The Neuroscience of Persuasion and Information Propagation: Key Role of the Mentalizing System

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Abstract

What are the psychological and neural processes that support successful information propagation between communicators and receivers? The current chapter draws upon recent contributions from neuroscience to focus on the role of mentalizing, or considering other people's mental states, as one factor that leads to successful social influence and information propagation. Across different contexts, messages that lead to information propagation are distinguished by higher levels of mentalizing in both communicators and receivers of influence. The chapter also highlights developmental, cultural, and social network factors that moderate the relationship between mentalizing and influence.

Keywords: ...

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What are the psychological drivers that lead communicators to share information with and influence others? How do receivers process shared content that leads to successful information propagation? How do contextual factors moderate the mechanisms at play? In this chapter, we focus on mentalizing (i.e., considering the mental states of other people). Among many processes involved in social influence, mentalizing is one key input to decision making in communicators and receivers of influence (Cascio, O'Donnell, Bayer, Tinney, & Falk, 2015; Baek, Scholz, O'Donnell, & Falk, 2017; Welborn et al., 2015; van Hoorn, van Dijk, Meuwese, Rieffe & Crone, E. A., 2016), and it is theorized to play a central role in whether efforts to persuade and influence are successful (Cascio et al., 2015; Falk, Morelli, Welborn, Dambacher, & Lieberman, 2013; Welborn et al., 2015); messages that lead to successful propagation of ideas are distinguished by higher levels of mentalizing in both the communicator and receiver. We also highlight key contextual factors, including development, culture, and social networks, that moderate the association between mentalizing and influence, and conclude by highlighting future research opportunities in these domains.

What is Metalizing?

Mentalizing, defined as considering the mental states of others, plays a critical role in the human social experience (Adolphs, 2009; C. D. Frith & Frith, 2006). Without the ability to interpret and understand the attitudes, beliefs, and feelings of others that precede their actions, we would be lost in navigating the social world. The ability to mentalize is not only necessary to explicitly understand that others might hold different beliefs than we do (e.g., "My brother never saw me eat the last banana, so he might look for it"), but also to navigate complex social

situations through implicit cues (e.g., “Susie feels embarrassed after falling, and she might feel better if I reassure her”). Indeed, deficits in the ability to mentalize characterize psychosocial disorders including autism (Chung, Barch, & Strube, 2014), schizophrenia (Chung et al., 2014), and borderline personality disorder (Bateman & Fonagy, 2012).

Behavioral tasks are often used to test and measure mentalizing abilities of individuals. In one classic task, participants are tested in their ability to understand that others might hold an incorrect belief about the state of the world (Wimmer & Perner, 1983). In this false-belief task, participants read through a narrative such as the following: *Mark puts his toy inside his drawer and leaves the room. Meanwhile, Katy moves the toy to under the bed. Upon returning, where will Mark look for the toy?* In order to identify that Mark will look for the toy in the drawer, participants must be able to understand that Mark holds a belief about the location of the toy that is both incorrect and different from their own. This simple false-belief task has mostly been utilized to test mentalizing abilities in children, and more complex versions of the task have been adapted for adults that test the ability to understand more complex mental states and intentions (Happé, 1994; Wang & Su, 2013). Findings from such tasks shed light on developmental stages in mentalizing ability (U. Frith & Frith, 2003) and mentalizing deficits that characterize psychosocial disorders (Chung et al., 2014).

Neuroscience evidence has also identified neural systems that support mentalizing. In particular, portions of the medial prefrontal cortex (MPFC), particularly subregions in the middle and dorsomedial prefrontal cortex (MMPFC, DMPFC), as well as bilateral temporoparietal junction (TPJ), precuneus (PC/PCC), superior temporal sulcus (STS), and temporal poles are robustly engaged when people are actively considering the mental state of others, as identified in a meta-analytic map retrieved from Neurosynth (See Figure 1; See also, Dufour et al., 2013; C.

D. Frith & Frith, 2006). These regions involved in mentalizing overlap substantially with the brain's 'default-mode network' (i.e., regions of the brain active when participants of fMRI studies are not given a specific task), which is thought to generally support continuous processing of the environment in order to anticipate future events and enact appropriate behavioral trajectories, including efficient social judgments (Meyer, Davachi, Ochsner, & Lieberman, 2018). Although we review evidence from prior work that interprets activity in these regions as involved in mentalizing, the subregions that form the mentalizing network have also been implicated in other cognitions as part of the default-mode network, including reinforcement learning and goal-directed action (for a review, see: Raichle, 2015). Thus, mentalizing may be one specific type of the broader class of processes that are implicated in interpreting the environment and predicting future events to optimize behavioral response.

