekeepers encode information differently than those with lower ego-betweenness centrality when thinking about sharing?

--- Insert Figure 1 ---

Current study

In the current investigation, we examine whether taking on the gatekeeper role (thinking about whether to share a piece of information with others or not) changes the way that information is encoded in the brain, especially in higher-order brain areas. Moreover, we explore whether a person's ego-betweenness centrality – a measure of information brokerage capacity in their own social network – relates to their brain's sensitivity to the gatekeeper role during the neural processing of information.

In the task of the current study, participants were first given text prompts signalling different conditions. They then read short headlines and abstracts of health-related news articles. The data analysed here have previously been used to answer research questions on the relationship between brain activity and population sharing behaviour (Scholz et al. 2017; Doré et al. 2019), neural correlates of individual-level sharing decisions (Baek et al. 2017) and neural mechanisms underlying narrow- and broadcasting (Scholz et al. 2020). The analyses reported here are fully novel and orthogonal to past reports on these datasets. Of interest in this study is the extent to which people show individualized neural patterns under sharing conditions (narrowcast and broadcast), compared to the non-sharing control condition of thinking about reading for themselves (Table 1).

Table 1. Sharing and non-sharing conditions in this study

Condition	**Gatekeeper role**	**Intended audience**	**Instruction**
Read	Absent	Self	'Would you read the full text of this article yourself?'
Narrowcast	Present	Specific other	'Would you share the article with [a specific friend] via a private Facebook message?'
Broadcast	Present	Broad audience	'Would you share the article on your Facebook wall?'

In each condition, we first conducted a whole-brain analysis in order to determine where in the brain we could observe consistent encoding of information, and located brain regions where encoding consistency was sensitive to the gatekeeper role. We then examined how neural patterns of these brain regions differed under the sharing conditions compared to the non-sharing condition. Lastly, we explored whether individualized encoding would be more pronounced in individuals with higher ego-betweenness centrality, i.e., who occupy more central positions of information brokerage in their social networks.

Materials and Methods

Participants

Forty-three participants were recruited from a large pool of several hundred pre-screened young adults at a U.S. university. Eligible participants were right-handed, could read and speak fluently in English, had normal or corrected-to-normal vision, had never been diagnosed with a psychiatric or neurological disorder, were not currently using psychiatric medication or legally prohibited drugs, were not currently pregnant or breastfeeding, and had no conditions that contraindicated MRI. Pre-screening also included collecting information about their social network configuration, and efforts were made to stratify sampling into participants with high and low ego-betweenness centrality in their social network (see below for details). Written informed consent was obtained according to procedures approved by the Institutional Review Board of the university. Two participants were excluded from analysis due to data corruption (one due to errors in stimulus presentation, and one due to poor normalization to the template brain), leaving a final sample of 41 (29 females) adults (mean age = 20.6 years, SD = 2.1 years, range: 18–24 years).

Ego-betweenness centrality. We computed a measure of information brokerage – ego-betweenness centrality – of the participants based on their online egocentric social networks. Specifically, at pre-screening potential participants were asked to install an application on their Facebook account that accessed information regarding their links to friends and links between their friends using the company's application programming interface (API)[1]. These data were anonymized and used to compute the ego-betweenness centrality score, a measure

[1] The Facebook OpenGraph API was functional during the time of the study (2014-2015) and is now obsolete.

of information brokerage capacity in each participant's ego-network (Borgatti and Everett 2006; O'Donnell et al. 2017). Each participant's ego-network contained information about the connections of the participant to other Facebook users ('Facebook friends'), and connections between these other users (i.e., who among the participant's Facebook friends were also Facebook friends with one another); here, we defined ego-betweenness centrality as the proportion of self-to-other connections to all possible connections in the network (Hagberg et al. 2008). The measure ranged from 0 to 1, where higher values indicate more opportunities to broker information between more different groups. (Implementation details can be found in O'Donnell et al. 2017.) In a previous, separate study, adolescents with high ego-betweenness centrality exhibited higher activation in regions of the default mode network when they evaluated whether to share information with others (O'Donnell et al. 2017), highlighting the relevance of this measure in the current investigation.

