Neural Mechanisms of Social Influence in Consumer Decisions

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ABSTRACT

It is well-known that social influences affect consumption decisions. Although a number of different mechanisms have been hypothesized, a consumer's tendency to purchase a product is influenced by the choices made by his associative reference group. Here, we use functional magnetic resonance imaging (fMRI) to elucidate the neural mechanisms associated with social influence on a common consumer good: music. We restricted our study population to adolescents between the ages of 12-17 because music is a common purchase in this age group, and it is widely believed that adolescent behavior is particularly influenced by perceptions of popularity in their reference group. Using 15-second clips of songs downloaded from MySpace, we obtained behavioral measures of preferences and neurobiological responses to the songs. The data were gathered with, and without, the popularity of the song revealed. The popularity had a significant effect on the participants' ratings of how much they liked the songs. The fMRI results showed a strong correlation between the participants' rating and activity in the caudate nucleus, a region previously implicated in reward-driven actions. The tendency to change one's evaluation of a song was correlated with activation only in the anterior insula, a region associated with physiological arousal, particularly to negative affective states. Our results suggest that a principal mechanism whereby popularity ratings affect consumer choice is through the anxiety generated by the mismatch between one's own preferences and others'. This mismatch anxiety motivates people to switch their choices in the direction of the consensus, suggesting that this is a major force behind conformity observed in music tastes in teenagers.

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Neural Mechanisms of Social Influence in Consumer Decisions

1. Introduction

It is well-known that social influences affect consumption decisions. In particular, a consumer's tendency to purchase a product is influenced by the choices made by his associative reference group (Bearden & Rose, 1990; Childers & Rao, 1992; Escalas & Bettman, 2005; Lascu & Zinkhan, 1999). Why do the actions of others affect a person's decisions? Following the pioneering work of (Asch, 1951, 1952), social psychologists have identified several reasons. These include the desire to avoid social sanctions, the need to comply with a perceived request, or simply the drive to conform. With respect to the latter reason, empirical research supports the conceptual distinction between informative and normative motivations to conform (Deutsch & Gerard, 1955), which translate roughly to the desire to behave accurately versus the desire to behave correctly in a social sense (Cialdini & Goldstein, 2004).

On the other hand, it is also possible that information about the decisions of one's reference group influences one's actual preferences about the product. That is, observing others' choice of an item changes the intrinsic value that one attaches to that item. Indeed, there is evidence that preferences are susceptible to various influences, such as the way information is provided or framed. This leads to the suggestion that preferences are not stable, but rather are constructed during a decision situation (Ariely, Loewenstein, & Prelec, 2006; Bettman, Luce, & Payne, 1998; Slovic, 1995). Thus, the mechanism whereby social influence affects purchasing decisions may be purely in action (due to informational or normative reasons) without exercising any effect on underlying preferences, or alternatively, it may be through an effect on preferences themselves.

In this paper we study whether and to what degree social information affects the evaluation of products and the resulting purchase decisions, and we explore the mechanism whereby it exerts its effect. Although several experiments have been designed to disaggregate the informational and normative motives to conform (see, for instance, (Capra & Li, 2008; Carpenter, 2004; Cason & Mui, 1998)), few people have studied the extent to which conformity is generated by changes in preferences (a recent exception in economics is (Cooper & Rege, 2008). One problem is that informational, normative, and preferential processes may all be at work in specific situations, and the influence of each element may be difficult to isolate, even if one is able to observe decisions in controlled experiments.

One method of bypassing this problem is to use brain imaging. This allows researchers to directly measure neurological activation during a decision task. The rapid evolution of the field of neuroeconomics has resulted in a wealth of data about discrete brain systems involved in elements of individual choice (see for example (Rangel, Camerer, & Montague, 2008). Based on these data, some consensus has arisen about the functions of different regions of the brain. For example, convergent evidence from these studies points to activation in dopaminergic receptive regions as associated with value (Camerer, Loewenstein, & Prelec, 2005; Glimcher, Dorris, & Bayer, 2005; Hampton & O'Doherty, 2007; Knutson, Rick, Wimmer, Prelec, & Loewenstein, 2007; Knutson, Taylor, Kaufman, Peterson, & Glover, 2005; Montague & Berns, 2002). Similarly, the activation of the insula has been associated with aversive states (Berns, Capra, Chappelow, Moore, & Noussair, 2008; Berns et al., 2006; Chandrasekhar, Capra, Moore, Noussair, & Berns, 2008; Craig, 2003; Koyama, McHaffie, Laurienti, & Coghill, 2005; Peyron, Laurent, & Garcia-Larrea, 2000; Ploghaus, Becerra, Borras, & Borsook, 2003; Porro et al., 2002). In contrast, there is less consensus about the neural mechanisms of social influence, but using current knowledge of how the brain processes reward, it is possible to utilize fMRI technology to discriminate between conformity that is merely in action and conformity that is generated by changes in preferences (see for example (Berns et al., 2005)).