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With these caveats in mind (see Poldrack, 2011 for a review), neuroimaging allows for activity in the mentalizing system to be tracked in 'real-time' as individuals are actively processing stimuli, and thereby does not rely on individuals' ability to introspect on their thought processes. This is an advantage because mentalizing is often an implicit, instinctive process (U. Frith & Frith, 2003); in many social situations, people understand others' perspectives without intentional effort. The ability to assess these processes implicitly has enabled researchers to study the role of mentalizing in non-verbal communication (Kampe, Frith, & Frith, 2003), predicting behavioral outcomes ranging from susceptibility to peer influence (Cascio et al., 2015; Welborn et al., 2015), and encoding of successful ideas (Falk et al., 2013; Falk, O'Donnell, & Lieberman, 2012).

The current chapter focuses on how mentalizing contributes to decision-making in one aspect of human communication—social influence. We highlight recent findings from neuroscience that suggest that mentalizing contributes to decision-making processes that determine whether specific forms of social influence, such as persuasion and information propagation, are successful. Findings highlight that neural measures of mentalizing activity can be used to predict behavioral outcomes of interest, such as the success of social influence at the message, individual person, and population-levels.

The Involvement of Mentalizing in Persuasion, Social influence, and Information Propagation

Depending on the context, people can be either communicators or receivers of social influence, influencing or being influenced by others to change behaviors or preferences. Social influence can take numerous forms such as active persuasion attempts (e.g., ordering a salad because your friend convinced you to eat healthy) or more subtle influences on behavior (e.g., ordering a salad because you saw your friend eat healthy). In order for social influence to successfully take place, a message of some form (e.g., verbal, written, non-verbal) from a communicator must be successfully transmitted to the receiver. We highlight neuroscientific evidence that implicates mentalizing in two types of social influence—persuasion (i.e., explicit attempts to influence others) and information propagation (i.e., transfer of information between communicators and receivers).

Mentalizing in Communicators Increases Success of Social Influence

Mentalizing is associated with communicators' decisions to share information with others, and predicts whether such shared information leads to success in persuading and

influencing others (for reviews, see: Baek & Falk, 2018; Falk & Scholz, 2018). This may be in part because to effectively share information and influence others, communicators should consider the audience of their message, taking into account the receiver's attitude, knowledge, and preferences. Mentalizing is one example of the broader human ability to learn about the world around us, predict future events, and reinforce previous knowledge. Specifically, mentalizing allows a communicator to estimate how a message might be received by the receiver and, thus, what the probable social consequences of a given interaction will be (Berger, 2014). For instance, sharing information may lead to social rewards through opportunities to bond and obtain others' approval; on the other hand, it can lead to social punishment, for instance when a message is ridiculed by the receiver. Indeed, one account suggests that communicators adjust their strategies based on the characteristics of the receivers of their messages (Barasch & Berger, 2014; Scholz, Baek, O'Donnell & Falk, 2019).

Further, communicators recruit portions of the mentalizing network (i.e., sub-regions ofMPFC, PC, bilateral TPJ, and right STS defined based on a meta-analysis of 'mentalizing') when making decisions about sharing news articles compared to decisions to read the articles themselves or considering the content (Baek, et al., 2017). Activity in mentalizing regions also positively scale with communicators' self-reported intentions to share the news articles; this suggests that the mentalizing system is recruited not only when communicators think about whether to share, but also that increased mentalizing is associated with increased sharing intention (Baek et al., 2017). This predictive power of activity in the mentalizing system extends beyond individual study participants to population-level behavior. Brain activity in a small number of participants as they considered news articles was associated with how often each article was actually shared by larger groups of people in real life (Scholz, Baek, O'Donnell &

Falk, 2017). Specifically, across two studies, brain activity in mentalizing regions showed an indirect effect on population-level sharing of the articles that was mediated through neural value-related activity; this suggests that articles that encouraged mentalizing activity also increased value-related brain activity in communicators (Scholz et al., 2017). In this way, mentalizing activity is associated with increased likelihood that information is shared.

Individual Differences in Mentalizing are Associated with Successful Influence

Given that a communicator decides to share information, what sets apart successful communicators from their less successful counterparts? Communicators who show heightened consideration of the thoughts of their receivers can be more likely to be successful (for a review, see: Baek & Falk, 2018). Successful communicators are more likely to be socially flexible, with higher levels of self-monitoring, or the tendency to adjust their behavior based on interpersonal cues (Baek & Falk, 2018; Snyder, 1974). Further, successful communicators are characterized by environmental contexts that encourage greater ability to take the perspective of others, such as occupying social network positions that span many structural holes, meaning that more of their contacts rely on them to communicate with one another (Burt, 2004). Within the brain, salespeople who self-reported higher levels of mentalizing also showed increased recruitment of brain regions associated with mentalizing, including the TPJ and MPFC, and were more successful at adapting their strategies to meet customers' needs (Dietvorst et al., 2009). Similarly, non-professional participants who were more successful at convincing others to accept or reject TV show ideas based on their own preferences showed greater recruitment of the TPJ during initial exposure to the ideas (Falk et al., 2013). Thus, the level of mentalizing in communicators is one indication of the likelihood that information is shared, as well as whether the shared information leads to successful social influence.