From the large pool of pre-screened young adults, recruitment invitations were sent to individuals on both the high and low ends of the ego-betweenness centrality score. Of the 41 participants included in the analysis, as intended, there was a bimodal distribution of ego-betweenness centrality score with the median at 0.7 (see supplementary material S1).

fMRI scanner task

The task completed in the fMRI scanner involved reading and rating of abstracts of newspaper articles (headlines and abstract) from the Health section of the *New York Times* website (www.nytimes.com). These articles were chosen from a larger pool (N = 760) published online between July 2012 and February 2013 (Kim 2015) based on their similarity in content (about healthy living and physical activity) and length (mean word count of title and abstract = 29.4, range = 21-35). To control for reading speed, audio narration (8, 10 or 12s in duration) of the content with a female voice accompanied the onset of the presentation of each article abstract.

For each participant, each article abstract was pseudo-randomly assigned to one of four goal conditions, within a randomization scheme that balanced text length across conditions. Each participant saw a total of 80 articles, of which a random sub-set of 20 articles was shown in each goal condition. (Due to technical error, three participants viewed 40 unique articles and one participant viewed 57 unique articles.) In each goal condition, an article abstract was accompanied with a lead-in cue (1.5s) for a particular goal, followed by a question and self-report rating pertinent to that goal (3s). The four goal conditions (and the questions respectively) were: (a) read: "How likely would you be to read the article yourself?"; (b) narrowcast: "How likely would you be to share this article with Facebook Friend _____?" (the name of a specific friend who was pre-selected to care about the article domain was inserted in the blank); (c) broadcast: "How likely would you be to share this article on your Facebook wall?"; and (d) content: "How sure are you that [age/nutrition/fitness/science/laws/well-being/cancer] is the topic of this article?". Participants responded to the questions on Likert scales from 1 (very unlikely) to 5 (very likely; in the content condition, 1 = certainly not and 5 = certainly yes). Trial order was randomly shuffled for each participant. A single trial is illustrated in Figure 2A[2].

For each participant, articles were pseudo-randomly assigned to goal conditions so that each article abstract was read on average by about 10 participants in each of the four goal conditions (content: M=9.81, SD=2.41; read: M=9.78, SD=2.53; narrowcast: M=9.81, SD=2.25; broadcast: M=9.81, SD=2.47), and the subsets of participants reading an article in a given goal condition varied from one article abstract to another. In this paper, we focused our analysis on the focal goals that most closely parallel real-world engagement with news (i.e.,

[2] Detailed task descriptions and materials are available at https://github.com/cnlab/article_sharing_task.

read as the control state of being an information recipient, and *narrowcast* and *broadcast* as being an information gatekeeper).

The task was incentive compatible: to ensure that participants processed the articles as intended by the different conditions, they were instructed that their ratings during scanning would be used to determine what articles they would be asked to read and share after the scan. After scanning, participants were given the choice to read the full text of one of the top-rated articles in the read condition. They were also asked to share one of the top-rated articles in the narrowcast condition to their actual friends, and to post one of the top-rated articles in the broadcast condition on their Facebook accounts.

fMRI data acquisition and preprocessing

Neuroimaging data were acquired using 3-T Siemens scanners. Two functional runs were acquired for each participant (500 volumes per run). Functional images were recorded using a reverse spiral sequence (repetition time = 1500 ms, echo time = 25 ms, flip angle = 70°, −30° tilt relative to the anterior commissure-posterior commissure line, 54 axial slices,[2] field of view = 200 mm, slice thickness = 3 mm; voxel size = 3.0 × 3.0 × 3.0 mm). High-resolution T1-weighted images (magnetization-prepared rapid-acquisition gradient echo, 160 slices, slice thickness = 0.9 × 0.9 × 1 mm) and T2-weighted images were used in place with the BOLD images for coregistration and normalization. To allow for the stabilization of the BOLD signal, we did not collect data from the first five volumes (7.5s) of each run.

