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The present study examines the relationship between social influence and recommendation decisions among adolescents in the new media environment. Participants completed the App Recommendation Task—a task that captures neural processes associated with making recommendations to others, with and without information about peer recommendations of the type commonly available online. The results demonstrate that increased activity in the striatum and orbitofrontal cortex in response to peer recommendations is significantly correlated with participants changing their recommendations to be consistent with this feedback within subjects. Furthermore, individual differences in activation of the temporoparietal junction during feedback that peer recommendations varied from those of the participant correlated with individual differences in susceptibility to influence on recommendation decisions between subjects. These brain regions have previously been implicated in social influence and the concept of being a "successful idea salesperson," respectively. Together, they highlight a potential combination of internal preference shifts and consideration of the mental states of others in recommendation environments that include peer opinions.

Keywords: social influence, recommendations, word of mouth, mentalizing, valuation

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Neural Correlates of Susceptibility to Group Opinions in Online Word-of-Mouth Recommendations

Sharing ideas and information is an essential aspect of communication, and it has a substantial impact on human preferences and behaviors (Bone 1995; Tzourio-Mazoyer et al. 2002). People frequently make recommendations about using or avoiding specific products and services, willingly sharing their experiences and opinions with others. In turn, word-of-mouth recommendations can significantly shape consumer decisions (Anderson and Magruder 2012; Berger 2014; Chevalier and Mayzlin 2006; Chintagunta, Gopinath, and Venkataraman 2010; Duan, Gu, and Whinston 2008; Ye et al. 2011). This phenomenon is particularly highlighted in the new media environment, in which people can instantly share with a wide range of friends, strangers, and imagined others online. In the online space, consumers make recommendations for everything from which services are most reliable to where to eat or what car to buy.

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From a marketing perspective, consumer recommendations can influence product and brand popularity and are commonly found within the competitive marketplace. In fact, successful product launches often rely on the pairing of the right product with recommendations from the right group of people (Aral and Walker 2011, 2012; Hinz et al. 2011; Van der Lans et al. 2010; Watts and Dodds 2007). Indeed, it is well documented that social influence (e.g., social proof; Cialdini and Goldstein 2004)—or, more generally, learning about the preferences and behaviors of others—can powerfully affect consumers' personal decisions (Senecal and Nantel 2004). Less is known, however, about the processes through which recommenders make recommendation decisions, especially in relation to how social information influences consumers' decisions about the recommendations they make. The ubiquity of opportunities to generate recommendations, combined with the power of the resulting decisions to influence other potential recommenders, highlights the importance of understanding the underlying processes through which recommendation decisions are made and affected by the preferences and opinions of others.

Neuroimaging is one valuable tool for understanding such mechanisms. Neuroimaging methods such as functional magnetic resonance imaging (fMRI) allow for simultaneous examination of multiple neurocognitive processes in real time, as decisions unfold. In particular, behaviors that appear similar on the surface may be produced by different underlying processes (Lieberman 2010); for example, neuroimaging may be well suited to discriminate between public compliance with the opinions of others while still maintaining an initial set of beliefs privately and actual shifts in privately held opinions (Zaki, Schirmer, and Mitchell 2011). Following this logic, a growing body of literature has characterized the neural systems associated with conformity and social influence on individual opinions and behaviors (Berns et al. 2005, 2010; Campbell-Meiklejohn et al. 2010; Chein et al. 2011; Falk et al. 2010; Klucharev et al. 2009; Mason, Dyer, and Norton 2009; McClure et al. 2004; Stallen, Smidts, and Sanfey 2013; Zaki, Schirmer, and Mitchell 2011; for reviews, see Falk, Way, and Jasinska 2012; Izuma and Adolphs 2013). An overarching theme from this work is that social influence seems not only to change surface-level decisions and reported preferences but also to genuinely alter the value of stimuli ascribed in the brain (Mason, Dyer, and Norton 2009; Zaki, Schirmer, and Mitchell 2011). However, no prior studies have investigated the neural processes involved in making and updating other-directed recommendations in response to peer recommendations. This is a critical gap in the literature given the importance of recommendation decisions for the aforementioned outcomes; other-directed recommendations may differ in key ways from self-oriented preferences and may be changed through mechanisms not apparent in previous studies of social influence.

In considering the neural processes that might be involved in decisions to update (or not update) a recommendation in the face of peer opinions that differ from one's own, we draw on two distinct bodies of research that have investigated two fundamental parts of this novel question. First, we review the neural processes that distinguish people who are more and less successful in making recommendations to others. Second, we review the neural processes that are associated with updating personal preferences in response to social influence. We hypothesize that decisions to update other-directed recommendations in response to peer opinions may unite these brain systems to arrive at final recommendation decisions.

NEURAL CORRELATES OF SUCCESSFUL RECOMMENDATIONS

A small number of neuroimaging studies have characterized neural processes involved in how people influence others through recommendation and related behaviors (Dietvorst et al. 2009; Falk et al. 2013; Falk, O'Donnell, and Lieberman 2012). These preliminary studies converge on the importance of activity in the communicator's temporoparietal junction (TPJ) for the successful transmission of ideas and recommendations. The TPJ is key to understanding the mental states of others (Saxe and Kanwisher 2003; Saxe and Powell 2006), termed "mentalizing." Previous work has speculated that successful recommenders may more actively consider what others are likely to think of ideas before recommending them (Falk et al. 2013).

More specifically, research has examined individual differences in people's effectiveness in promoting their ideas to others (termed the "idea salesperson effect"). Increased activation of the TPJ has been associated with being a "successful idea salesperson" (Falk et al. 2013) and was the only brain region robustly observed to track this ability. Examination of the coordinates observed by Falk et al. (2013) using the Neurosynth database suggests that the probability of mentalizing given the activations observed is high (Yarkoni et al. 2011). It is possible that those who are better at persuading others or conveying their ideas to others may already be thinking about how to make shared information useful to others during initial idea encoding (Falk et al. 2013). These people may also be more receptive to social cues more broadly and may make more use of social information as they formulate their recommendations, a focus of the current investigation.

In addition, research has examined related neural processes associated with actual salespeople's increased ability to get inside the minds of their consumers—a salesperson theory-of-mind index (Dietvorst et al. 2009). These researchers also found that increased activity in the TPJ and medial prefrontal cortex (mPFC) was associated with greater tendency to mentalize about consumers and, ultimately, better sales performance (Dietvorst et al. 2009). Taken together, these results suggest that activity in TPJ (and mPFC) may be important for dynamically updating in the face of social signals that could play an especially important role in the context of making recommendations.

NEURAL CORRELATES OF SOCIAL INFLUENCE ON INDIVIDUAL PREFERENCES AND DECISIONS

Building on decades of literature demonstrating the power of social proof to alter individual preferences and decisions, a separate body of neuroimaging literature has documented the neural shifts that occur in evaluating stimuli that are judged more or less favorably by others. In attempting to explain why the brain would alter its representation of objectively identical inputs in response to different group opinions, much of this work has focused on the broader evolutionary benefits of fitting in with a social group (for a review, see Falk, Way, and Jasinska 2012).

Given the benefits of group membership, susceptibility to social influence is thought to be reinforced, in part, by activity in the brain's valuation system, including parts of the ventral striatum (VS) and oribitofrontal cortex (OFC)/ventromedial prefrontal cortex (Campbell-Meiklejohn et al. 2010; Chein et al. 2011). A substantial body of literature has established that social feedback is encoded in similar parts of the valuation system as primary rewards such as food and sex (Bartra, McGuire, and Kable 2013; Lieberman and Eisenberger 2009; McClure, York, and Montague 2004). This responsiveness to social signals in the valuation system may help maintain group harmony and encourage cohesion. In line with this argument, fMRI studies of social influence have used neural signals within the brain's valuation system to demonstrate that group opinions actually change the underlying responses in these regions to social stimuli (Klucharev et al. 2009; Mason, Dyer, and Norton 2009; Zaki, Schirmer, and Mitchell 2011). These studies suggest that valuation may be one key driver of susceptibility to social influence, with people updating their internal preferences according to social norms.

Likewise, humans have developed alarm systems that detect conflict and respond to social threats (Cacioppo et al. 2002; Eisenberger 2012; Hawkley et al. 2003, 2010; Peters et al. 2011). For example, it is believed that the brain's response to social exclusion is built on the evolutionarily older neural system that responds to physical pain in service of maintaining group cohesion (Eisenberger 2012; Eisenberger, Lieberman, and Williams 2003; Panksepp 1978). Neural regions include the dorsal anterior cingulate cortex (dACC) and anterior insula in adults (Eisenberger 2012; Eisenberger, Lieberman, and Williams 2003) and the subgenual cingulate cortex (subACC) in adolescents (Falk et al. 2014; Masten et al. 2009). Beyond studies of social pain, the dACC has also been implicated in basic cognitive processes such as conflict monitoring and error detection (Carter et al. 1998; Critchley et al. 2005; Kerns et al. 2004), which would also be highly relevant to maintaining alignment with group opinions.

