Social Influence and the Brain: Persuasion, Susceptibility to Influence and Retransmission

Christopher N. Cascio, Christin Scholz, & Emily B. Falk
University of Pennsylvania

Correspondence:

Christopher N. Cascio
Annenberg School for Communication
University of Pennsylvania
3620 Walnut St.
Philadelphia, PA 19104
ccascio@asc.upenn.edu

Abstract

Social influence is an important topic of research, with a particularly long history in the social sciences. Recently, social influence has also become a topic of interest among neuroscientists. The aim of this review is to highlight current research that has examined neural systems associated with social influence, from the perspective of being influenced as well as influencing others, and highlight studies that link neural mechanisms with real-world behavior change beyond the laboratory. Although many of the studies reviewed focus on localizing brain regions implicated in influence within the lab, we argue that approaches that account for networks of brain regions and that integrate neural data with data beyond the laboratory are likely to be most fruitful in understanding influence.

Introduction

Social influence is omnipresent, occurring through implicit observation of cultural norms, face-to-face and mediated interpersonal communication, as well as mass mediated communication. Even though individuals are often unaware of the power of social influence, research shows its effects on behavior in a wide variety of circumstances [1]. The mechanisms driving social influence thus remain of high interest in diverse fields including psychology, sociology, communications, health, political science, marketing, and economics.

Recently, neuroscientists have begun to contribute to our understanding of social influence, especially with respect to underlying mechanisms that are not necessarily accessible with traditional self-report methodologies (Figure 1; for reviews see: [2–4]). For example, neuroimaging enables examination of mental processes in real time and reduces the need to rely exclusively on participant introspection [5]. This review highlights recent advances in neuroscience research on social influence, examining the core processes believed to be associated with susceptibility to influence, as well as successfully influencing others. To connect the study of influence with the broader social and cognitive neuroscience literature, we summarize evidence for overlap between neural systems implicated in conflict detection, positive valuation, social cognition, and self-related processing in the context of social influence. We conclude with a discussion of new insights and methods within social and cognitive neuroscience and computational social science disciplines that promise to advance our understanding of influence moving forward.

Susceptibility to Social Influence

Building on a long history of social sciences studying compliance and conformity (for a review, see [1]), a growing body of research has documented neural correlates of attitude and

behavior change in response to social norms or peer pressure. Converging evidence emphasizes overlap with brain systems associated with conflict detection and valuation in susceptibility to social influence [4].

Conflict Detection and Distress of Misalignment with the Group

Social psychologists have suggested that one core function of compliance and conformity is to maintain group harmony [1]. This account suggests that attitude and behavior change in response to social influence require the ability, whether conscious or unconscious, to detect conflicts between one's current behavior, preference or choice and those of others. The perception of being misaligned with others may elicit distress [6,7], which can motivate behavioral and attitudinal adjustments to realign with the group [8]. In this context, conformity may be enacted to gain group acceptance or support, which are also key to survival in evolutionary contexts [9].

The dorsal anterior cingulate cortex (dACC) is one key brain region implicated in conflict monitoring and detection [10–17], and early studies of influence demonstrated that updating behavior in response to misalignment with the group is associated with increased activity within this region [6,18], as well as in anterior insula (AI), a region hypothesized to encode the discomfort of being misaligned with the group [6,7]. To further test the causal role of brain regions hypothesized to be involved in conflict monitoring and detection in social influence, researchers used transcranial magnetic stimulation (TMS) to downregulate the posterior medial frontal cortex (pMFC), overlapping with dACC, during a social influence task. This manipulation reduced conformity to social influence, possibly by interrupting key processes relevant to reinforcement learning, and hence social conformity [19].

Extending to behaviors beyond the neuroimaging lab, individual differences in reactivity to social exclusion within dACC, AI, and subgenual cingulate predicted susceptibility to risky social influence in teens in a driving context one week after data were collected within these hypothesized regions using fMRI [20]. Taken together, these studies are consistent with the idea that sensitivity to social conflict and distress in form of anticipated or actual 'social pain' may contribute to conformity, such that individuals may conform to avoid negative social consequences and promote social bonding [3,8].