Functional images were despiked, corrected for slice time and head motion, then co-registrated with structural images and affine-transformed to a template brain (Montreal Neurological Institute standard) using the Statistical Parametric Mapping 8 (SPM) software. A light smoothing Gaussian kernel (3mm full width at half maximum) was applied. To extract neural patterns during the processing of the article abstracts, we first generated beta images of brain activity for each article abstract seen by each participant with a high-pass filter (128s cutoff), along with six motion regressors and average grand and white matter signals. Beta image extraction and multivariate pattern analysis (described below; see Figure 2B) was conducted using the nistats and nilearn package (Abraham et al. 2014), alongside with custom scripts.

Consistent encoding within a condition

To replicate previous findings on the neural encoding of narrative content (Chen et al. 2017), we first conducted a whole-brain multivariate analysis using a searchlight of a 5×5×5 voxel cube (125 voxels) to uncover brain areas where participants had similar spatial patterns for each article in each condition. Following the procedure established by Chen and colleagues (2017), we calculated the Pearson's correlations between the neural patterns of each participant reading each article abstract and the average neural patterns of the group reading the corresponding article abstracts in the same condition. If certain brain areas contain content-specific information that is common across individuals, it follows that neural patterns expressed in those brain areas by different participants in response to the same article should exhibit higher inter-subject encoding consistency than those of different articles. Statistical significance (i.e., regions showing significant similarity across participants in the way each article was encoded) was therefore calculated by obtaining a null distribution (10,000 permutations) of the average Pearson's correlations between the same number of articles seen by each participant and group-averaged patterns expressed in response to randomly chosen (i.e., shuffled) articles (Figure 2B). Based on the empirical *p* value obtained at each voxel, we computed a pseudo-*z* map for each condition, encompassing the 20 articles that participant evaluated in that condition. These maps show effectively, at each voxel, the extent to which neural patterns contained participant-invariant and article-specific information in a specific condition. At the group level, one whole-brain statistical map per condition was generated using one-sample *t*-tests of all participants' pseudo-*z* maps, showing brain regions with high consistency across participants within a given condition.

To understand how encoding consistency (i.e., having content-specific neural patterns common across participants) varied under the sharing conditions compared to the control, we conducted paired-sample *t*-tests of the participants' pseudo *z*-maps between read and narrowcast conditions, and between read and broadcast conditions.

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Individualized encoding under sharing conditions and ego-betweenness centrality

Next, we looked at whether persons with higher ego-betweenness centrality – i.e., more likely to act as information gatekeeper in their real life – individualized their neural encodings of information to a greater extent under the sharing conditions. For this analysis, we focused on brain regions that display more individualized (i.e., less consistent) neural patterns across participants during the sharing conditions compared to the read condition, as identified in the previous analysis.

We hypothesize that ego-betweenness centrality of a person's social network is related to the distinctiveness of the person's neural encodings (compared to others) when they need to think about sharing. That is, participants with lower ego-betweenness centrality (less likely to act as an information gatekeeper) should display less sensitivity to the sharing conditions, and their neural encodings should be more consistent with each other; whereas people with higher ego-betweenness centrality should produce more distinct neural encodings when processing the same content.

To operationalize this, we conducted inter-subject representational similarity analysis (IS-RSA; Kriegeskorte and Kievit 2013) by comparing the inter-subject dissimilarity matrix of neural patterns and the distinctiveness matrix based on the participants' social network positions (Figure 2C). The neural-based dissimilarity matrix contains correlation distances between neural patterns extracted from the brain regions noted above, depicting how dissimilar the neural encodings are between any given pair of participants. On the other hand, the social network-based distinctiveness matrix is derived from the participants' social network positions – defined as ${}^{1}\!/_{2}\sqrt{{e_i}^2 + {e_j}^2}$ where e_i and e_j are the ego-betweenness centrality of participants *i* and *j* – describes the expected distinctiveness of neural encodings between any given pair of participants.

Under each condition, we constructed a neural-based dissimilarity matrix for each article abstract based on the respective subsets of participants (one article abstract was excluded because it was read by only two participants under the control condition). For each of the neural-based dissimilarity matrices, a social network-based distinctiveness matrix was constructed based on the participants' ego-betweenness centrality scores. Spearman correlations between the two matrices for each of the 79 article abstracts were then averaged for the three conditions (control, broadcast and narrowcast), offering a measure of whether ego-betweenness centrality played a role in neural encoding when individuals think about sharing. To determine the statistical significance, empirical *p* values were calculated by 10,000 permutations where ego-betweenness centrality scores were randomly shuffled each time when calculating the mean Spearman correlation between neural- and social network-based matrices.