Here, we study the nature of the effect of social influence on adolescents' evaluation of different music tracks. In our experiment, participants were asked to rate songs according to their own preference before and after observing a rating of how popular the song was among a large reference group. To generate incentives to evaluate different songs in accordance with one's willingness to purchase the product, participants received a CD with the music they rated most highly at the end of the session. The use of music as the consumption good for the experiment has the methodological advantage that it can be easily delivered and consumed while the subject is being scanned. We chose adolescents between the ages of 12 and 17 as our subject pool for two reasons. The first was that this cohort of people is believed to be highly responsive to social influence (Steinberg & Monahan, 2007). The second is that consumers in this age group are typically consumers of music, responsible for more than one third of all single album consumption in the United States and perhaps a greater proportion when on-line digital purchases are included.

We study the effect of social influence by considering how information about the popularity ratings of particular songs influences an individual's own evaluation of the songs. We choose popularity ratings for two reasons. The first is that such ratings for music are widely present on the internet, and thus likely to be a familiar medium of information transmission for our participants. The second is that they provide a simple numerical measure of the degree of conformity. We consider whether providing popularity rating information results in individuals changing their ratings in the direction of the popularity rating. We then investigate, using brain imaging, the mechanism underlying the effect. Ex-ante, we believed that the design choices of music and popularity ratings for our experiment mean that there is scope for ratings to change because of both a desire to match ratings to a popular view, as well as an actual change of an individual's intrinsic preferences. We use brain imaging to distinguish between these forces and to advance claims about which force is at work in our experiment.

We find that the observation of popularity ratings does affect the individuals' ratings for songs, and individuals tend to adjust their ratings to make them more consistent with the population. We find that activation in the left and right anterior insula is strongly associated with a subject's tendency to change his/her ratings in response to the popularity information. Because insula activation tends to be associated with a state of physiological arousal, our results suggest that a principal mechanism by which popularity ratings affect consumer choice is through the anxiety generated by the mismatch between one's preferences and others'. This mismatch anxiety appears to motivate people to switch their choices in the direction of the popularity rating, suggesting that this type of mismatch is a major force behind conformity observed in music tastes in teenagers. Because activation in regions traditionally associated with value are not associated with popularity, it seems that at least in our specific context, preference effects do not play a major role in explaining conformity.

2. The Experiment

2.1. General setting

A total of 27 participants were studied. Prior to the experiment, they were screened for the presence of medical and psychiatric diagnoses, and none were taking medications.[1] The participants, (14 female and 13 male) ranged in age from 12-17 years old (mean 14.6). Fifteen were Caucasian, 8 were African-American, 1 was Hispanic, and 3 were "Other." The primary stimuli used were 15-second clips from songs downloaded from MySpace.com. Songs were downloaded between October 23 and November 8, 2006. In order to minimize the possibility that participants would recognize well-known artists, only songs from unsigned musicians were used. A total of 20 songs were downloaded in each of the following genres: Rock, Country, Alternative/Emo/Indie, Hip-Hop/Rap, Jazz/Blues, and Metal (identified by the MySpace category). At the time of download, the number of times each song had been played was recorded, and this was used to calculate the popularity of each song among MySpace users. The popularity was calculated by determining the Z-score of each song within its genre and binning the Z-scores into quintiles, resulting in popularity scores that ranged from 1-5. Each song was converted from MP3 to WAV format and a 15-second clip was extracted that included either the hook or chorus of the song. These 15-second clips were subsequently used in the experiment.

2.2. Timing

At the beginning of each session, we asked participants to rank the musical genres. Participants were provided with a list of the six musical genres, and were instructed to rank the genres from 1 ("the type you like the best") to 6 ("the type you like the least.") Each of our

[1] A total of 32 individuals participated, but 5 participants were not used in the fMRI analysis due to a combination of motion and/or susceptibility that affected the striatum (a primary region of interest). Although this was a relatively high exclusion rate compared to adult studies, it was comparable to previous fMRI studies in children and adolescents, who tend to move more than adults (Galvan et al., 2006).

participant's top three genres was subsequently used in the experiment. Subjects then completed a battery of tasks[2] that are described and reported in detail elsewhere.