Valuation

In addition to conflict detection, social influence may derive power from positive value placed on social relationships [21]. Expected or experienced reward of social belonging or approval from others is thought to motivate conformity [22]. The ventral striatum (VS) and ventromedial prefrontal cortex (VMPFC) are known to respond to a wide variety of rewarding stimuli, including primary and secondary rewards [23]; VMPFC is known to convert various types of value (e.g., monetary and social) into a common scale which allows individuals to anticipate overall benefits of a stimulus based on diverse types of information (e.g., [24]). In studies of social conformity, neural activity within VS and VMPFC have been implicated in updating preferences to be in line with group opinions [25–27], which may reflect anticipated social rewards of group alignment. Some authors have also interpreted this to suggest that participants internalize what is valued by peers and come to value attitude objects rated positively by others more highly.

One study that directly tested neural differences between public and private conformity, however, found that brain regions hypothesized to be involved in conflict detection (dACC) during compliance decisions were associated with public compliance, while amygdala and

hippocampus activity was associated with private opinion changes [28]. Additional research is needed to convincingly demonstrate whether neural activity in each of the brain systems reviewed above directly produce private acceptance of norms, or whether this activity reflects anticipated or actual reward (or distress) derived from alignment (or misalignment) with the group.

Moderators of neural conformity effects

The brain systems reviewed above do not work in isolation and neural activity during social influence can also be moderated according to social context. For example, research has demonstrated that neural underpinnings of social influence are modulated by message source variables (such as communicator celebrity and expertise) [29] and in-group versus out-group status [30]. Furthermore, research examining peer influence and risk behaviors among adolescents suggests that developmental factors modulate neural processes key to influence; for example, the mere presence of another peer is associated with increased activity in hypothesized reward regions (VS, orbitofrontal cortex) during the decision-making process in adolescents (compared to adults), which in turn is associated with increased risk-taking [31]. Likewise, social norms expressed by adolescent peer confederates (risky versus cautious) interact with individual differences in neural regions associated with response inhibition (including the right inferior frontal gyrus and basal ganglia) to predict later risk-taking behavior in adolescents, suggesting that neural resources may be used differently in different social contexts [32].

Together, these studies demonstrate the power of social variables (e.g., group closeness, peer presence, and expertise) to influence the relationship between neural processing and social influence outcomes. These results also highlight the importance of longitudinal research to capture changes that occur within individuals over development [33]. More broadly, these

studies also highlight a wider range of neural systems that interact depending on contextual variables to determine influence and highlight the complexity of the influence process. Given this complexity, we argue for the potential value in examining networks of brain regions when studying influence. Such approaches will allow development of more comprehensive, integrative models of influence in the brain (see Future Directions).

Predicting Behavior Change

Many of the studies reviewed above focus on proximal outcomes that can be measured in a neuroimaging context (e.g., preference shifts). Some of the studies reviewed above, however, allude to a growing trend to explore not only proximal outcomes, but also the extent to which activity in key brain regions can predict longitudinal behavior outside the laboratory [34]. Consistent with the idea that multiple social and contextual signals are integrated to produce behavior change, initial work predicting behavior change from brain activity examined the role of the VMPFC in persuasive message processing. VMPFC is known to integrate multiple types of value signals [23] from limbic and prefrontal regions [35], which may serve as a summary value signal in response to social influence. Indeed, individual differences in VMPFC activity during persuasive message exposure successfully predicted participants' changes in sunscreen use one week after the scanning session compared to baseline usage beyond the participants' self-reported attitudes toward sunscreen and intentions to change their behavior [36]. In addition, research examining the effectiveness of smoking quit messages found that increased activity in the VMPFC during ad exposure predicted reductions in smoking one month following the scanning session compared to baseline beyond a number of self-report measures collected [37]. The authors of these behavior change studies suggest that the VMPFC may integrate information about the value placed on message content with respect to one's own goals and motivations.

Differences in participants' average responses to campaigns within VMPFC have also predicted success of the campaigns at the population level above and beyond standard self-report measures [38–40], suggesting that VMPFC in small groups of people may index the value to larger groups as well. These studies highlight VMPFC's potential key role in influence and demonstrate the utility of the *brain-as-predictor* approach [34] by showing that neural data explains variance in real-world behavior above and beyond self-report measures and highlights specific psychological pathways to change (e.g., [40,41]).