Results

Consistent encoding of information in sensory cortices and default mode network

Do different individuals have similar neural patterns when evaluating brief, factual information (such as health-related news articles), as in previous work with stories and narratives (Chen et al. 2017; Yeshurun et al. 2017)? For each of the three focal conditions (read, broadcast and narrowcast), whole-brain analysis revealed consistent spatial neural patterns across individuals in the occipital and auditory cortices, and also precuneus, angular gyri, temporal poles, and medial prefrontal cortices (Figure 3; peak coordinates in supplementary material S2). These results are consistent with past studies showing that common encoding not only appears at sensory and semantic processing levels, but also to some extent in higher-order default mode network regions (Hasson 2004; Hasson et al. 2008; Chen et al. 2017).

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Individualized processing (i.e., decrease in encoding consistency) under the sharing conditions

Comparing whole-brain encoding consistency maps of narrowcast and broadcast to the control (read), we found greater individuation of participant brain responses when participants thought about sharing, such that encoding consistency decreased within bilateral fusiform cortex, MPFC, vmPFC, posterior cingulate cortex (PCC), and precuneus (i.e., yellow regions denoted in Figure 4 right panel; see Table 2 for cluster coordinates). In other words, whereas neural patterns in these areas were (relatively) consistent across participants when they evaluated the articles based on their own interests (i.e., thinking about whether to read themselves), they diverged from each other and were more individualized in the same brain regions when taking on the information gatekeeper role (i.e., thinking about whether to share information). In addition, in the narrowcast condition (sharing with a specific other), encoding consistency also decreased within bilateral angular gyri and cerebellum.

In a supplementary whole-brain analysis of activation (supplementary material S5), we found stronger activation in the narrowcast condition (compared to the control) in precuneus, MPFC and angular gyri, but not the fusiform cortex; while no significant voxels were found in the broadcast condition.

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Table 2. Peak MNI coordinates of significant clusters (k > 30) where encoding consistency decreased under the sharing conditions

	L/R	**x**	**y**	**z**	***t***	**k**
Read > Broadcast						
Posterior cingulate cortex	L/R	12	-55	10	7.46	240
Middle temporal gyrus	R	54	-46	-5	5.41	81
Ventromedial prefrontal cortex	L	-6	50	-20	5.96	65
	R	9	38	-8	5.19	56
Caudate	L	-9	14	-11	5.32	34
Lingual cortex	R	6	-73	-5	-5.47	34
Read > Narrowcast						
Angular gyrus	R	30	-79	34	7.65	291
	L	-39	-49	61	5.59	74
Fusiform cortex	L	-36	-52	-14	5.88	147
Medial prefrontal cortex	L	-27	47	28	7.00	75
	R	18	59	28	6.76	70
Cerebellum	R	12	-43	-44	5.58	50
	L	-12	-76	-20	5.69	47
	L	-33	-61	-26	4.78	45
Precuneus	R	6	-64	58	4.53	47
Precentral gyrus	L	-48	-7	28	4.39	32
Lingual cortex	R	12	-70	10	-7.18	51

Note: negative *t* values mean that encoding consistency increased in broadcast or narrowcast condition

Individualized encoding moderated by social network position

Having found that thinking about sharing affected encoding consistency, such that a constellation of brain regions – fusiform cortex, MPFC, vmPFC, PCC and precuneus – had higher encoding consistency across individuals under the control condition (read) and more individualized neural patterns under the sharing conditions (broadcast and narrowcast), we pooled these regions together (i.e., union of read>narrowcast and read>broadcast, i.e., blue and yellow regions denoted in Figure 4 right panel; 2134 voxels in total), and studied the role of social network position in individualized encoding under the sharing conditions. Compared to the read condition, neural patterns were more dissimilar in these brain regions under the broadcast and narrowcast conditions, based on same-article non-parametric test (Figure 5A). That confirms that participants had more idiosyncratic neural encodings in these brain regions when thinking about sharing.