In the domain of social influence, neural sensitivity within these brain regions has been implicated in conformity (Berns et al. 2005; Gunther Moor et al. 2010; Peake et al. 2013). In one study, individual differences in sensitivity to popularity ratings of music within the anterior insula and dACC were associated with tendency to conform (Berns et al. 2010). In another recent study, individual differences in neural activity within the subACC and anterior insula, as well as in brain regions selected for their role in mentalizing (i.e., TPJ, posterior cingulate, and dorsomedial prefrontal cortex [dmPFC]) during exclusion, predicted later susceptibility to social influence in teens (Falk et al. 2014). In this same investigation, self-reports of sensitivity to social cues (distress during exclusion) did not predict susceptibility to social influence, highlighting the value of fMRI for helping unpack mechanisms that may not be apparent using traditional self-report measures alone. Although one of several possible interpretations, these data are consistent with the idea that teens whose brains are more sensitive to a range of social cues may attend more strongly to the potential for social consequences of their actions and take steps preemptively to gain attention or fit in by conforming. More broadly, to the extent that people are more sensitive to social conflict and experience greater physiological reactivity to being out of line with a group, they might be more inclined to behave in ways that preemptively avoid exclusion and promote bonding by conforming (Falk, Way, and Jasinska 2012).

THE CURRENT STUDY

In the current study, we combine the two previously reviewed literature streams on the neural mechanisms underlying recommendations (Dietvorst et al. 2009; Falk et al. 2013; Falk, O'Donnell, and Lieberman 2012) and on social influence (Berns et al. 2010; Mason, Dyer, and Norton 2009; Zaki, Schirmer, and Mitchell 2011) to test predictions about mechanisms that lead participants to update their recommendations in response to feedback about peers' recommendations. We unite these previously disjointed literature streams to investigate the intersection of recommendation decisions and social influence in an adolescent population.

We examine neural and behavioral responses as participants make recommendation decisions and then update those decisions in response to the recommendations of other peers. We hypothesize that both neural systems previously implicated in successfully recommending ideas to others and neural systems previously implicated in susceptibility to social influence will come together when participants update their recommendations to others on the basis of peer recommendations.

Unlike previous research on social influence that has examined how social feedback influences people's own opinions, the current investigation examines how social feedback influences the recommendations people make for others. Thus, the current study examines social influence that goes beyond the end user and reflects how information passed on to other potential consumers may be biased by the current average group opinion. The current findings associated with other-directed recommendations can then be qualitatively compared with previous studies that have examined self-directed recommendations, though the primary purpose of our study is to first describe the neural processes implicated in other-directed recommendations. In addition to investigating the neural processes associated with socially prompted shifts in recommendation behavior on average, the present study also aims to understand individual differences that lead some young consumers to readily and dynamically update their recommendations in the face of peer group feedback, but not others.

In parallel with such basic science objectives, we also intend to create an experimental manipulation that mimics the new media recommendation environment. Recommendations are made frequently online with limited information, with large consequences for sales and marketing. Recommendation platforms often offer anonymity and require limited effort to engage. To maximize the external validity of this research, the current study addresses the intersection of recommendation decisions and social influence in adolescents in a task that mimics several of these qualities. The task involves recording recommendations of real mobile game apps on the basis of information provided by app developers at the iTunes store. This task enables us to explore real-world relevant marketing stimuli in the context of a well-controlled lab setting, providing high levels of external and internal validity.

We focused on ratings of mobile game applications, which are a fast-growing component of the new media market; forecasts estimate that an estimated 268 billion apps will be downloaded per year by 2017 (Shen and Blau 2013). Furthermore, the mobile app industry is projected to produce $76 billion in revenue by 2017 (Shen and Blau 2013). The ubiquity of mobile technology and constant contact with mobile devices make it especially important to understand how people make choices about what to consume and recommend to others in this arena.

Finally, we focus on adolescents given that preferences and ways of processing social information are learned during this developmental period (Cummings et al. 1997; Schindler and Holbrook 2003; Valkenburg and Cantor 2001). In addition, adolescents have a high level of engagement with the new media environment, such as the use of mobile apps (Bellman et al. 2011). There is increasing recognition that substantially more research is needed to understand how social, cognitive, and affective processes interact in the adolescent brain during social influence (Pfeifer and Allen 2012), and no prior research has investigated the neural processes at play as adolescents make recommendation decisions or how social influence might affect the neural processes underlying recommendation decisions.

METHODS

Pilot Study for the App Recommendation Task

Before running the main fMRI study, behavioral pilot data were gathered on the App Recommendation Task (described next) to test whether group recommendation information could affect participants' final recommendations. Initial pilot testing was carried out using 106 undergraduate students enrolled in an introductory communications class at the University of Michigan. Participants completed a computer-based version of the App Recommendation Task in exchange for course credit. We analyzed the pilot study and behavioral results using repeated-measures analyses of variance to detect overall group differences and planned contrasts to determine whether the specific group recommendation condition altered the mean likelihood of changing one's final recommendation.

fMRI Study Participants

Seventy eligible male adolescents took part in the current study and were recruited from the Michigan Driver History Record through the University of Michigan Transportation Research Institute as part of a larger series of studies examining adolescent driving behavior. One participant was excluded because he noted that he had used the incorrect finger when making final ratings for a portion of the task; two participants were excluded because they did not complete enough of the initial/final recommendations to model behavior; one participant was excluded for incomplete data resulting from scanner error; and one participant was excluded because of a lack of variability in recommendations, which prevented behavior change models from running. Removing these participants resulted in a final sample size of 65. All participants were aged between 16 and 17 years (M = 16.9 years, SD = .30), were right-handed, did not suffer from claustrophobia, were not currently taking any psychological medications, had normal (or corrected-to-normal) vision, did not have metal in their body that was contraindicated for fMRI, and did not typically experience motion sickness. Legal guardians provided written informed consent following a telephone discussion with a trained research assistant, and teens provided written assent.

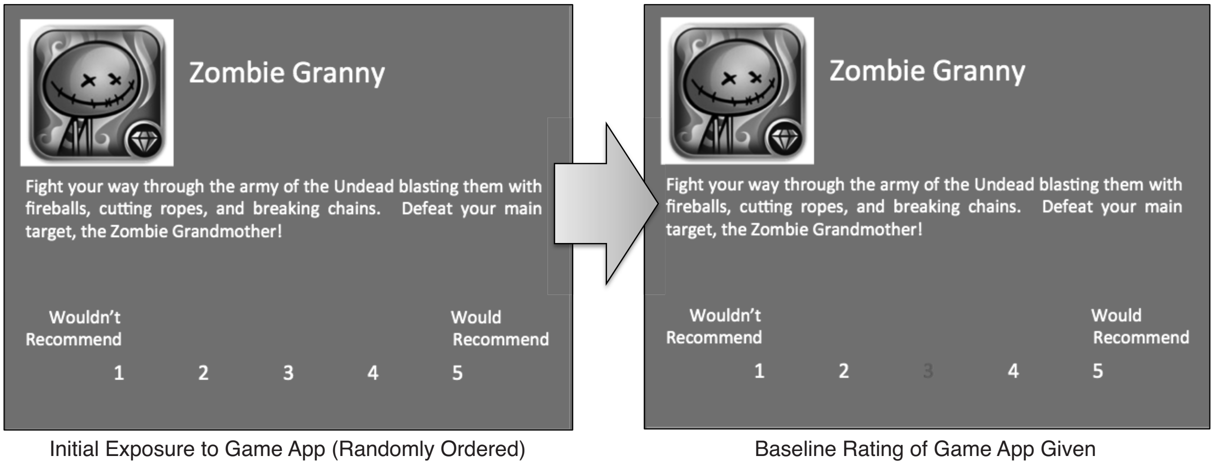
App Recommendation Task

We developed the App Recommendation Task for the fMRI environment to examine the intersection between recommendation decisions and social influence on such decisions. The task captures neural processes associated with sharing online recommendations for a mobile game website and manipulates social feedback regarding the recommendations of peers. The task stimuli consist of real puzzle-based game app titles, images, and their associated descriptions acquired from the iTunes App Store. We used actual apps from the App Store to maximize external validity and engagement for the target participants, maintain a sense of realism, and present a product that adolescents and young adults are likely to buy and rate online in real life. As part of the task, participants were exposed to information that is available at the App Store: game titles, logos, and brief descriptions of the games (Figure 1). We used games from one category (puzzle-based games) to reduce strong preferences for one particular game genre over another (e.g., shooter game vs. sports game), and all game descriptions were limited to a consistent two-sentence structure (e.g., Zombie Grandmother: "Fight your way through the army of the Undead blasting them with fireballs, cutting ropes, and breaking chains. Defeat your main target, the Zombie Grandmother!").