Individuals then entered the scanner, and the total scan time was approximately 1 hour.[3] Each individual participated in 60 trials. The sequence of events in each trial is illustrated in figure 1. Each trial was divided into two stages; in each stage the subject listened to the same 15-second song clip. During stage one, no popularity information was shown. After listening, subjects were required to rate the song based on (a) how familiar it was and (b) how much they liked it. Both ratings used a 1-5 star scaling system. To prevent the subject from passively accepting a default rating, each rating screen began with 0 stars, which could not be accepted as a final selection. After the rating was entered, stage two of the trial took place. The clip was played again, after which the subject provided another likability rating. Twenty songs in each of the subject's top-three genres were presented in random order throughout the experiment. On 2/3 of the trials, during the second listen, the song's popularity was displayed in the 1-5 star scaling system. The 40 trials in which the popularity display appeared were sequenced randomly among the 60 trials. As an incentive to accurately reveal their song preferences, each subject received a CD with their top-rated songs.

Insert figure 1 about here

[2] After taking a urine test to screen for illicit substances abuse and pregnancy, subjects completed a Childhood Depression Inventory. No subject met the exclusion criterion of a T-score greater than 70 (clinically depressed). Next, they completed the Adolescent Risk Questionnaire, a 22-item survey of activities such as drinking and driving, driving without a license, having unprotected sex, and taking drugs (Gullone, Moore, Moss, & Boyd, 2000). Then, they completed a gambling task (Harbaugh, Krause, & Vesterlund, 2002), and then completed the WASI IQ test. All procedures were approved by the University Institutional Review Board.

[3] The scanning was performed on a Siemens 3T Trio. Each subject received a T1-weighted structural image (TR = 2600 ms, TE = 3.93 ms, flip angle = 8, 224x256 matrix, 176 sagittal slices, 1 mm cubic voxel size), a DTI scan (TR = 6500 ms, TE = 90 ms, flip angle = 90, FOV = 220mm, 128x128 matrix, 34 axial slices, 1.7x1.7x2.5mm voxel size, 6 sets of 12 directional b = 1000 and 1 b = 0 images), and 3 functional runs of BOLD-weighting (TR = 2000 ms, TE = 31 ms, flip angle = 90, FOV = 192mm, 64x64 matrix, 28 axial slices, 3 mm cubic voxel size).

2.3. Hypotheses and Statistical Analysis

In order to quantify the effect of popularity on an individual's rating of songs, the regression model in equation (1) was conducted on each participant's stage 2 rating in the 40 trials where the popularity was revealed. In our specification, the stage 2 rating was formulated as a linear function of the rating in stage one and the popularity level revealed at the end of stage one. We estimate separate coefficients for the effect of popularity for trials in which the popularity rating was (a) greater than or equal to the individual's stage one rating and (b) for trials in which the popularity was less than the original likability rating. The coefficients were estimated separately to allow for effects of different magnitudes depending on whether the popular opinion was more positive versus less positive than that of the participant.

We estimate:

$$lik_2 = \beta_0 + \beta_1 lik_1 + \beta_2 d_2 pop + \beta_3 d_3 pop \quad \begin{cases} d_2 = 1, d_3 = 0;\ pop \geq lik_1 \\ d_2 = 0, d_3 = 1;\ pop < lik_1 \end{cases} \tag{1}$$

where lik_1 and lik_2 are the stage one and stage two ratings respectively, *pop* is the popularity of the song, and d_2 and d_3 are dummy variables for the conditions of the first rating being (a) less favorable than, or (b) more favorable than, the popularity rating. The first coefficient in (1), β_0, represented any potential systematic bias to change the rating between the 1st to the 2nd listen. A positive β_0 would indicate a tendency to rate songs more favorably on the second than on the first listen. Large values for β_2 and β_3 relative to β_1 indicated that the popularity rating had greater weight in determining the stage two likability rating than did the stage one rating; small values indicated the opposite. A mixed-model linear regression was performed at the individual subject level with regression coefficients derived for each subject for later incorporation in the fMRI model. The two popularity weights for each participant (β_2 and β_3) were divided by the coefficient of the first likability rating (β_1) to produce a vector (β_2/β_1, β_3/β_1) representing how much an individual was influenced by the popularity information.