Influencing Others

In addition to studying those being influenced by social information, neuroscientists have started to consider the perspective of the influencer. Although this line of inquiry is still in its infancy, existing studies highlight the importance of increased temporoparietal junction (TPJ) activity in communicators who effectively influence others [37,42,43]. The TPJ is commonly associated with considering the intentions and perspectives of others, called mentalizing [44,45].

For example, research has examined neural correlates associated with a salesperson's ability to effectively take the perspective of their customers as indicated by a "salesperson theory of mind scale". Specifically, increased activity in bilateral TPJ and the medial prefrontal cortex was correlated with an increased self-reported likelihood to mentalize about consumers' cognitive states, which in turn was associated with greater sales performance [43]. Similarly, neural activity in the right TPJ during an fMRI recommendation task was associated with greater success in convincing others of the value of one's own opinions during a retransmission task after the scan [37]. The authors suggest that those who were more successful in propagating their own preferences may have engaged in mentalizing (e.g., considering how to make relevant information useful for others) during initial idea encoding inside the scanner [37].

Finally, research has examined the intersection of social influence and making recommendations for others using an fMRI task in which participants make recommendations to others while being exposed to experimentally assigned feedback about the recommendations previously made by peers [42]. Consistent with conformity research reviewed above, participants displayed greater activity in VS and VMPFC when conforming to peer recommendations versus maintaining their initial recommendations. Furthermore, consistent with research reviewed above on successful retransmission of influence, individual differences in right TPJ was associated with using social feedback to update recommendations for others [42]. These findings highlight the intersection of brain systems implicated in social influence and successful sharing in contexts that are highly pervasive now, e.g., writing online reviews in the face of existing reviews [42].

Follow-up research has also begun to consider how the social environment might moderate the neural mechanisms implicated in social influence and sharing behavior, for example contextualizing neural data with tools from social network analysis (SNA). SNA tools examine the size, structure, and scope of participants' social networks. By quantifying patterns of social relationships, social network analysis can operationalize sociological concepts such as an individual's access to social capital, influence, support and brokerage [46], as well as individual differences in disposition [47]. One such social network characteristic that has been studied as a potential moderator of neural activity in the context of influencing others is *ego betweenness centrality.* Ego betweenness centrality is a measure of information brokerage capacity—the extent to which an individual connects otherwise unconnected individuals within their network, and hence is positioned to broker the spread of ideas and information [48]. Although those who are high and low in betweenness centrality both update recommendations for others in response to social feedback, the underlying neural processes differ [48]. Those higher in betweenness

centrality showed more mentalizing activity when making recommendations and updating them in response to peer feedback compared to those who are lower in ego betweenness centrality; the authors suggest that having access to more diverse points of view or more practice translating ideas between different groups may encourage use of the brain's mentalizing system in day to day life, and/or that those who tend to engage in more mentalizing may position themselves in greater brokerage roles [48]. This work highlights potential value in integrating new tools from computational social science (e.g., social network analysis) to study how the brain responds to influence (for reviews, see [49,50]).

Conclusion and Future Directions

Neuroimaging provides a unique view of the underlying mechanisms that contribute to attitude and behavior change in response to social influence that are difficult to access using traditional methodologies [5]. The current review highlights early studies demonstrating relations between neural systems associated with valuation, conflict detection and social influence, between neural systems implicated in integrating value signals with respect to one's own motivations and behavior change, and between neural systems associated with mentalizing and successful influence over others (Figure 2). As reviewed above, however, social context variables modulate both neural and behavioral responses to influence and it is clear that brain systems work together in complex ways that go beyond the foundational brain-mapping research in this area. Neuroimaging research must now examine more complex neural network patterns within and between key systems involved in influence. Some (of many possible) theoretical and methodological means to this end are suggested below.

First, data analysis approaches that move beyond traditional mean activation estimates will offer new perspectives on social influence, for instance, by examining neural networks

rather than individual regions [51,52]. Specific examples of this would include using techniques derived from graph theory [53–56], connectivity analysis [57], or cognitive architectures [58,59]. It is almost certain that social influence processing is not localized to specific brain areas and the incorporation of network methods may reveal new knowledge about complex interconnections between neural regions during social influence and their interactions with context and development [60,61]. Thereby, knowledge gained from the studies reviewed above can suggest key nodes to consider in neural network analysis.