We next conducted an IS-RSA analysis to see whether participants with higher ego-betweenness centrality score (i.e., more likely to be an information gatekeeper in real life) produced more distinct neural patterns compared to others. We therefore examined the mean correlations (averaged over article abstracts) between neural-based dissimilarity matrices and social network-based distinctiveness matrices under the three conditions, and estimated the statistical significance of each correlation with the null distributions derived from permutations (Figure 5B): .005 for read (empirical p value = .429), .021 for narrowcast (p = .182) and .040 for broadcast (p = .042) respectively. The positive correlation in the broadcast condition means that (a) two participants with high ego-betweenness centrality produced more distinct neural encodings between them; and (b) two participants with low ego-betweenness centrality produced most similar encodings. The results suggests a selective sensitivity of the ego-betweenness centrality measure under the broadcast condition. In other words, participants with higher ego-betweenness centrality produced more individualized neural encodings under the broadcast condition, but not in the narrowcast and read conditions.

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We examined whether ego-betweenness centrality also affected self-reported ratings (i.e., how much the participants liked to read for themselves, share with their friends, or share on their Facebook feed), and whether that in turn led to individualized neural encodings. In a supplementary analysis (S6), we found that participants with high ego-betweenness centrality tended to agree more on the intention to share with friends, despite showing higher variability in the neural encoding of the articles. We also found that participants who rated similar reading intentions had more similar neural patterns (supplementary analysis S7), while no significant relationships were observed in the broadcast and narrowcast conditions. These supplementary analyses suggest that it is unlikely the effect of ego-betweenness centrality on individualized encoding was driven by differences in the participants' preferences for the different article abstracts.

Discussion

Sharing is an inherently social behaviour, whether it is for coordination (Balliet 2010) or for bonding (Cohen 2004). In everyday life, people take on the role of a gatekeeper by thinking about whether to share information or not. Building on prior work showing that people encode complex information with common neural patterns (Hasson et al. 2012; Honey et al. 2012; Zadbood et al. 2017), we examine whether taking on the gatekeeper role changes the encoding process, and whether people in different social network positions do this to different degrees.

Our findings provide evidence that people tune their brain responses as they take on the gatekeeper role for others. We show that participants had more individualized neural responses when thinking about whether to share information with others, especially when the intended audience was a specific other person (narrowcast). Furthermore, when thinking about whether to share the information with their broader social network (broadcast), participants with high ego-betweenness centrality (i.e., with greater capacity for information brokerage in their real-world social network) displayed more individualized neural encoding. Thus, individuals who occupy social network positions that are more likely to involve directing information flow between otherwise unconnected social groups show a higher sensitivity to this gatekeeper role. Taken together, our results highlight the ways that the brain processes incoming information differently as a person toggles their roles between receiver and gatekeeper.

Neural encoding of information in higher-order regions

Consistent with past literature, participants exposed to the same information showed similar neural patterns, both within brain regions involved in perceptual and language processing as well as higher-order regions of the default mode network involving self and social cognition. Extant studies, which observed encoding consistency within higher-order regions, had participants passively consume narrative-rich and emotionally-laden materials, such as music, movies, and spoken stories (Hasson 2004; Hasson et al. 2008; Regev et al. 2013; Chen et al. 2017; Yeshurun et al. 2017). Here we use fact-based news articles about health, and still show significant encoding consistency within these high-order regions. What is the source of between-person neural pattern similarity that goes beyond the shared sensory and semantic features? One possibility is that these higher-order regions are implicated in the higher construal of the content, i.e., the formation of abstract concepts (Baetens et al. 2014). However, in a supplementary analysis of the content condition (S3), when participants were directed to attend to the more abstract features of the information (identifying the subject nature of the news articles), encoding consistency at PCC, bilateral angular gyrus and vmPFC *decreased* compared to the control condition (read) when they reflected upon their own (presumably more idiosyncratic) interest in the articles. This suggests that before the evaluation of personal interest in factual information, people need to relate content to concepts that go beyond the provided information itself. One possibility is that the neural processing of information evokes a set of societal norms, values and associations shared across individuals in a given cultural context, thereby representing a shared reality in which individuals then determine the relevance of the information according to their own idiosyncratic preferences.