Participants completed two rounds of the App Recommendation Task. First, an initial set of recommendation intentions were recorded during a prescan session in which participants initially learned about the games. During the initial rating session, participants were asked to give their preliminary opinions on 80 previously unknown mobile game apps in response to a prompt asking, "How likely would you be to recommend the game to a friend?" Participants rated the games on a five-point Likert scale (1 = "wouldn't recommend," and 5 = "would recommend"). The 80 games were randomly ordered within participants.

During the fMRI session, participants completed a second round of the App Recommendation Task, which occurred approximately 40 minutes after the initial recommendations were given. Participants were told that they would be rerating the same 80 mobile game apps to be recorded for a review website; however, mimicking the experience of several online rating platforms, this time participants would be shown the title, logo, and a reminder of how they initially rated the game. It was explained that they would then be shown information about whether their peers in the study were more likely, less likely, or equally likely to recommend the games to others; however, they were told that peer recommendation information was not available for some games because we had not yet collected recommendation information. Peer group recommendations were pseudorandomly computer generated to maintain 20 trials for each feedback

Figure 1
ROUND 1: PRESCAN BASELINE RATINGS

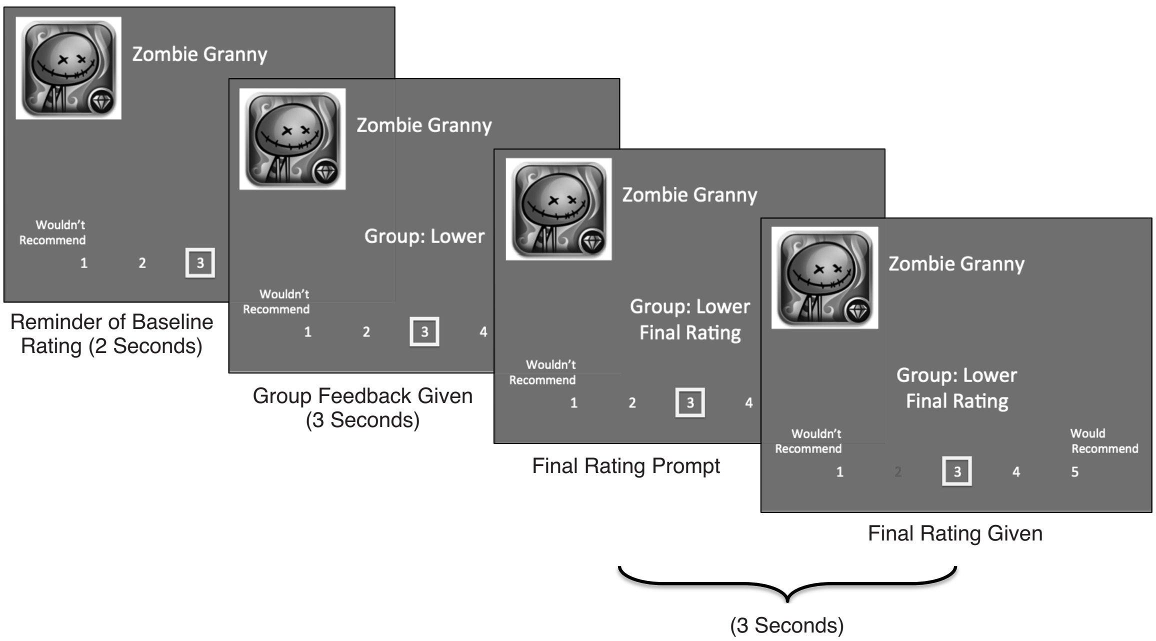


Notes: Participants completed the initial recommendation portion of the App Recommendation Task before the scanning session. Recommendations were given on a five-point Likert scale (1 = "wouldn't recommend," and 5 = "would recommend"). Recommendations were based on exposure to game titles, logos, and brief descriptions of the games.

type. Finally, participants were instructed that they would be given an opportunity to update their initial recommendations if they wanted and told to lock in a final response in the scanner. In other words, during the fMRI portion of the task, each game rating block consisted of three parts.

Consistent with these instructions, in the scanner, participants first saw a reminder of the game using the title and logo along with a reminder of how they initially rated the game (two seconds). Next, participants were exposed to manipulated peer group recommendations relative to their own (higher, lower, or same) or no peer group feedback (not rated) (three seconds). Finally, participants were asked to lock in a final recommendation for each game for the website (three seconds; Figure 2). Following the scanning ses-

Figure 2
ROUND 2: fMRI GROUP RATINGS



Notes: Participants completed the group feedback portion of the App Recommendation Task during the fMRI session. Recommendations were given on a five-point Likert scale (1 = "wouldn't recommend," and 5 = "would recommend"). Ratings were based on exposure to peer group feedback (higher, lower, same, or not rated) in conjunction with a reminder of the participant's initial recommendation.

sion, participants completed a debriefing interview in which they were asked what they believed the goal of the task was ("What type of strategy did you use during this task?" "What did you think of your group members' ratings?" "What do you think the purpose of the experiment was today?" and "What was the experiment trying to study?"). No participants reported any explicit connection between social influence and the App Recommendation Task. As we expected, given that the task was completed as part of a larger study on teen driving, participants commonly indicated that they thought the study was attempting to examine processes related to driving behaviors, such as decision-making skills, emotions, judgments made in various situations, and individual differences in focus and memorization. In addition, participants completed the App Recommendation Task as part of a larger fMRI session that examined three additional tasks that were not the focus of the current investigation, which also served to reduce demand artifacts.

Finally, we took several measures to increase the plausibility of the task: participants were told that we were conducting a marketing study to understand how relatively unknown apps become popular, given that when they are introduced on sites such as iTunes, there is generally very little information with which to make purchasing decisions. In addition, participants were specifically told that we were interested in how they made recommendations on the basis of exposure to limited information and that we wanted them to give their best recommendation for their peers as they would on the type of mobile game site from which the app descriptions were originally pulled.

fMRI Data Acquisition and Analysis

Imaging data were acquired using a 3 Tesla GE Signa MRI scanner. Functional images were recorded using a reverse spiral sequence (TR = 2,000 ms, TE = 30 ms, flip angle = 90°, 43 axial slices, FOV = 220 mm, slice thickness = 3 mm; voxel size = 3.44 mm × 3.44 mm × 3.0 mm). We also acquired in-plane T1-weighted images (43 slices; slice thickness = 3 mm; voxel size = .86 mm × .86 mm × 3.0 mm) and high-resolution T1-weighted images (spoiled gradient echo; 124 slices; slice thickness = 1.02 mm × 1.02 mm × 1.2 mm) for use in coregistration and normalization.

Functional data were preprocessed and analyzed using Statistical Parametric Mapping (SPM8, Wellcome Department of Cognitive Neurology, Institute of Neurology, London). To allow for the stabilization of the blood oxygen level–dependent signal, the first four volumes (eight seconds) of each run were discarded prior to analysis. Functional images were despiked using the 3dDespike program as implemented in the AFNI toolbox. Next, data were corrected for differences in the time of slice acquisition using sinc interpolation; the first slice served as the reference slice. Data were then spatially realigned to the first functional image. We then coregistered the functional and structural images using a two-stage procedure. First, in-plane T1 images were registered to the mean functional image. Next, high-resolution T1 images were registered to the in-plane image. After coregistration, high-resolution structural images were skull-stripped using the VBM8 toolbox for SPM8 (http://dbm.neuro.uni-jena.de/vbm) and then normalized to the skull-stripped Montreal Neurological Institute (MNI) template provided by FSL ("MNI152_T1_1mm_brain.nii"). Finally, functional images were smoothed using a Gaussian kernel (8 mm full width at half maximum). Following the preprocessing steps, motion parameters from SPM were examined, and no participants displayed greater than 3 mm (translation) or 2 degrees (rotation) of head movement during a task run.