Mentalizing in Receivers Leads to Increased Likelihood of Social Influence

Receivers of social influence also engage in mentalizing, and consideration of others' perspectives can increase a receiver's susceptibility to influence and persuasion. Social belonging and the maintenance of social relationships are fundamental human needs (Baumeister & Leary, 1995). As such, the value of complying with a message is influenced by social norms and by the potential social rewards of compliance (Cialdini & Goldstein, 2004). For instance, agreeing with a message shared by a friend can lead to positive relational outcomes, increasing the value of compliance (Berger, 2014). Likewise, acting to be in compliance with a perceived social norm can lead to a feeling of belongingness (Cialdini & Goldstein, 2004). In order for receivers to find conforming to social influence valuable, it is helpful to understand others' mindsets, perspectives, and values. For instance, receivers may be more likely to find adopting an idea valuable if they are able to understand the perspectives of the communicators. The use of social norms in persuasive communication increases the likelihood of an individual shifting their behavior or attitude toward the norm (Cialdini et al., 2006; Goldstein, Cialdini, & Griskevicius, 2008). For instance, hotel room signs promoting reuse of towels that invoke social norms and group belongingness (e.g., "majority of guests reuse their towels") were more successful at gaining compliance from guests compared to signs solely focusing on environmental appeals (e.g., "you can show your respect for nature and help save the environment by reusing your towels during your stay"; Goldstein et al., 2008). Although not explicitly measured, invoking a social norm likely activated mentalizing in the receivers of the influence as they considered the behavior of others in calculating the value of complying.

Neural evidence provides additional insights to this theory. Text-based persuasive messages that invoked higher activity in regions of the brain implicated in mentalizing (DMPFC,

posterior STS, temporal pole) were rated to be higher in persuasiveness across two cultural contexts (i.e., American and Korean participants) and message modalities (i.e., text and video messages; Falk et al., 2010). Thus, messages that elicit thoughts of social implications, even if not explicitly from a social source, may be more likely to lead to successful influence.

The mentalizing system is also associated with successful influence during dyadic interactions. Receivers engage the mentalizing system when considering the opinions of others, and this activity is predictive of whether the message will lead to successful social influence (Cascio, et al., 2015; Welborn et al., 2015). Increased activity in the mentalizing system while receivers were reading and considering peer recommendations of mobile game apps was associated with increased likelihood that receivers changed their own recommendations toward that of their peers, leading to successful propagation of recommendations (Baek et al., in submission). Likewise, in adolescents, greater neural activity in regions of the mentalizing system (DMPFC, rTPJ, left temporal pole) was associated with increased likelihood that adolescent participants shifted their preference of art based on social feedback from both their peers and parents (Welborn et al., 2015). In this way, mentalizing activity may be one signal that contributes to whether receivers are socially influenced.

Given that mentalizing is associated with increased likelihood that a receiver will be successfully influenced, can it also distinguish individual differences in susceptibility to social influence? Indeed, individuals more susceptible to social influence (i.e., more likely to change their own opinion to match that of their peers) also showed greater recruitment of the brain's mentalizing system while they were exposed to the opinions of others (Cascio et al., 2015; Welborn et al., 2015). Thus, the extent to which a receiver considers the social implications of incorporating a communicator's opinion may be a key input to an overall value calculation that

determines whether the receiver will be socially influenced (for a review, see: Falk & Scholz, 2018).

Mentalizing Supports Information Transfer Between Communicators and Receivers

Evidence reviewed thus far has highlighted the role of mentalizing in both communicators and receivers of messages, demonstrating that social relevance is a key consideration when a communicator determines the value of sharing information with others, and when a receiver determines the value of incorporating such shared information. Further, the extent to which communicators and receivers consider social relevance contributes to whether a message from a communicator will lead to successful propagation in the receiver. In this section, we highlight evidence suggesting that these processes in communicators and receivers do not exist in isolation but interact with one another to lead to successful communication.

Communicating dyads show behavioral and biological coupling during interactions, coordinating with their partner in the use of language (e.g., linguistic style matching, word matching) (Gonzales, Hancock, & Pennebaker, 2010), non-verbal signals (e.g., physical gestures, vocalizations, eye movements) (Cappella, 1997; Richardson & Dale, 2005), and brain activity (e.g., similar time course of neural activations; Stephens, Silbert, & Hasson, 2010). Higher levels of coupling and coordination between communicating dyads across these measures predict the success of various interpersonal outcomes, including conversational satisfaction (Cappella, 1997), discourse comprehension (Richardson & Dale, 2005), and group performance (Gonzales et al., 2010). Indeed, the large literature on behavioral mimicry (see also the chapter from Bente & Novotny, this volume) suggests that this human tendency to match or mimic one's interaction partner occurs automatically without conscious effort, and has evolutionary advantages in

supporting the need of humans to socially affiliate with one another for survival (Lakin & Chartrand, 2003; Lakin, Jefferis, Cheng, & Chartrand, 2003).