Second, techniques such as TMS and tDCS can provide stronger evidence for causal relationships (i.e., regions or network nodes that are not only involved but necessary for influence to occur) [19,62]. In addition, taking advantage of alternative neuroimaging tools such as functional near-infrared spectroscopy can allow researchers to capture neural mechanisms of more natural, live social interactions, allowing for greater external validity of findings [63]. Methods such as inter-subject correlation analysis [64,65] can also aid in moving toward greater external validity of findings by allowing examination of influence in response to naturalistic media [66,67].

Finally, as the neuroscience of social influence remains a relatively new area of inquiry, researchers should continue to develop tasks suitable for neuroimaging environments that are optimized for methods that offer high degrees of promise (e.g., network connectivity analyses, multivariate pattern classification approaches), and that are optimized to characterize how influence is modulated across different populations and across development [33]. More broadly, the findings reviewed above and those to come will offer new insights into social influence processes and using this information in conjunction with findings from other methodologies

(e.g., self-report, analytic methods from computational social science) can help us develop a more holistic understanding of social influence.

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Demonstrates that susceptibility to social influence is determined by individual differences in brain regions implicated in sensitivity to social cues (hypothesized 'social pain' and 'mentalizing' networks). Those who showed more activity in dACC, AI and subACC, as well as rTPJ, PCC and DMPFC during social exclusion were more likely to engage in risky driving in the presence of a peer (compared to driving alone) in an independent driving simulator session one week later.

29. Stallen M, Smidts A, Sanfey AG: **Peer influence: neural mechanisms underlying in-group conformity**. *Front. Hum. Neurosci.* 2013, **7**. *

Highlights the sensitivity of social influence effects to specific social contexts. Conformity with an in-group was more related to increased striatal activity, among others, than conformity to an out-group, suggesting the importance of social context in understanding the neural processes involved in influence.

33. Berkman ET, Falk EB: **Beyond Brain Mapping: Using Neural Measures to Predict Real-World Outcomes**. *Curr. Dir. Psychol. Sci.* 2013, **22**:45–50. **

This review provides an overview of the brain-as-predictor approach, i.e. the idea that neural data collected in the laboratory can be used to predict long-term, ecologically valid outcomes in the real world. This is relevant for social influence given that unobtrusive neuroimaging can help to circumvent the limitations of introspection and predict influence outcomes that are difficult to predict using other measures.

36. Falk EB, Morelli SA, Welborn BL, Dambacher K, Lieberman MD: **Creating buzz: the neural correlates of effective message propagation**. *Psychol. Sci.* 2013, **24**:1234. *

This is an early examination of social influence from the perspective of the propagator. The authors show that higher activity in hypothesized mentalizing regions (bilateral TPJ) during first exposure to new ideas, predicts a person's success in propagating their evaluation of these ideas to others. Considerations of others' likes, wants, and needs may put individuals in a better position to convince others.

41. Cascio, C. N., O'Donnell, M. B., Bayer, J. B., Tinney, F. J., & Falk, E. B: **Neural correlates of susceptibility to group opinions in online word-of-mouth recommendations.** *Journal of Marketing Research,* in press. *

One of the first studies on the neural correlates of the dynamic interplay between influencing others and being influenced at the same time. Neural correlates similar to those found when both processes are studied in isolation, namely valuation (OFC, VS) and mentalizing (TPJ) were found to play a role in updating recommendations in response to peer recommendations.

47. O'Donnell MB, Falk EB: **Big data under the microscope: Using brains, networks and language to link individual and population level data**. *Ann. Am. Acad. Pol. Soc. Sci.* in press. **

Advocates a multi-method approach to the study of social influence, combining large-scale data from computational social science such as information about participants' social networks with individual-level neural data. The authors argue that computational social science can help to strengthen and contextualize neural approaches and offer two accessible examples of this approach. We believe that such methods will be highly valuable in future social influence research, as they allow us to make diverse links between detailed, mechanistic neural data and participant's social reality outside the lab.