The analysis of the fMRI data was conducted in the following manner. Preprocessing of the fMRI data was executed in SPM5 (Functional Imaging Laboratory, UCL, London). The preprocessing pipeline consisted of slice timing correction, motion correction, spatial normalization, and smoothing (with an 8mm Gaussian kernel). A first-level GLM, also constructed in SPM5, contained 9 conditions for the 27 participants, and its structure is shown in Table 1. Stage one of each trial was a variable duration event with 2 parametric modulators: the popularity rating (*pop*) and the participant's likability rating (lik_1) after listening to the song clip once. Stage two, also a variable duration event, was binned into one of two columns based upon whether the popularity was shown or blocked on that trial. The condition where the popularity was shown was also modulated by popularity (*pop*) and stage one rating (lik_1), while the condition where popularity was blocked was modulated by the stage one rating only. All three variable duration rating phases of the trial (familiarity, stage one likability, and stage two likability) were collapsed into one condition with no parametric modulators. The motion parameters were also included in the model as an effect of non-interest.

Insert table 1 about here

Three second-level models were constructed as one-sample t-tests in SPM5 using contrast images from the first-level model above. The first model simply included the main effect of Stage 1. This contrast identified brain regions that responded to the music clips relative to the implicit baseline of doing nothing. The second model was formulated to identify brain regions in which there was a significant correlation between the individual's likability of the song during Stage 1 and the level of BOLD response. This contrast simply included the Stage1 x lik_1 condition, and therefore only had one column. The third model was formulated to identify brain regions that were more responsive to popularity *in subjects who exhibited conforming behavior*. This contrast was constructed from the first-level contrast, Stage2 (popularity shown) x *pop* along with two subjectwise covariates based on the behavioral regression (equation 1). Because the behavioral regression yielded a two-dimensional vector for each subject for the effect of popularity (β_2/β_1 - upside and β_3/β_1 - downside effects of popularity), we used principal components analysis (PCA) to determine the natural way to combine these dimensions based on the distribution of values in our cohort of subjects. The principal component scores were then used as subjectwise covariates in the second-level fMRI model of *Stage 2 activation x pop*. The three columns that made up this model were the main effect of popularity on brain activation, the interaction of the weighted sum of $\beta_2/\ \beta_1$ and $\beta_3/\ \beta_1$ (the first PCA score) with popularity, and the interaction of the weighted difference of $\beta_2/\ \beta_1$ and $\beta_3/\ \beta_1$ (the second PCA score) with popularity.

3. Results

3.1 Individual Ratings and Social Influence

The two panels of Figure 2 illustrate the percentage of individuals who changed their ratings between stages one and two. The popularity information had a significant effect on participants' ratings of how much they liked the songs. The upper panel of the figure shows that when no popularity information was given, participants changed their ratings in 11.6% of the trials. However, when popularity was shown, they changed their ratings 21.9% of the time (P=0.0006, paired t-test, 31 d.f.). The lower panel in the figure displays the percentage of time (out of the trials in which the rating was changed) that the rating was changed in the direction of the popularity. Conditional on a change in rating, it was in the direction of the observed popularity rating 38.3% of the time when the rating was not displayed versus 79.9% of the time when the popularity was shown (P<0.00001). The figure clearly shows that the popularity rating influenced individual ratings.

We also considered the correlation between the demographic factors variables gender and age, and the effect of popularity on the likability ratings. Gender was not significantly correlated with the percentage of trials in which the individual changed his/her rating in the direction of the observed popularity rating. However age did exhibit a significant correlation, with younger subjects changing their ratings more frequently [R = -0.46, P=0.02].[4]

[4] The percentage of trials in which individuals changed their ratings was also uncorrelated with the risk aversion coefficients estimated from the Harbaugh risk aversion task. However, there was a correlation between the tendency to change ratings and the ARQ measure, with individuals with higher ARQ scores p=0.02, r=-0.4, n=32, with a greater propensity toward risky behavior having a negative correlation with the tendency to change one's rating. However, ARQ and age were also correlated with each other.