Neuroscience evidence corroborates and extends such findings, showing that the human brain has not only evolved systems dedicated to support social coordination for individuals in isolation, but also that the brains of communicating dyads display coupling that supports coordination during social interactions (Schippers, Roebroeck, Renken, Nanetti, & Keysers, 2010; Stephens et al., 2010). In particular, neural coupling has not only been observed in low-level sensory regions of the brain but also in high-level cognitive systems including those that support mentalizing (Schippers et al., 2010; Scholz et al., in submission; Stephens et al., 2010), with increased coupling in these regions predicting communication success (Scholz, et al., in submission; Stephens et al., 2010).

Brain activity while a set of communicators told real-life stories was associated with brain activity in receivers who listened to these stories; specifically, significant temporally-coupled activity was found in brain regions within the mentalizing system (dorsolateral prefrontal cortex, precuenus, MPFC, TPJ), as well as in low-level auditory regions and mirror neuron system (ventral premotor area and intraparietal area; Stephens et al., 2010). Further, greater neural coupling in these regions between communicators and receivers was associated with higher receiver scores on story comprehension, suggesting that biological coordination between communicating dyads may be a critical component of successful communication (Stephens et al., 2010). Similarly, significant neural coupling was found in brain regions previously implicated in mentalizing (bilateral TPJ, right superior temporal lobe, PC and portions of the MPFC), as well as in self-related processing (posterior cingulate cortex, MPFC), and subjective valuation (ventral striatum, VMPFC) while communicators were considering news

articles to share, and receivers who saw the written shared messages (Scholz, et al., in submission). In addition, neural coupling in all three brain systems was associated with coupling in self-reported perceived benefits of sharing in the communicator-receiver pairs (Scholz et al., in submission), further supporting the theory that neural coupling in the mentalizing system may contribute to the propagation of ideas in a communicating dyad. Coupling also occurs during non-verbal social interactions. Communicators and receivers in a non-verbal game of charades showed significant neural coupling in VMPFC and the putative mirror neuron system (Schippers et al., 2010).

Combined, findings highlight that the brain's mentalizing system supports the transfer of ideas between communicators and receivers, with neural coupling in systems relevant to mentalizing robustly implicated across different forms of communication, including verbal, non-verbal, and short text-based interactions on social media. This coupling in the brain's mentalizing system may be necessary to promote the successful propagation of ideas through facilitating mutual understanding of the perspectives, thoughts, and emotions of others, and increasing the value of social coordination. This coordination in the brain's mentalizing system may reflect communicators transferring the social value of information to their receivers through their messages, providing cues to which information may be socially valued (Scholz et al., 2017). This transfer may rely on the communicator and receiver sharing a social context in which a collective sense of identity, norms, and values exists.

Moderators of Mentalizing and Future Directions

With few exceptions, extant studies linking mentalizing activity with successful social influence, persuasion, and message propagation have focused on highly educated young adult populations in the West, primarily observing individuals (and their brains) removed from their

environmental and social contexts. However, the effect of mentalizing on social influence may be moderated by various contextual variables. For instance, social norms vary across populations (e.g., cultures that emphasize interdependence), and the same content may be processed differently depending on how it is framed (e.g., when described in more vs. less social terms). Likewise, a vast majority of studies utilizing neuroscience have studied brain systems in isolation, extracting mean activation using a region-of-interest approach.

Growing bodies of research in recent years have begun to address this gap, suggesting that incorporating contextual variables in conjunction with neural networks can further our understanding of how the brain interacts dynamically with its environment. These new methods afford opportunities for increased precision in understanding brain activity beyond mean activation in a large brain system, by measuring patterns of brain activity and interactions between and within brain systems. In the present section, we highlight key developments in the study of social influence, and communication processes more broadly, that have incorporated these contextual considerations. Given these promising findings, we suggest that new research in each of these areas may be fruitful in moving the field forward.

Message-Level and Contextual Considerations

Recent findings suggest that certain message-level features may increase the likelihood of a message being shared, such as novelty, perceived utility, and emotionality (Berger & Milkman, 2012; Kim, 2015). Less is known, however, about how these message-level features may moderate the relationship between brain activity and successful propagation of ideas as explored in previous sections, or whether mentalizing is the key mediating factor between these message variables and their effects. In one recent study (Baek et al., in submission), participants first saw generic descriptions of numerous mobile game apps and provided initial ratings on their

likelihood to recommend each mobile game app. Next, in the fMRI scanner, participants read peer recommendations about the same mobile game apps and had the opportunity to update their initial ratings after incorporating this social feedback. Corroborating previous findings (Cascio, et al., 2015), greater mentalizing activity while participants considered social recommendations was associated with successful recommendation propagation, in that participants shifted their initial ratings toward that of the peer recommender. In this case, the relationship between mentalizing and opinion change was particularly strong when people responded to negative recommendations. One possibility is that understanding the mental states of others is particularly critical in situations involving negative feedback. More generally, certain message-level characteristics may lead to a greater consideration of social implications that drive social influence, and future studies are needed to explore these interactions further.