Data were modeled at the single-subject level using the general linear model as implemented in SPM8. The four feedback conditions in the group feedback trials (not rated, same, higher, and lower) were combined with outcomes pertaining to whether participants updated their initial recommendation following feedback about group recommendations (change and no change) as regressors in the model (e.g., gHIGHER_bCHANGE indicates a block during which a participant received higher feedback during the group feedback trial and made a change to his initial rating during the final rating trial). We modeled the three-second period during which participants were exposed to the feedback as a boxcar (duration = 3 seconds). Two of these combinations, gNOTRATED_bCHANGE and gSAME_bCHANGE, did not have sufficient instances across participants to be modeled on their own, and so the few instances in which this occurred were grouped with trials in which no response was recorded under an "OTHER"/nuisance regressor condition. The six rigid-body translation and rotation parameters derived from spatial realignment were also included as nuisance regressors. Data were high-pass filtered with a cutoff of 128 seconds. Volumes were weighted according to the inverse of their noise variance using the robust weighted least squares toolbox (Diedrichsen et al. 2005).

Neural Responses to Group Feedback Across Participants

First, we aimed to understand which neural processes were associated with recommendation change across participants in response to feedback that group recommendation differed from one's own. We first examined neural activity associated with receiving feedback that the peer group had made different recommendations (gDIFFERENT = average of higher and lower) than the participant compared with receiving no social feedback (not rated). This contrast identifies aggregate neural processes associated with the core feedback conditions of interest, controlling for processes associated with considering the games and the act of making recommendations without such feedback. In addition, we compared neural activity associated with receiving feedback that the peer group had made different recommendations (gDIFFERENT) with neural activity associated with feedback that the peer group had made the same recommendation (gSAME). This second contrast compares receipt of conflicting versus affirming social feedback. The contrasts gDIFFERENT > gNOTRATED and gDIFFERENT > gSAME were modeled for each participant at the single-subject level using SPM8. The results from the first-level models were combined at the group level using a random effects model implemented in SPM8, using a Gaussian filter width of 8 mm.

Next, we aimed to identify neural mechanisms associated with changing one's recommendations in response to feedback that group recommendations differed from the participants'. To explore this substantive question, we examined differences in behavior (change vs. no change) while receiving feedback that the peer group made different recommendations (higher and lower) than the participant. The contrast gDIFFERENT_bCHANGE > gDIFFERENT_bNOCHANGE was modeled for each participant at the single-subject level and combined at the group level using a parallel random-effects model as described previously, implemented in SPM8. All results were thresholded at $p = .001$, uncorrected. All coordinates are reported in MNI space.

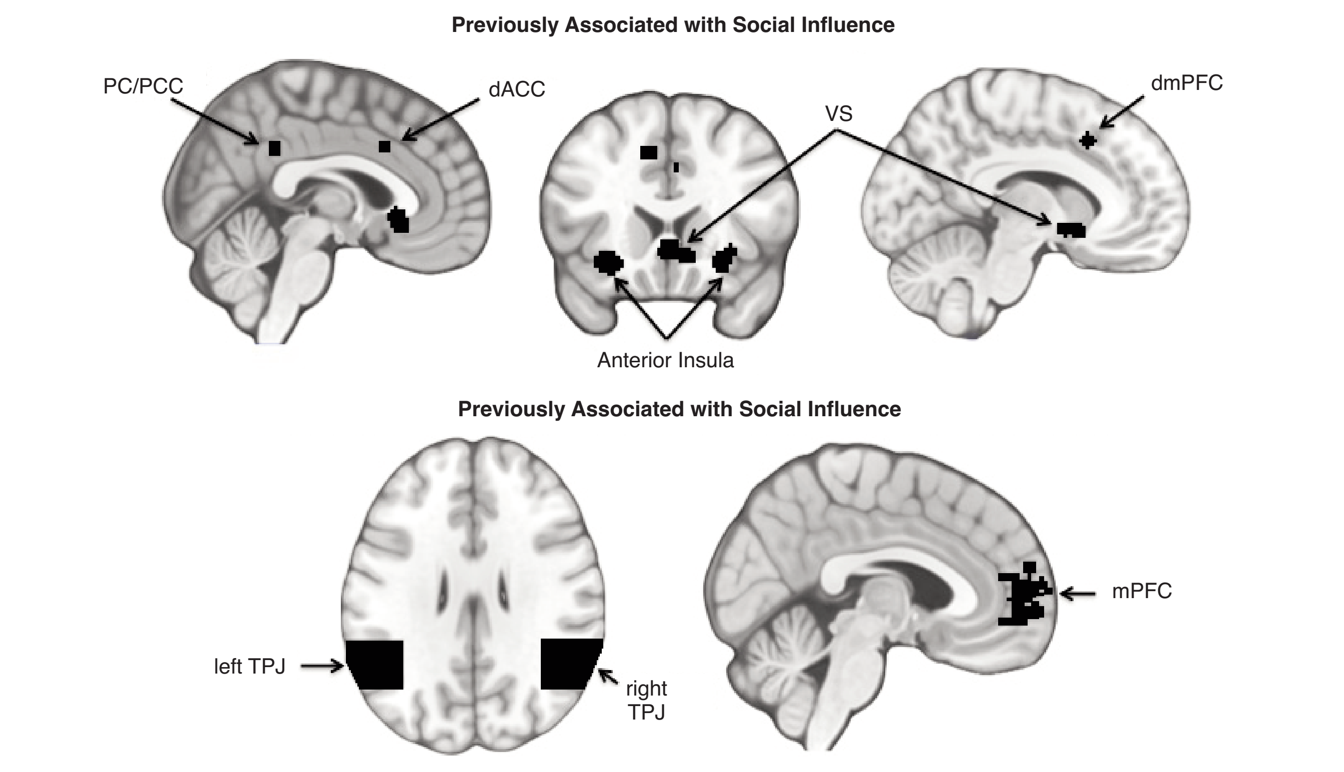
Individual Differences in Receptivity to Peer Feedback

We next examined individual differences in the tendency to update one's recommendations on the basis of peer recommendations. More specifically, we examined neural activity in regions of interest (ROIs) that have previously been implicated in successful recommendations (bilateral TPJ and mPFC) and social influence (VS, subACC, anterior insula, dACC, dmPFC, precuneus [PC]/posterior cingulate cortex [PCC]) as defined by a meta-analysis of studies on social influence (Cascio et al. 2015). We examined neural activity (average percent signal change) within each ROI between subjects as a potential correlate of the overall tendency for participants to update their recommendations in the face of feedback that peer recommendations differed from the participant's (percentage of trials in which the participant changed his initial rating in response to group feedback). Thus, an ROI analysis enables us to examine how individual differences in average levels of intensity within specific neural regions during social feedback relates to a person's overall susceptibility to update his recommendation. This analysis differs from our whole-brain analysis in that neural activity is extracted solely on the basis of group feedback and does not consider behavioral outcomes. In addition, unlike our whole-brain contrasts, which examine within-subject differences in neural activity, our ROI analysis enables us to examine between-subjects differences in neural activity. We combined neural and behavioral data from the App Recommendation Task in an ordinary least squares regression, implemented in R (version 3.0.1).

ROIs based on literature on recommendations. Right and left TPJ and mPFC ROIs (Figure 3) were constructed in Wake Forest University PickAtlas toolbox within SPM (Maldjian et al. 2003), combining Brodmann areas intersected with x, y, z bounds (as we note subsequently) to restrict subregions and refined in fslview on the basis of a review of literature relevant to social cognition (courtesy of the Pfeifer Lab). MarsBaR (Brett et al. 2002) was used to convert these anatomical images to ROIs. The right TPJ ROI was defined as all voxels within Brodmann areas 22, 39, and 40 intersected with a box-shaped mask centered at (x = 60, y = –52, z = 30) and extending 40, 16, and 24 mm along the x, y, and z axes. The left TPJ was a mirrored version of the right TPJ. The mPFC ROI was defined as all voxels within Brodmann area 10 and restricted medially by intersecting a box-shaped mask that extends from x = –20 to 20, y = 45 to 70, and z = –10 to 30.

ROIs based on literature on social influence. Regions of interest were also constructed within regions most strongly

Figure 3
ROIs



associated with social influence (AI, dACC, dmPFC, PC/PCC, and VS) on the basis of a meta-analysis examining social influence (Cascio et al. 2015) using GingerALE (version 2.3) (Eickhoff et al. 2009, 2012; Turkeltaub et al. 2012). GingerALE performs an activation likelihood estimation on coordinates in MNI and/or Talairach space (Eickhoff et al. 2009, 2012; Turkeltaub et al. 2012). We used MarsBaR (Brett et al. 2002) to convert these images to ROIs (Figure 4). Additional details are provided in Table S1 of the Web Appendix.