Thinking about sharing alters neural processing of information

Next, we tested whether taking on the role of information gatekeeper would change the neural processing of incoming information. Past studies show that having common neural responses seems to be a hallmark of successful communication and a shared sense of reality within a social group. For example, previous studies found consistent neural patterns within individuals during memory encoding and retrieval (Xiao et al. 2017), between individuals during communication and reception (Stephens et al. 2010; Zadbood et al. 2017), and displaying similar neural patterns when different individuals perceive (Nguyen et al. 2019) and recall the same experience (Chen et al. 2017), with particularly similar responses between individuals who are friends (Parkinson et al. 2018). In the current study, we looked at neural encoding consistency while participants thought about sharing. On one hand, thinking about whether to share a piece of information might produce consistent neural patterns across individuals, if determining the relevance for others invokes the kind of uniform neural encoding evoked in determining the relevance for oneself. On the other hand, sharing considerations might increase individualized responses in how people approach the content, if they increasingly incorporate contextual information about their audience's needs, goals and preferences when thinking about whether to share.

In this study, we found evidence consistent with the latter – when considering whether to share (either narrowcast or broadcast), participants had more individualized brain responses within key regions of the default mode network involved in self and social processing; that is, encoding consistency decreased in bilateral fusiform cortex, MPFC, vmPFC, PCC, and precuneus. It should be noted that self-reported ratings for sharing, however, were more consistent among participants compared to ratings in the read condition.

This brain-behavior discrepancy – participants had idiosyncratic reading preference for news articles yet displayed more consistent neural processing – highlights value in measuring both neural encoding and subsequent subjective assessments, and suggests a fruitful set of further investigations to understand where and how the measures diverge.

These regions are broadly in line with past studies on social cognition involving activation (van Overwalle and Baetens 2009; Hervé et al. 2013) and pattern analyses (Thornton and Mitchell 2018). When thinking about sharing, individuals have the dual task of (a) understanding the content and (b) mentalizing about the intended audience's likely reaction to the content (in order to determine its relevance to them). In a similar study, Thornton and Mitchell (2017) asked participants to imagine various friends in different situations. They found both person- and situation-specific neural patterns in precuneus and PCC, suggesting that the integration of these two tasks might take place there. Here, we found that participants produced more individualized neural patterns in these regions when thinking about whether to share the content with others. This may suggest the involvement of idiosyncratic knowledge during information gatekeeping (such as the knowledge about one's intended audience, or consideration of what is likely to be of interest in one's network), which in turn affects how the information is represented in neural patterns.

It should be noted that a parallel whole-brain univariate analysis of activation comparing to the control condition (supplementary material S5) revealed *stronger* activation in similar areas (precuneus, MPFC and angular gyri) under the narrowcast condition, but not broadcast. This divergence of results between univariate and multivariate analyses highlights the value of studying spatial patterns of neuroimaging (Norman et al. 2006; Nastase et al. 2019) in order to shed light on complementary neural mechanisms.

The role of social network position on individualized neural encoding

Finally, we examined whether the tendency to individualize neural responses under the sharing conditions differed by participants, specifically with regard to their occupied positions in their real-life social networks that allow for more opportunities to be an information broker. The distinction between narrowcast (sharing with a specific person) and broadcast (disseminating to a group of people) conditions is important, as the audience size alters motivation and decision factors behind information gatekeeping (Barasch and Berger 2014; Berger 2014; Meshi et al. 2015). Moreover, the emergence of social media has afforded individuals unprecedented opportunities to engage in broadcasting, even though opportunities for information brokerage varies considerably among community members, depending on the features of their social networks. Previous studies have shown that people display varying sensitivity in the neural processing of social information depending on their own social network configuration. For example, Zerubavel et al (2015) found that in a task where participants were instructed to passively observe the faces of peers, individuals who were themselves more popular (as operationalized by in-degree centrality, or the number of times they were "liked" by others) within their social network showed greater vmPFC sensitivity in tracking the popularity of their peers. In a study investigating how individuals process opinions from peers (O'Donnell et al. 2017), participants with high ego-betweenness centrality in their social network showed greater activity in mentalizing regions when they received peer feedback that differed from their own, again indicating a higher sensitivity to social information.