Development

The mentalizing system undergoes changes throughout the course of human development, and processes underlying social influence are also differently implicated based on a person's age. Research in this area may be particularly important given that the mentalizing system develops significantly over childhood and adolescence, with implicit abilities to take others' mental states developing at around 18 months of age and explicit abilities emerging between 4 and 6 years of age (U. Frith & Frith, 2003). The mentalizing system continues to change throughout adolescence (Blakemore, 2008; Harenski, Harenski, Shane, & Kiehl, 2012) and into older adulthood (Harenski et al., 2012; Moran, Jolly, & Mitchell, 2012; Wang & Su, 2013). Regions of the mentalizing system undergo structural and functional changes during adolescence (Blakemore, 2008; Steinberg, 2008), and one account suggests that this leads to heightened sensitivity to social cues and rewards during this time (Blakemore, 2008; Blakemore

& Mills, 2014). Corroborating this theory, adolescents showed stronger functional connectivity within regions of the mentalizing system than young adults during a task that required processing of social emotions (Burnett & Blakemore, 2009). Further, older adulthood is marked with decreased functionality of the brain's mentalizing system (Moran et al., 2012). Older adults showed behavioral impairments in social judgment tasks, and these deficits were reflected by decreased activity in the brain's mentalizing system during social cognition tasks (Moran et al., 2012). Combined, findings suggest that age should be carefully considered in studying the processes involved in social influence, especially given that extant studies have primarily recruited young adult participants.

Recent research has begun to address some of these considerations, with researchers investigating the neural signatures of social influence in adolescents (Cascio et al., 2015; Falk et al., 2014; Peake, et al., 2013; van Hoorn, et al., 2016; Welborn et al., 2015). Adolescent male participants who showed greater engagement in regions of the mentalizing system (DMPFC, rTPJ, PCC) while being socially excluded were also more likely to conform to social influence, showing an increased likelihood of driving more risky when paired with a peer passenger who encouraged risky-taking in a simulated driving task (Falk et al., 2014). This suggests that although similar mechanisms may be in play in adolescents and adults during social influence, additional research investigating how such effects may be moderated by age (as well as contexts such as during exclusion) may be fruitful.

Cultural and Environmental Considerations

A majority of research investigating social influence, persuasion, and propagation has focused on Western samples. Recent evidence, however, suggests the importance of considering cultural variables that may moderate these effects (Tompson, Lieberman, & Falk, 2015). For one,

persuasive messages promoting healthy behavior that align with individuals' cultural and social norms are more effective (Kalichman & Coley, 1995; Uskul & Oyserman, 2010). European Americans were more likely to find messages on health risks of caffeine more persuasive after reading messages emphasizing individualism, whereas Asian Americans were more likely to find the messages persuasive after reading messages emphasizing relational obligations (Uskul & Oyserman, 2010). Further, a meta-analysis comparing neural activity in East Asians and Westerners in social and non-social processes reported that East Asians show increased recruitment of brain systems associated with mentalizing (DMPFC, TPJ) compared to Westerners during social compared to non-social processing (Han & Ma, 2014).

Neural patterns associated with social influence and persuasion might also be moderated by environmental variables, such as socioeconomic status (Cascio, O'Donnell, Simons-Morton, Bingham, & Falk, 2017). Critically, socioeconomic status moderated the effects of mentalizing activity during social exclusion on subsequent susceptibility to social influence, such that increased mentalizing activity during social exclusion was associated with less likelihood of conformity to social influence in adolescents higher in socioeconomic status (Cascio et al., 2017). Combined, these studies emphasize the importance of considering cultural and environmental contexts in the study of social influence in the brain.

Dynamic Brain and Social Networks

A growing body of research has begun to leverage recent developments in the analysis of social networks and brain network dynamics to understand how an individual's real-life social network position might influence brain patterns associated with social influence, persuasion, and information propagation. For instance, adolescents who hold positions of brokerage in their online social networks (i.e., higher ego-betweenness centrality, meaning that individuals have

more opportunities to 'broker' information between others who are otherwise not directly connected to one another) also showed greater mentalizing activity (MPFC, PC, TPJ) when making recommendations about products to their peers (O'Donnell, Bayer, Cascio, & Falk, 2017). Indeed, the human brain is dynamically associated with an individual's social network, and the brain has mechanisms to track and update social network positions of others (Parkinson, Kleinbaum, & Wheatley, 2017; Zerubavel, Bearman, Weber, & Ochsner, 2015; for a review, see Falk & Bassett, 2017).