RESULTS

Pilot Testing of the App Recommendation Task

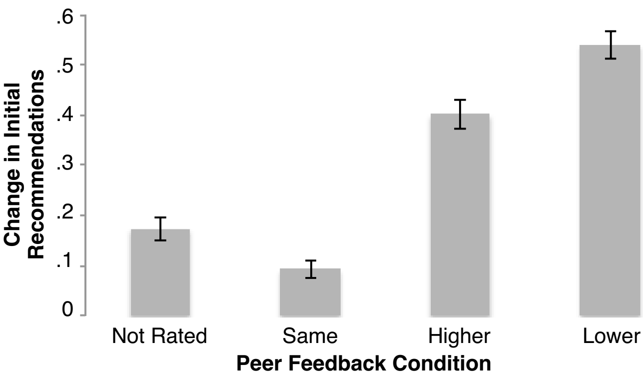
The results from our pilot participants indicated that information about peer recommendations significantly altered the proportion of the time that participants changed their final recommendations ($M_{not\ rated} = 15.38\%$, $SD_{not\ rated} = 18.68\%$; $M_{same} = 7.36\%$, $SD_{same} = 12.67\%$; $M_{higher} = 22.83\%$, $SD_{higher} = 22.07\%$; $M_{lower} = 33.77\%$, $SD_{lower} = 26.24\%$; $F(3, 103) = 32.41$, $p < .001$). In addition, the results of planned contrasts confirmed that participants changed their recommendation significantly more often when peer group recommendations differed from the participants' initial rating (combined average of higher and lower) versus the same condition ($F(1, 105) = 85.14$, $p < .001$) and the no-feedback (not rated) control condition ($F(1, 105) = 28.91$, $p < .001$). The pilot test results increased our confidence that participants could easily understand the task and that the feedback provided regarding group recommendations in the App Recommendation Task could alter participants' likelihood of changing their recommendations.

fMRI Participants' Behavioral Data

Within our main fMRI data set, participants' recommendation decisions were well dispersed across the recommendation scale (initial ratings on a scale from 1 = "definitely would not recommend" to 5 = "definitely would recommend": 1: 14.82%, 2: 24.18%, 3: 24.00%, 4: 22.38%, and 5: 13.83%). Replicating the behavioral results from pilot testing, we first examined the relationship between the type of peer feedback provided and participants' changes from their initial recommendations to final recommendations. The peer feedback manipulation exerted effects parallel to those observed in our pilot testing, such that we observed significant differences in how frequently participants changed their recommendations across feedback conditions ($M_{not\ rated} = 17.38\%$, $SD_{not\ rated} = 18.84\%$; $M_{same} = 9.31\%$, $SD_{same} = 14.06\%$; $M_{higher} = 40.15\%$, $SD_{higher} = 23.07\%$; $M_{lower} = 54.00\%$, $SD_{lower} = 22.87\%$; $F(3, 62) = 60.93$, $p < .001$; Figure 4). Participants changed their recommendations significantly more often when peer group feedback was different from their initial rating (combined average of higher and lower; $M_{different} = 46.66\%$, $SD_{different} = 22.92\%$) versus the same condition ($F(1, 64) = 178.07$, $p < .001$) and the no-feedback (not rated) control condition ($F(1, 64) = 102.82$, $p < .001$). In addition, we examined changes in recommendation behavior across initial recommendation conditions to determine whether participants were more likely to change their behavior depending on how they initially rated the apps. The results indicated that participants did not significantly change their recommendations more or less often depending on their initial recommendation ($F(4, 61) = 1.13$, $p = .291$).

Figure 4

CHANGE IN INITIAL RECOMMENDATIONS



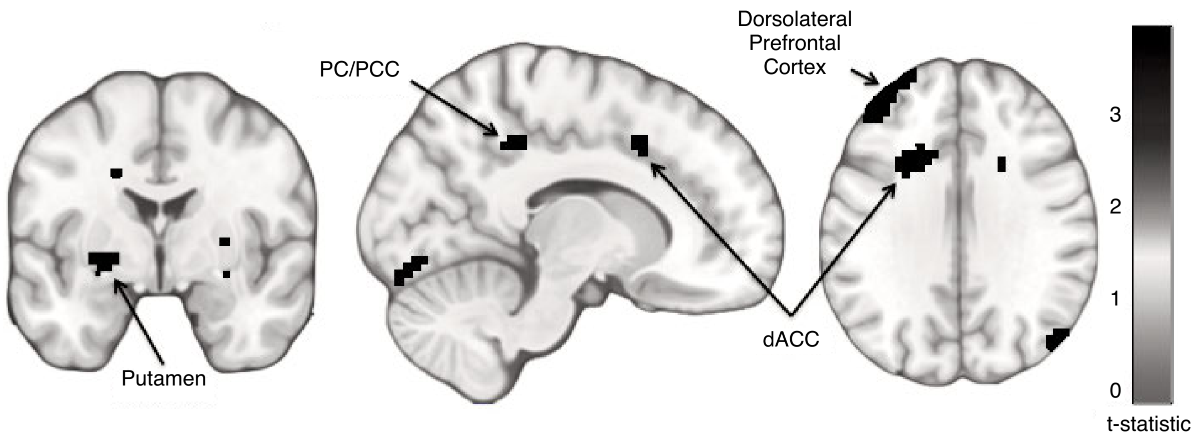
Notes: We calculated the change in initial recommendations by examining the percentage of trials in which participants changed their initial prescan recommendation in response to peer group feedback. Participants gave their final recommendations during the final block of the fMRI group App Recommendation Task. All conditions are significantly different from one another at $p < .001$. Error bars represent standard errors of the mean.

Neural Processes Associated with Recommendation Change Across Participants

Within subjects, we examined the neural mechanisms that preceded participants changing their recommendations. We broke this process down by first examining neural activity associated with feedback that the group made different recommendations than the participant (compared with not receiving any social feedback; gDIFFERENT > gNOTRATED). This contrast controls for processes related to exposure to the mobile game app information as well as for general processes associated with considering one's own recommendation. The resulting contrast highlights activity related to receiving socially relevant feedback that peers' recommendations differ from that of the participant. On average, we found the precuneus, dACC, putamen, dorsolateral prefrontal cortex, and parahippocampal gyrus, among other regions, were significantly more active while receiving feedback that the peer group made different recommendations from the participant versus receiving no social feedback (uncorrected $p = .001$; Figure 5). We found no significant activity in the reverse contrast (gNOTRATED > gDIFFERENT). For a full list of activations, see Table 1.

Next, we examined neural activity associated with feedback that the group made different recommendations than the participant (compared with receiving social feedback that is the same as the participant; gDIFFERENT > gSAME). This contrast controls for the task-related activity noted previously but is comparable to a socially affirming condition. On average, we found that the precuneus, TPJ/angular gyrus, and globus pallidus, among other regions, were significantly more active while receiving feedback that the peer group made different recommendations from the participant versus receiving feedback that the peer group made

Figure 5
GROUP FEEDBACK: DIFFERENT VERSUS NOT RATED



Notes: This figure shows a whole-brain analysis examining the contrast gDIFFERENT > gNOTRATED during the group block of the App Recommendation Task (uncorrected $p = .001$, $K \geq 5$).

Table 1
WHOLE-BRAIN ANALYSIS EXAMINING THE DIFFERENCE BETWEEN EXPOSURE TO GROUP FEEDBACK THAT DIFFERED FROM PARTICIPANTS' INITIAL RECOMMENDATION VERSUS NOT RECEIVING GROUP FEEDBACK (gDIFFERENT > gNOTRATED)

Region	*x*	*y*	*z*	*K*	*t*
Putamen (left)	–23	–2	–5	40	3.81
Parahippocampal gyrus (right)	11	1	–32	6	3.58
Frontal pole (right)	25	70	–5	6	3.37
Dorsolateral prefrontal cortex (left)	–26	60	31	107	4.19
dACC (left)	–23	15	31	69	5.08
—	–13	21	34		
—	–20	–5	34	5	3.48
dACC (right)	15	12	40	42	4.41
Precuneus (right)	4	–43	40	32	3.95
Supramarginal gyrus (right)	32	–53	25	9	3.64
Middle temporal gyrus (right)	49	–57	13	36	4.26
Middle temporal gyrus (left)	–51	–47	7	40	4.43
Inferior temporal gyrus (left)	–64	–57	–11	6	3.90
Inferior temporal gyrus (right)	49	–60	–20	12	3.52
—	59	–9	–38	34	4.51
Caudate tail (right)	25	–40	10	14	3.83
Occipital lobe (right)	49	–74	28	28	4.19
—	11	–88	–14	29	3.71
Occipital lobe (left)	–30	–91	34	8	3.70
Cerebellum (left)	–37	–57	–44	156	4.37