Our analysis shows that the ego-betweenness centrality of a person's social network – an indicator of their capacity to broker information between different groups – moderated the extent of individualized neural processing when thinking about whether to broadcast the information (but not narrowcast). Specifically, while individuals recruited the same brain regions to consider whether to broadcast a piece of information or not, those who had more capacity to serve as information gatekeepers in their social networks displayed a greater sensitivity to the task, as evidenced by how distinct their neural encodings were compared to others. This finding suggests that, in addition to the processing of social information (e.g., seeing faces of peers or receiving feedback from them), individual differences in a person's social network position also affect their sensitivity to the processing of factual information solely in the anticipation of sharing.

Limitations

It should be noted that while the task was intended to capture the act of information sharing and gatekeeping during fMRI scanning, and despite the fact that participants acted on their in-scanner preferences with actual reading and sharing at the end of the task, it is possible the observed neural effects could be attributed to other psychological processes. For example, mentioning the presence of potential others might evoke the audience effect (Fridlund 1991; Finger et al. 2006; Dumontheil et al. 2016), i.e., individuals behave differently when told others are watching. Another possibility is that the observed neural effect could be attributed to mentalizing more about others in the sharing condition (Thornton and Mitchell 2017, 2018), without the subsequent gatekeeping decisions. Future studies are needed to directly test this idea, for example by explicitly comparing participants who are told to mentalize others' reactions towards a piece of information (would my friends like it?) and participants who are told to consider whether to actually share the same information with others (would I share it with my friends?).

Secondly, it would be valuable to compare in a within-subject fashion how neural encodings might change depending on the condition. However, the task design was that each participant encountered an article once only, in one of the four conditions, so no participant saw the same article more than once. (This was also designed to avoid memory effects in multiple exposures.) Thus, it is not possible to compare a participant's neural patterns of the same article under different conditions. Nonetheless, a future study with multiple scanning sessions might be able to investigate within-subject comparisons while keeping the memory effect minimal.

Finally, in the supplementary analyses on self-reported ratings on the news articles, we found more rating divergence in the read condition (compared to the sharing conditions), whereas we found more neural divergence in the sharing conditions (compared to the read condition). This is consistent with the idea that people differentiate their own preferences and attributes more than others', even if the neural processes employed to do so are similar across individuals. The exact relationship between information processing under different conditions and its subsequent valuation in the brain, as well as relationship to subsequent preferences, requires more research.

Conclusion

In summary, we extend the current literature on neural encoding of information by showing that thinking about sharing alters neural encoding of information, and that this effect is stronger for those whose real-life social network positions afford greater capacity for information gatekeeping. With neural pattern analysis, this study reveals how gatekeeping shapes our brain's processing of incoming information.

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Figure 1. Illustrative diagram adapted from Baek et al, 2020, showing a social network where the nodes represent individuals and the edges represent connections between them. For the three persons – A, B, and C – occupying different positions in the network, their ego-betweenness centrality are varying in the order of A > B > C, since A connects most individuals in the network that are otherwise disconnected. In other words, A has the largest capacity of brokering information as a gatekeeper.

Figure 2. Task and analysis overview

Figure 3. Brain regions showing significant inter-subject encoding consistency in each condition ($p < .05$ FDR adjusted)

Figure 4. Brain regions showing significantly different encoding consistency under the sharing conditions compared to the control ($p < .05$ FDR adjusted)

Figure 5. (A) Neural-based dissimilarity in the selected brain regions across conditions. Comparisons are based on same-article, paired, non-parametric Wilcoxon test. (B) Mean correlation (denoted in black squares) between neural-based dissimilarity matrix and social network-based distinctiveness matrix under each condition, showing the selective sensitivity of ego-betweenness centrality measure under the broadcast condition. In other words, participants with higher ego-betweenness centrality produced more individualized neural encodings under the broadcast condition. Note: Shaded areas are violin plots of the null distributions of 10,000 permutations.