Highlighting the value of incorporating real-life social networks, brain dynamics, and social context, adolescents who had real-life social networks that were less dense (i.e., had less friends who were connected with one another) also showed greater changes in functional connectivity within the mentalizing system when being socially excluded (Schmälzle et al., 2017). Further, adolescents who showed greater global functional connectivity within the brain's mentalizing system during social exclusion were also more susceptible to peer influence in a driving simulation task (Wasylyshyn et al., 2018). Thus, susceptibility to social influence may not only involve mean engagement of the brain's mentalizing system (Falk et al., 2014), but also functional coordination within the system. Accordingly, incorporating variables from real-life social networks and dynamic neural patterns are promising avenues to uncover variables that lead to social influence.

Conclusion

Extant research highlights mentalizing as one signal that contributes to decision-making that lead to successful social influence, persuasion, and information propagation. Both communicators and receivers of social influence engage in mentalizing as they consider the social implications of their actions, and the degree to which they engage in these processes are

predictive of whether attempts at social influence, persuasion, and message propagation will be successful. Recent research has also begun to uncover contextual variables that may moderate the relationship between mentalizing and social influence. Future research that explores these avenues may be productive in understanding the variables that lead to social influence.

References

Adolphs, R. (2009). The social brain: neural basis of social knowledge. *Annual Review of Psychology*, *60*, 693–716.

Baek, E.C., Scholz, C., O'Donnell, M.B., & Falk, E.B. (in submission). The Involvement of mentalizing and valuation brain networks in social influence on message receivers.

Baek, E. C., & Falk, E. B. (2018). Persuasion and influence: what makes a successful persuader? *Current Opinion in Psychology*, *24*(1), 53-57.

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.

Bateman, A. W., & Fonagy, P. (Eds.). (2012). *Handbook of mentalizing in mental health practice*. Arlington, VA: American Psychiatric Publishing, Inc.

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.

Berger, J. (2014). Word of mouth and interpersonal communication: A review and directions for future research. *Journal of Consumer Psychology*, *24*(4), 586–607.

Berger, J., & Milkman, K. L. (2012). What makes online content viral? *Journal of Marketing Research*, *49*(2), 192–205.

Blakemore, S. J. (2008). The social brain in adolescence. *Nature Reviews Neuroscience, 9*(4), 267-277.

Blakemore, S. J., & Mills, K. L. (2014). Is adolescence a sensitive period for sociocultural processing? *Annual Review of Psychology*, *65*(1), 187–207.

Burnett, S., & Blakemore, S. J. (2009). Functional connectivity during a social emotion task in

adolescents and in adults. *European Journal of Neuroscience*, *29*(6), 1294–1301.

Cappella, J. N. (1997). Behavioral and judged coordination in adult informal social interactions: Vocal and kinesic indicators. *Journal of Personality and Social Psychology*, *72*(1), 119–131.

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.

Cascio, C. N., O'Donnell, M. B., Simons-Morton, B. G., Bingham, C. R., & Falk, E. B. (2017). Cultural context moderates neural pathways to social influence. *Culture and Brain*, *5*(1), 50–70.

Chung, Y. S., Barch, D., & Strube, M. (2014). A meta-analysis of mentalizing impairments in adults with schizophrenia and autism spectrum disorder. *Schizophrenia Bulletin*, *40*(3), 602–616.

Cialdini, R. B., Demaine, L. J., Sagarin, B. J., Barrett, D. W., Rhoads, K., & Winter, P. L. (2006). Managing social norms for persuasive impact. *Social Influence*, *1*(1), 3–15.

Cialdini, R. B., & Goldstein, N. J. (2004). Social influence: compliance and conformity. *Annual Review of Psychology*, *55*, 591–621.

Dmochowski, J. P., Bezdek, M. A., Abelson, B. P., Johnson, J. S., Schumacher, E. H., & Parra, L. C. (2014). Audience preferences are predicted by temporal reliability of neural processing. *Nature Communications*, *5*, 1–9.

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): e75468.

Falk, E. B., & Bassett, D. S. (2017). Brain and Social Networks: Fundamental Building Blocks of Human Experience. *Trends in Cognitive Sciences*, *21*(9), 674–690.

Falk, E. B., Cascio, C. N., Brook O'Donnell, M., Carp, J., Tinney, F. J., Bingham, C. R., … Simons-Morton, B. G. (2014). Neural responses to exclusion predict susceptibility to social influence. *The Journal of Adolescent Health : Official Publication of the Society for Adolescent Medicine*, *54*(5 Suppl), S22-31.

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.

Falk, E. B., O'Donnell, M., & Lieberman, M. (2012). Getting the word out: Neural correlates of enthusiastic message propagation. *Frontiers in Human Neuroscience*, *6*, 313.