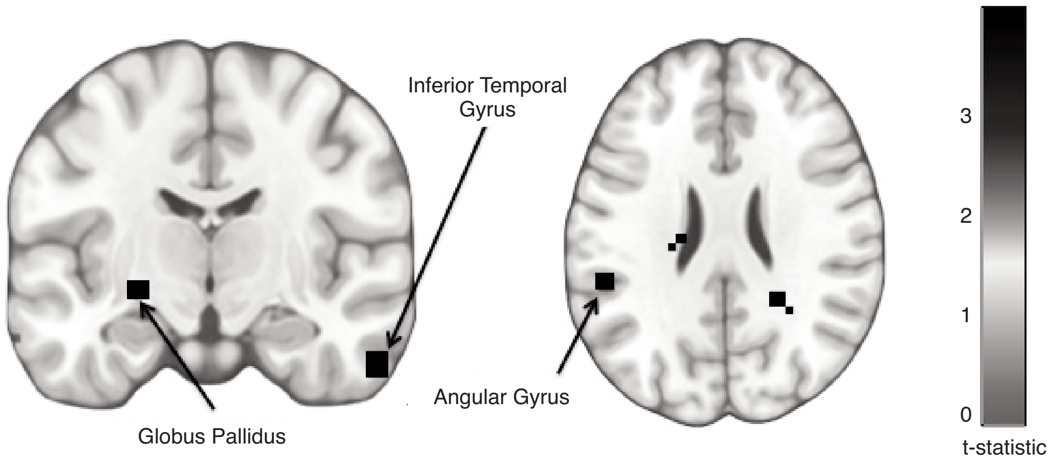
Notes: Uncorrected $p = .001$, $K \geq 5$.

the same recommendations as the participant (uncorrected $p = .001$; Figure 6). We found no significant activity in the reverse contrast (gSAME > gDIFFERENT). For a full list of activations, see Table 2.[1]

Finally, we examined the neural mechanisms associated with changing (vs. not changing) recommendations when group recommendations differed from the participants'. More specifically, we examined neural activity while participants received feedback that the group made different recommendations than they did and subsequently changed versus did not change their behavior (gDIFFERENT_bCHANGE > gDIFFERENT_bNOCHANGE). On average, we found that regions of the VS and OFC were significantly more active when participants changed versus did not change their recommendations when receiving feedback that the group made different recommendations (uncorrected $p = .001$; Table 3; Figure 7). In other words, when participants showed more activity in the VS and OFC in response to group recommendations that conflicted with their initial recommendations, they were more likely to change their recommendations in response to this social feedback. No regions were significantly more active in the inverse contrast (gDIFFERENT_bNOCHANGE > gDIFFERENT_bCHANGE).

[1]Whole-brain results examining differences between higher and lower feedback appear in the Web Appendix, Tables S2–S4.

Figure 6
GROUP FEEDBACK: DIFFERENT VERSUS SAME



Notes: This figure shows a whole-brain analysis examining the contrast gDIFFERENT > gSAME during the group block of the App Recommendation Task (uncorrected $p = .001$, $K \geq 5$).

Table 2
WHOLE-BRAIN ANALYSIS EXAMINING THE DIFFERENCE BETWEEN EXPOSURE TO GROUP FEEDBACK THAT DIFFERED FROM PARTICIPANTS' INITIAL RECOMMENDATION VERSUS FEEDBACK THAT THE GROUP MADE THE SAME RECOMMENDATION (gDIFFERENT > gSAME)

Region	*x*	*y*	*z*	*K*	*t*
Globus pallidus (left)	–26	–16	–5	8	3.57
Precuneus (right)	21	–49	18	33	4.03
Angular gyrus (left)	–47	–77	40	5	3.5
TPJ/supramarginal gyrus (left)	–54	–40	28	12	3.53
Inferior temporal gyrus (right)	56	–19	–32	25	4.32
Inferior temporal gyrus (left)	–61	–5	–38	11	3.62
Cerebellum	–2	–78	–20	48	3.63
Cerebellum (left)	–57	–64	–29	11	3.93
—	–40	–81	–32	22	3.96
—	–19	–91	–32	17	4.02
—	–33	–57	–44	10	3.97
Cerebellum (right)	39	–29	–32	15	4.99
—	32	–84	–38	56	4.04
—	28	–70	–47	13	3.84

Notes: Uncorrected $p = .001$, $K \geq 5$.

Activity in the Right TPJ Correlates with Individual Differences in One's Tendency to Incorporate Group Feedback into Recommendations

Finally, we examined whether activity in ROIs previously implicated in successful recommendation behavior and social influence during peer feedback that diverged from the participants' initial recommendation (gDIFFERENT) related to which participants were most likely to change their initial recommendations in the face of this feedback. We found that within our hypothesized ROIs, only increased activity in right TPJ during feedback that the group made recommendations different from the participant significantly correlated with the participant's tendency to change his recommendation in the face of peer feedback ($r = .25$, $t(63) = 2.09$, $p = .041$). However, one participant had neural activity that was 3.88 standard deviations above the mean; thus, we reperformed the analysis after removing this participant. The results were consistent after this outlier was removed ($r = .27$, $t(62) = 2.25$, $p = .028$; Figure 8).[2] In other words, participants who showed more activity in the right TPJ when receiving social feedback that the group made different recommendations from their own changed their recommendations of the game apps more frequently than participants who showed less activity in right TPJ during this type of feedback. Table 4 presents a full list of results.[3]

[2]In addition, it should be noted that the ROI results have been presented without Bonferroni correction and therefore should be interpreted with caution; future studies that replicate these findings will strengthen confidence in the effects observed.

[3]Anatomically defined versions of the meta-analytic ROIs (AI, dACC, dmPFC, PC/PCC, and VS) were also examined. All ROIs yielded null results ($p > .05$).

Table 3

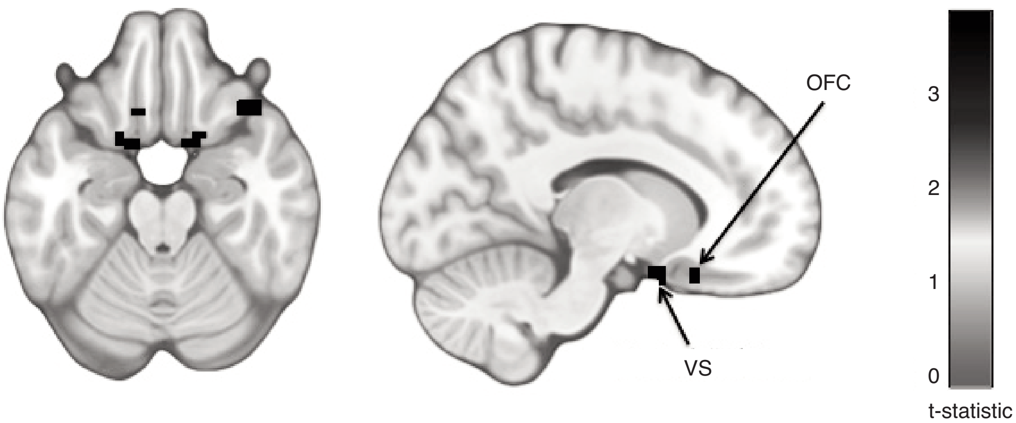
WHOLE-BRAIN ANALYSIS EXAMINING THE DIFFERENCE BETWEEN CHANGING ONE'S RECOMMENDATION WHILE BEING EXPOSED TO GROUP FEEDBACK THAT DIFFERED FROM PARTICIPANTS' INITIAL RECOMMENDATION VERSUS MAINTAINING ONE'S INITIAL RECOMMENDATION (gDIFFERENT_bCHANGE > gDIFFERENT_bNOCHANGE)

Region	*x*	*y*	*z*	*K*	*t*
VS/OFC (left)	–16	8	–23	10	3.68
OFC/temporal pole (right)	39	22	–23	12	3.92
VS/OFC (right)	15	8	–23	8	3.77

Notes: (uncorrected $p = .001$, $K \geq 5$).

Figure 7

DIFFERENT GROUP FEEDBACK: RECOMMENDATION CHANGE VERSUS NO CHANGE



Notes: This figure shows a whole-brain analysis examining the contrast gDIFFERENT_bCHANGE > gDIFFERENT_bNOCHANGE during the group block of the App Recommendation Task (uncorrected $p = .001$, K ≥ 5).