49. Bassett DS, Wymbs NF, Rombach MP, Porter MA, Mucha PJ, Grafton ST: **Task-based core-periphery organization of human brain dynamics**. *PLoS Comput. Biol.* 2013, **9**:e1003171. **

Demonstrates how network approaches to the analysis of neural data can be leveraged to gain a more detailed, mechanistic understanding of cognitive processes that we advocate be applied to the study of social influence. The authors explore brain systems that enable robust learning of motor skills and are able to identify changes in connectivity patterns in two time-evolving neural communities in which changes over time trace participants' learning progress.

56. Barrett LF, Satpute AB: **Large-scale brain networks in affective and social neuroscience: towards an integrative functional architecture of the brain**. *Curr. Opin. Neurobiol.* 2013, **23**:361–372. **

Argues for social neuroscience research on the level of large-scale, domain-general neural networks rather than domain-specific modules. As outlined above, we believe that this will be a crucial approach in future research on social influence, because complex social interactions likely rely on multiple, related mechanisms at once rather than on isolated, specialized brain regions.

62. Schmälzle, R., Häcker, F., Renner, B., Honey, C. J., & Schupp, H. T: **Neural Correlates of Risk Perception during Real-Life Risk Communication.** *The Journal of Neuroscience* 2013, **33*:***10340–10347. *

Presents an application of inter-subject correlation for the study of responses to naturalistic and influential media. The authors use inter-subject correlation analyses on neural time courses to assess similarity of neural responses to a 30-minute TV report about the H1N1 pandemic. Inter-subject correlation was moderated by participant's topic-related risk perceptions so that those with high risk perceptions showed stronger within-group similarity in ACC activity than those with low risk perceptions.

Figures

Figure 1. Example heuristic model demonstrating the use of multiple methodologies to understand unique variance in behavior change in response to social influence manipulations (modified from; [2]).

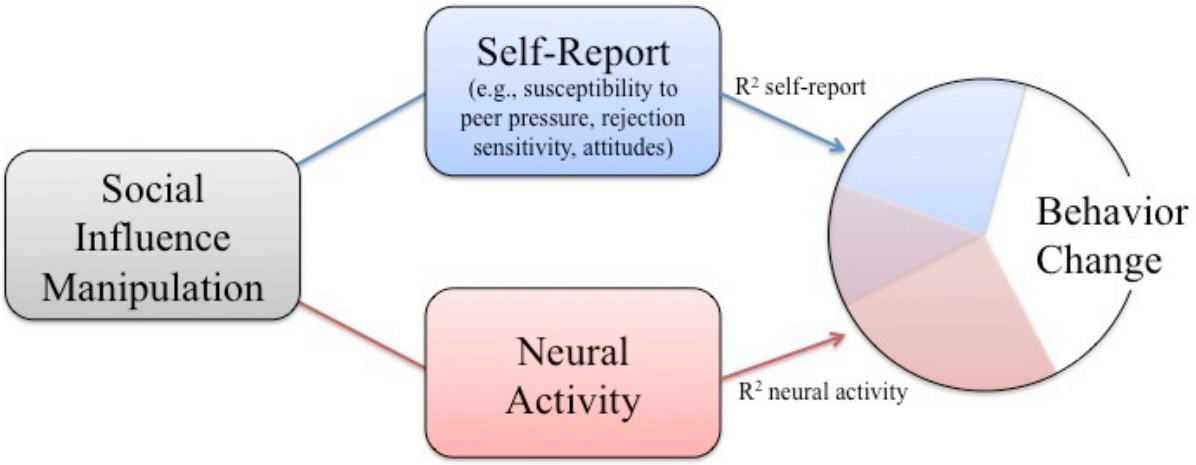

Figure 2. Hypothesized neural systems that may contribute to social influence. Valuation: VS = Ventral Striatum, VMPFC = ventral medial prefrontal cortex; Conflict detection and response: AI = anterior insula, dACC = dorsal anterior cingulate cortex; Self-related processing: MPFC = medial prefrontal cortex; and Mentalizing: DMPFC = dorsomedial prefrontal cortex, TPJ = temporal parietal junction