Falk, E. B., Rameson, L., Berkman, E. T., Liao, B., Kang, Y., Inagaki, T. K., & Lieberman, M. D. (2010). The neural correlates of persuasion: a common network across cultures and media. *Journal of Cognitive Neuroscience*, *22*(11), 2447–2459.

Falk, E. B., & Scholz, C. (2018). Persuasion, influence and value: Perspectives from communication and social neuroscience. *Annual Review of Psychology*, *69,* 329-356.

Frith, C. D., & Frith, U. (2006). The neural basis of mentalizing. *Neuron*, *50*(4), 531–534.

Frith, U., & Frith, C. D. (2003). Development and neurophysiology of mentalizing. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *358*(1431), 459–473.

Goldstein, N. J., Cialdini, R. B., & Griskevicius, V. (2008). A room with a viewpoint: Using social norms to motivate environmental conservation in hotels. *Journal of Consumer Research*, *35*(3), 472–482.

Gonzales, A. L., Hancock, J. T., & Pennebaker, J. W. (2010). Language style matching as a predictor of social dynamics in small groups. *Communication Research*, *37*(1), 3–19.

Han, S., & Ma, Y. (2014). Cultural differences in human brain activity: A quantitative meta-analysis. *NeuroImage*, *99*, 293–300.

Happé, F. G. E. (1994). An advanced test of theory of mind: Understanding of story characters' thoughts and feelings by able autistic, mentally handicapped, and normal children and adults. *Journal of Autism and Developmental Disorders*, *24*(2), 129–154.

Harenski, C. L., Harenski, K. A., Shane, M. S., & Kiehl, K. A. (2012). Neural development of mentalizing in moral judgment from adolescence to adulthood. *Developmental Cognitive Neuroscience*, *2*(1), 162–173.

Kalichman, S. C., & Coley, B. (1995). Context framing to enhance HIV-antibody-testing messages targeted to African American women. *Health Psychology*, *14*(3), 247–254.

Kampe, K. K. W., Frith, C. D., & Frith, U. (2003). "Hey John": Signals conveying communicative intention toward the self activate brain regions associated with "mentalizing," regardless of modality. *The Journal of Neuroscience*, *23*(12), 5258–5263.

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.

Lakin, J. L., & Chartrand, T. L. (2003). Using nonconscious behavioral mimicry to create affiliation and rapport. *Psychological Science*, *14*(4), 334–339.

Lakin, J. L., Jefferis, V. E., Cheng, C. M., & Chartrand, T. L. (2003). The chameleon effect as social glue: Evidence for the evolutionary significance of nonconscious mimicry. *Journal of Nonverbal Behavior*, *27*(3), 145–161.

Meyer, M. L., Davachi, L., Ochsner, K. N., & Lieberman, M. D. (2018). Evidence that default

network connectivity during rest consolidates social information. *Cerebral Cortex*, *29*(5), 1910–1920.

Moran, J. M., Jolly, E., & Mitchell, J. P. (2012). Social-Cognitive deficits in normal aging. *Journal of Neuroscience*, *32*(16), 5553–5561.

O'Donnell, M. B., Bayer, J. B., Cascio, C. N., & Falk, E. B. (2017). Neural bases of recommendations differ according to social network structure. *Social Cognitive and Affective Neuroscience*, *12*(1), 61-69.

Parkinson, C., Kleinbaum, A. M., & Wheatley, T. (2017). Spontaneous neural encoding of social network position. *Nature Human Behaviour*, *1*(5), 0072.

Peake, S. J., Dishion, T. J., Stormshak, E. A., Moore, W. E., & Pfeifer, J. H. (2013). Risk-taking and social exclusion in adolescence: Neural mechanisms underlying peer influences on decision-making. *NeuroImage*, *82*(7), 23–34.

Poldrack, R. A. (2011). Inferring mental states from neuroimaging data: From reverse inference to large-scale decoding. *Neuron*, *72*(5), 692–697.

Raichle, M. E. (2015). The Brain's Default Mode Network. *Annual Review of Neuroscience*, *38*, 433–447.

Richardson, D. C., & Dale, R. (2005). Looking to understand: The coupling between speakers' and listeners' eye movements and its relationship to discourse comprehension. *Cognitive Science*, *29*(6), 1045–1060.

Schippers, M. B., Roebroeck, A., Renken, R., Nanetti, L., & Keysers, C. (2010). Mapping the information flow from one brain to another during gestural communication. *Proceedings of the National Academy of Sciences*, *107*(20), 9388–9393.

Schmälzle, R., Brook O'Donnell, M., Garcia, J. O., Cascio, C. N., Bayer, J., Bassett, D. S., …

Falk, E. B. (2017). Brain connectivity dynamics during social interaction reflect social network structure. *Proceedings of the National Academy of Sciences*, *114*(20), 5153-5158.