DISCUSSION

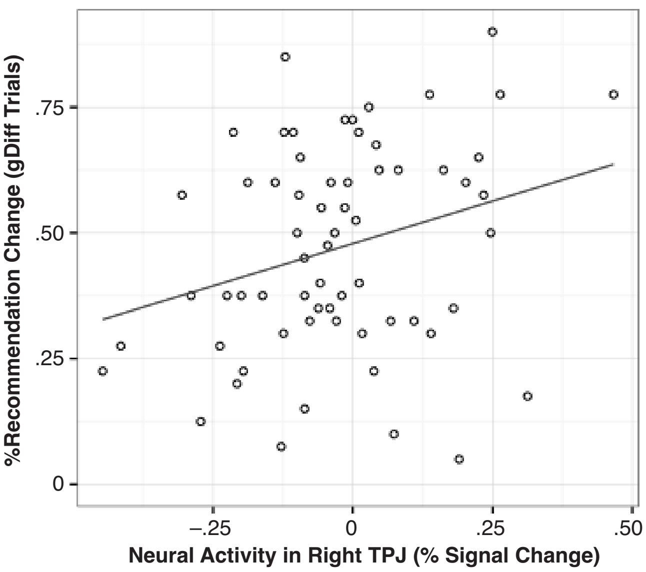
The recent rapid growth of online and mobile technology (Bold and Davidson 2012; Hampton 2012) has increased reliance on aggregated recommendation systems for choosing everything from mobile game apps to household products to restaurants and vacation destinations. Consumers use opinions of unknown peers in making relatively important decisions, and such recommendations can facilitate decision making by making the processes easier and more helpful (Dabholkar 2006; Mudambi and Schuff 2010). Furthermore, in aggregate, viral trends can be a result of cascading recommendations reinforcing one another (Phelps et al. 2004). This suggests that information shared with other potential consumers may be influenced by the current average group recommendation. However, prior research has not examined the underlying mechanisms that lead consumers to update their feedback in the face of peer recommendations or what leads some people to do so more readily.

We report evidence from two groups of participants (behavioral pilot and fMRI) showing that (1) online recommendations can be significantly influenced by information about what others recommend but (2) people are not uniformly susceptible to such influence. Participants changed their recommendations most often when receiving feedback that others had made different recommendations than their own and least often when group opinions reinforced their initial recommendation or when no social feedback was given. The tendency to incorporate this social feedback into the final ratings, however, varied across participants, with some participants readily updating their initial recommendations and others sticking consistently to their initial views.

With behavioral data alone, it is difficult to address the extent to which people might conform in their public recommendations to avoid social consequences of deviating from group opinions, conform because they come to see value in the recommendations of the group, or both. It is also difficult to know whether additional processes beyond those found to correlate with conformity in prior studies of influence might be at play for influence on recommendation decisions; people are notoriously limited in their ability to accurately report on the internal psychological states that precede such decisions (Dijksterhuis 2004; Nisbett and Wilson 1977) and may have self-presentation concerns related to their decision-making process. Thus, to complement our behavioral results, we examined neural activity using fMRI as participants engaged with an online recommendation system in the presence and absence of information about peer recommendations. We focused on the neural mechanisms associated with decisions to update one's recommendation to be consistent with group recommendations measured within subject as well as individual differences in susceptibility to social influence on recommendation behavior, observed as the tendency to update recommendations (pro-

Figure 8

SCATTERPLOT OF THE ANATOMICAL RIGHT TPJ CORRELATED WITH THE PERCENTAGE OF TRIALS IN WHICH THE PARTICIPANT CHANGED HIS RECOMMENDATION WHEN RECEIVING FEEDBACK THAT THE GROUP MADE DIFFERENT RECOMMENDATIONS



Notes: r = .27, p = .028.

portion of trials in which each participant changed their initial recommendation when the group's recommendation differed from his own).

Recommendation Change Within Subjects

Although relatively widespread activity was associated with feedback that group recommendations differed from the participant's, only neural activity within the VS and OFC was significantly greater when participants changed their recommendation rather than maintaining their initial recommendation. Although these results should be interpreted with caution because of the relatively small cluster sizes, the findings are consistent with previous research on social influence. In prior studies, the VS and OFC have been implicated in changing individual preferences in response to different forms of social influence in a range of individual decision-making contexts (Campbell-Meiklejohn et al. 2010; Chein et al. 2011; Mason, Dyer, and Norton 2009), and in positive valuation more broadly (Bartra, McGuire, and Kable 2013). This may suggest that beyond mere self-presentation concerns, adolescent recommenders may update their recommendations, on average, when they experience actual positive value in the recommendations of others, as opposed to merely conforming publicly while privately derogating the opinions of others. In this sense, social influence on recommendation behavior may parallel social influence on other types of decision making.

Prior research on adolescent samples has also demonstrated that the mere presence of peers sensitizes these neural regions, which in turn influence decision making (Chein et al. 2011); the recommendation context may effectively surround adolescent recommenders with imagined others (e.g., potential recipients of their recommendations, other recommenders) and heighten receptivity to relevant social information and potential for social rewards resulting from making socially consistent recommendations. It is possible that the effects observed are particularly pronounced during adolescence, a developmental period characterized by heightened sensitivity to social cues. Future developmental comparisons are warranted to establish whether similar processes also support updating recommendation decisions into and across adulthood.

Diverging partially from previous studies of conformity in adolescents and young adults, however, we did not find that neural activity in brain regions associated with conflict monitoring, social pain, or broader social cognition were associated with increased recommendation change within subjects. As reviewed by Izuma and Adolphs (2013) and Falk, Way, and Jasinka (2012), several studies have implicated regions of the posterior medial prefrontal cortex (including the dACC and dmPFC) in conformity, in addition to affective processing regions (e.g., the anterior insula). For example, Berns et al. (2010) examine the relationship between music preferences and popularity ratings. They find that increased activity within the anterior insula and dACC were correlated with an increased likelihood to change one's evaluation in the face of social feedback compared with evaluations made in the absence of social feedback. Given that these neural regions had previously been associated with affective salience and conflict monitoring (Carter et al. 1998; Critchley et al. 2005; Eisenberger 2012; Eisenberger, Lieberman, and Williams 2003; Kerns et al. 2004), Berns et al. interpret these findings as suggesting that conflict detection and negative affect associated with diverging from peer opinions may prompt conformity. Likewise, Klucharev et al. (2009) report that the dACC was associated both with feedback that group opinions differed from those of the participant and with actual conformity.

Table 4

SUMMARY OF THE ZERO-ORDER CORRELATIONS BETWEEN NEURAL ACTIVITY IN ROIs AND UPDATING RECOMMENDATIONS IN THE FACE OF PEER GROUP FEEDBACK

	t	r	p
Anatomically Defined ROIs			
Right TPJ	2.25	.27	.028[a]
Left TPJ	.75	.09	.458
mPFC	−1.43	−.18	.158
Meta-Analytically Defined ROIs			
Anterior insula	.36	.05	.721
dACC	.22	.03	.827
Dorsomedial prefrontal cortex	.93	.12	.354
PC/PCC	−.03	−.00	.975
VS	−.41	−.05	.683
		d.f. = 63	

[a]Results reported with outlier removed, d.f. = 62.

Notes: This table is derived from literature on successful recommendations and is based on a meta-analysis of social influence and participants' overall likelihood of updating their recommendation in the face of peer group feedback that differed from their own.

We observed increased activity in the dACC when participants were exposed to peer recommendations that were different from their own compared with exposure to no peer feedback; however, in the current study this activity was not associated with actual recommendation behavior change. One possibility is that our participants were less sensitive to rejection than the participants observed by Berns et al. (2010), who report that their participants were particularly risk averse, potentially carrying over to social domains; however, Klucharev et al. (2009) do not specifically highlight such an explanation. Although our data cannot speak directly to this point, it is also possible that recommendation decisions may differ from personal preference endorsement in the perceived affective consequences of the decision; that is, recommendations may not reflect a participant's personal opinion but rather what he believes others will value.

More directly consistent with Klucharev et al. (2009), we also observed a significant increase in precuneus activity during group recommendations that differed from the participant's compared with feedback that the group made the same recommendation as well as no group feedback. Consistent with the explanation offered by Klucharev et al., in the context of recommendation decisions, the precuneus may also aid in conflict monitoring or tracking divergent group recommendations. The precuneus has also been implicated in mentalizing processes (Fletcher et al. 1995; Spunt, Falk, and Lieberman 2010). For example, a study examining why versus how people perform actions shows that "why" actions were associated with increased activity in the precuneus and right TPJ (Spunt, Falk, and Lieberman 2010). Also consistent with this explanation, we observed activity in the ventral putamen during exposure to conflicting group recommendations versus not receiving feedback. Similarly, increased ventral putamen activity has been associated with maintaining prediction error in the actor/critic model of reinforcement learning, suggesting that the ventral putamen contributes to the prediction of future outcomes (O'Doherty et al. 2004). Finally, going beyond what has previously been highlighted in studies of social influence on individual preferences, we also observed activity within the TPJ, a key component of the mentalizing system, during divergent compared with reinforcing group recommendations.

Taken together, our results suggest that the process of updating recommendations in response to peer recommendations shares some qualitative commonalities, but evidences some potential differences, with social influence on individual preferences. In particular, consistent with prior work on social influence for personal preferences, the precuneus is associated with receiving divergent social information, whereas neural activity within the valuation system is associated with actual change. Furthermore, although activity in subregions of the posterior medial frontal cortex were observed both in our study with conflicting recommendations and in prior studies of individual preference shifts, we did not observe additional relationships between activity in these regions and recommendation behavior change. Further research that directly compares recommendation and personal preference ratings may be able to speak more directly to the robustness and potential causes of such divergence.

Individual Differences in Susceptibility to Recommendation Change

In addition to examining the processes that were associated with recommendation change on average across participants, we also examined individual differences in tendency to change recommendations in response to peer recommendations. Our results demonstrated that increased activation in the right TPJ was significantly associated with an increased susceptibility to social influence on recommendation behavior. These results dovetail with prior studies demonstrating that increased activation of the TPJ is associated with successful message propagation/being a more effective communicator or "idea salesperson" (Dietvorst et al. 2009; Falk et al. 2013). More specifically, previous work examining the spread of ideas has found that activation of the TPJ could differentiate between communicators who were able to successfully propagate their preferred ideas to others versus those who were not (Falk et al. 2013). As Falk et al. (2013) note, the TPJ may be key to simulating the mental states of others in current interactions as well as in preparing for successful social interactions in the future. Our findings extend these results to suggest that TPJ is involved not only in the simulation of the mental states of others but also in more actively using social information provided to arrive at a final recommendation decision. Consistent with the idea that the TPJ may facilitate both preparation and execution of successful social interactions, activity in the TPJ is also associated with greater ability of actual salespeople to get inside the minds of their customers—a salesperson theory-of-mind index (Dietvorst et al. 2009). This salesperson theory-of-mind index has also been associated with indicators of better sales performance. In conjunction with these prior studies, our data may suggest that adolescents who have an increased tendency to consider the mental states of others are also more likely to incorporate that information into their own recommendation. Further research is needed to explore whether this might also increase the chance of successfully transmitting ideas that are preferred by more peers.

More generally, these results also expand our understanding of the role of TPJ in theory of mind to include an increasingly common task in day-to-day life—publicly committing our recommendations for the benefit of others. The right TPJ is shown to be particularly active when considering the mental states of others (Saxe and Kanwisher 2003; Saxe and Wexler 2005). Furthermore, a meta-analysis examining theory of mind, empathy, attention orientation, and sense of agency demonstrates that the right TPJ is active across all four conditions (Decety and Lamm 2007). Thus, the authors suggest that the right TPJ is involved in generating, testing, and modifying our internal predictions on the basis of external stimuli (Decety and Lamm 2007). Finally, research examining how participants make socially guided decisions has found that the right TPJ helped people track socially relevant stimuli in the environment that were then used to help guide future decisions and behavior (Carter et al. 2012). Results from the current study demonstrate that those who show increased activity in the TPJ when making a recommendation are more influenced by social feedback. Thus, although our current data cannot speak directly to this conclusion, in combination with prior studies (Dietvorst et al. 2009; Falk et al. 2013), they may suggest that people who are more influential communicators in society might also more readily incorporate social norms and cues in their final recommendations and that those who effectively influence others may be more open to social information regarding an issue, idea, product, or brand.

Implications for Marketing

The influence of word of mouth is becoming increasingly apparent as society moves toward online commerce and recommendation systems, in which consumer recommendations are quantified and attached to everything from where to eat to what car to buy. Researchers have posited that the presence of consumer recommendations improves a consumer's perception of the usefulness and social presence of a website (Kumar and Benbasat 2006); our results suggest one set of possible mechanisms that could underpin such effects and demonstrate effects that go beyond what has been observed in prior studies of social influence on individual preferences. The present findings lay the groundwork for further research that integrates neural mechanisms into the exploration of whether (1) increased susceptibility to social influence when making recommendations leads to more effective propagation and (2) people who exhibit such susceptibility derive mental health benefits, social benefits, or connection from doing so. Furthermore, future studies examining social influence, word of mouth, and the spread of ideas may use the neural regions identified to prospectively predict when and how people are most likely to update their recommendations and how these processes interact with social network position. A successful campaign launch depends on having a good product or idea coupled with the right community of people to spread and reinforce information in the most direct way (Aral and Walker 2011, 2012; Hinz et al. 2011; Van der Lans et al. 2010; Watts and Dodds 2007).

Study Limitations

As with any study, several limitations should be considered when interpreting the reported findings. One such limitation is that this study is a first attempt at creating an fMRI task that examines the influence of social feedback on participants' recommendations; for simplicity, feedback conditions were limited to lower, higher, same, and not rated. However, additional comparison conditions could be useful in further specifying the psychological mechanisms responsible for effects observed. For example, it would be worthwhile to examine nonsocial feedback that differs from that of the participant (e.g., feedback that is believed to be computer generated that mimics recommendations one may receive from websites while online shopping). This would allow for the comparison of social versus nonsocial feedback that differs from that of the participant to better understand what is unique about processing social feedback. Future studies might also benefit from directly comparing influence on recommendation and personal preference decisions. The current study makes qualitative comparisons with other published studies that have examined social influence on user opinions; however, direct examination of these differences within the same study would allow for a quantitative comparison of neural differences in processing social feedback associated with one's opinion versus one's recommendation. Finally, given the set of regions previously implicated in social influence, we explored several potential ROIs as correlates of individual differences in susceptibility to influence on recommendations. Further research that replicates our findings with even more targeted hypotheses will add confidence to the results.

A second category of limitations stems from the fact that participants were told that the group feedback provided within the task is an average recommendation calculated from peers who had previously taken part in the study; however, we gave no specific information about these "peers." Future studies might manipulate who is providing the social feedback to shed light on how similar versus dissimilar social others may change how social information is processed. Recent research has begun to examine neural responses associated with conforming to in-group and out-group opinions (Stallen, Smidts, and Sanfey 2013). In this work, in-group conformity > nonconformity was associated with increased activity in the subACC, posterior superior temporal sulcus/insula, caudate, and hippocampus, suggesting potential roles for both positive valuation of in-group opinions and mentalizing in conforming to in-group opinions.

A third limitation is that participants were asked to make recommendations about each app; however, in a real-world context, not all of these participants would engage in this type of behavior. Therefore, it would be useful to know which participants are more likely to carry out these behaviors in the real world, which could be tracked using observational downstream behavioral measures. Similarly, our peer recommendations were pseudorandomly computer generated, and similar studies might benefit from naturalistic observation of how such processes evolve with real peers to confirm that similar processes occur (cf. Salganik, Dodds, and Watts 2006).

Finally, the current study examines social influence in the context of male adolescents as part of a larger investigation of risky adolescent driving behavior, which limits generalizations to other populations of interest. It would be valuable to expand these results to include female adolescents, young adults, and adult populations to compare whether neural patterns of activation are similar across development and other demographic groups. In particular, adolescent cognitive control systems that facilitate self-regulation mature differently than affective processing systems (Blakemore 2008, 2012; Casey, Getz, and Galvan 2008; Steinberg 2008) and function differently according to social context (Pfeifer and Allen 2012). Social cues are especially salient during adolescence, and it is possible that sensitivity to social cues may differ in adolescents compared with adult populations. In parallel, brain systems that support recommendation decisions would also vary across development. Each of the limitations reviewed here offers opportunities for further research that could easily be integrated into the App Recommendation Task.

CONCLUSION

In the present study, we examine the intersection of social influence and social sharing (recommendations) in the context of a rapidly growing market sector: mobile game applications. We found that peers' recommendations had significant impact on the final recommendations of male adolescent recommenders. Although neural activity in a constellation of regions previously implicated in susceptibility to social influence was associated with processing feedback that group recommendations differ from one's own, actually updating recommendations in response to this feedback within subjects was limited to activity in the VS and OFC. These results highlight the possibility that incorporating peer recommendations into one's own recommendation goes beyond mere public compliance and may also reflect updating of internal valuation of the opinions of others. We also observed individual differences in the tendency to incorporate peer recommendations into one's own recommendation; only neural activity within the right TPJ was related to individual differences in susceptibility to social influence on recommendation behavior. In conjunction with previous studies finding that those who show increased activity in the TPJ during initial idea exposure are better at propagating their preferred ideas, this may suggest that recommenders who are most attuned to the social environment might incorporate the recommendations and views of others more often in developing their own recommendations. More broadly, the results of this study provide insight into the psychological and neurocognitive processes underlying recommendations and address important basic psychological forces that help people share and spread ideas.

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