Schmälzle, R., Häcker, F. E. K., Honey, C. J., & Hasson, U. (2014). Engaged listeners: Shared neural processing of powerful political speeches. *Social Cognitive and Affective Neuroscience*, *10*(8), 1137–1143.

Scholz, C., Doré, B.P., Baek, E.C., O'Donnell, M.B., & Falk, E.B. (in submission). A neural propagation system: Neurocognitive and preference synchrony in information sharers and their receivers.

Scholz, C., Baek, E.C., O'Donnell, M.B. & Falk, E.B. (2019) Decision-making about broad- and narrowcasting: a neuroscientific perspective, Media Psychology, doi: 10.1080/15213269.2019.1572522

Scholz, C., Baek, E. C., O'Donnell, M. B., Kim, H. S., Cappella, J. N., & Falk, E. B. (2017). A neural model of valuation and information virality. *Proceedings of the National Academy of Sciences*, *114*(11), 2881-2886.

Snyder, M. (1974). Self-monitoring of expressive behavior. *Journal of Personality and Social Psychology*, *30*(4), 526–537.

Steinberg, L. (2008). A social neuroscience perspective on adolescent risk-taking. *Developmental Review*, *28*(1), 78–106.

Stephens, G. J., Silbert, L. J., & Hasson, U. (2010). Speaker-listener neural coupling underlies successful communication. *Proceedings of the National Academy of Sciences*, *107*(32), 14425–14430.

Tompson, S., Lieberman, M. D., & Falk, E. B. (2015). Grounding the neuroscience of behavior change in the sociocultural context. *Current Opinion in Behavioral Sciences*, *5*, 58–63.

Uskul, A. K., & Oyserman, D. (2010). When message-frame fits salient cultural-frame, messages feel more persuasive. *Psychology and Health*, *25*(3), 321–337.

Wang, Z., & Su, Y. (2013). Age-related differences in the performance of theory of mind in older adults: A dissociation of cognitive and affective components. *Psychology and Aging*, *28*(1), 284–291.

Wasylyshyn, N., Falk, B. H., Garcia, J. O., Cascio, C. N., O'Donnell, M. B., Bingham, C. R., … Falk, E. B. (2018). Global brain dynamics during social exclusion predict subsequent behavioral conformity. *Social Cognitive and Affective Neuroscience*, *13*(2), 182–191.

Welborn, B. L., Lieberman, M. D., Goldenberg, D., Fuligni, A. J., Galván, A., & Telzer, E. H. (2015). Neural mechanisms of social influence in adolescence. *Social Cognitive and Affective Neuroscience*, *11*(1), 100–109.

Wimmer, H., & Perner, J. (1983). Beliefs about beliefs: Representation and constraining function of wrong beliefs in young children's understanding of deception. *Cognition*, *13*(1), 103–128.

van Hoorn, J., van Dijk, E., Meuwese, R., Rieffe, C., & Crone, E. A. (2016). Peer influence on prosocial behavior in adolescence. *Journal of Research on Adolescence*, *26*(1), 90–100.

Yarkoni, T., Poldrack, R. A., Nichols, T. E., Van Essen, D. C., & Wager, T. D. (2011). Large-scale automated synthesis of human functional neuroimaging data. *Nature Methods*, *8*(8), 665–870.

Zerubavel, N., Bearman, P. S., Weber, J., & Ochsner, K. N. (2015). Neural mechanisms tracking popularity in real-world social networks. *Proceedings of the National Academy of Sciences*, *112*(49), 15072–15077.

Figures

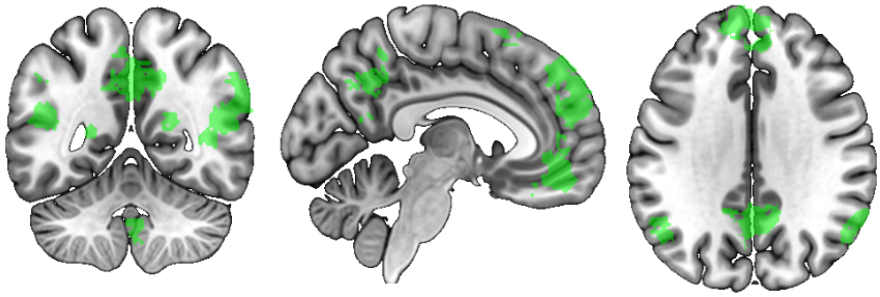

Figure 1. Brain regions associated with mentalizing.

A reverse inference meta-analytic map of the functional neuroimaging literature on "mentalizing" retrieved from Neurosynth shows that subregions in the middle and dorsal medial prefrontal cortex (MMPFC, DMPFC), bilateral temporoparietal junction (TPJ), precuneus (PC/PCC), superior temporal sulcus (STS), and temporal poles have been implicated in mentalizing.