Insert figure 2 about here

Estimation of equation (1) for the pooled data from all participants yielded the following results. β_0 = -0.15 [se=0.05, *t*(319)=-2.73, *P*=0.007], indicating that there was a small, but systematic, tendency to decrease the rating between stages 1 and 2. The stage 1 rating was highly significant: β_1 = 0.90 [se=0.02, *t*(1029)=48.6, *P*<0.0001], indicating a generally high degree of stability between an individual's stage 1 and stage 2 ratings. The primary regressors of interest, β_2 and β_3, were both significant: β_2 = 0.15 [se=0.01, *t*(1069)=12.1, *P*<0.0001] and β_3 = 0.08 [se=0.03, *t*(1066)=2.5, *P*=0.013]. This indicates a significant tendency for ratings to adjust in the direction of the popularity rating between stages 1 and 2, irrespective of whether the popularity is more or less favorable than one's own stage 1 rating, although the effect was greater when popularity was greater than the stage 1 rating. Estimation of the model for each individual separately yielded the result that the overall regression was significant for every subject at *P*<0.001, with individual model R^2s ranging from 0.37 to 1 (mean=0.81, SD=0.15). The PCA of the dimensions of sensitivity to popularity information, β_2/β_1 and β_3/β_1, yielded a factor weightings of 0.88 for β_2/β_1 and 0.48 for β_3/β_1, which again was consistent with the somewhat greater effect of popularity when $pop>lik_1$. The first PCA component was the weighted sum: $0.88*\beta_2/\beta_1 + 0.48*\beta_3/\beta_1$, and the second PCA component was the weighted difference: $-0.88*\beta_2/\beta_1 + 0.48*\beta_3/\beta_1$.

3.2. fMRI Results

Figure 3 illustrates the regions of the brain that activated in response to listening to the musical stimuli in stage 1. The music elicited activation in a broad network of brain regions associated with auditory and visual sensory processes. These included bilateral superior temporal gyri (auditory cortex), occipital cortex (visual cortex), superior parietal cortex (multimodal sensory integration regions), thalamus, and basal ganglia (caudate nucleus and putamen). The activity in these regions was our reference in comparison to the implicit baseline of no stimulation.

Insert figure 3 about here

Figure 4 shows the regions whose activation correlated with the Stage 1 likability rating of the song, and Table 2 lists the regions and indicates their location. Greater activation is associated with a higher rating for the song. The activation is measured during the stage 1 listen, but before the stage 1 rating was actually submitted. The set of regions activated was distinct from the auditory network and was restricted to bilateral caudate nuclei, right lateral prefrontal cortices (middle and inferior gyri), and thalamus.

Insert table 2 and figure 4 about here

Figure 4 also shows the brain regions that exhibited greater activation for individuals with a greater tendency to conform. The results are also shown in Table 3. The figure indicates the interaction between the second component of the PCA (the weighted difference), and the sensitivity of activation to popularity during Stage 2. Only two regions showed a significant relationship: the left and right anterior insula. The finding that it was the weighted difference of the components underscores an important finding about the relationship of insula activation to popularity. A positive interaction with β_2/β_1 suggests that subjects who changed their ratings when $pop>lik_1$ had increasing insula activation as popularity increased. At the same time, a negative interaction with β_3/β_1 indicates that these same subjects also had increasing insula activation as popularity decreased when $pop<lik_1$. Together, the two dimensions of the weighted difference indicate a V-shaped relationship of insula activation to popularity with the minimum located at the subject's lik_1 rating. In other words, it is the absolute difference $|pop - lik_1|$ that correlates with insula activity – *but only in those subjects who change their ratings in response to popularity* (conformists).

Insert table 3 about here

4. Discussion

To our knowledge, this is the first neuroeconomic study of the effect of popularity on the preference for a consumer good. One possibility for why popularity information affects consumer decisions is that popularity, like market price, changes the intrinsic value of the consumption good at the most basic level (Plassmann, O'Doherty, Shiv, & Rangel, 2008)[5]. This would presumably occur via a mechanism operating directly on reward pathways in the orbitofrontal cortex and striatal systems. A second possible mechanism, and one for which we find evidence in this study, is that the resolution of personal preference with a consensus opinion invokes a different set of cognitive and emotional processes outside the reward/utility system in the brain. The bilateral insula activation we observe suggests that the latter mechanism is at work, for the specific population, social information, and consumption good we consider here.

The effect of music on the brain spans several different brain regions and cognitive systems. Not surprisingly, the primary effect is on the auditory cortex, located around Heschl's gyrus in the superior temporal lobes. Consistent with previous studies of music stimuli, we observed the largest activations in these regions (Janata et al., 2002; Koelsch, 2005; Koelsch, Fritz, Schulze, Alsop, & Schlaug, 2005; Sridharan, Levitin, Chafe, Berger, & Menon, 2007). Beyond the raw effect of auditory stimulation, music invokes semantic processes such as whether the musical phrases make sense, and language processes for lyrical content (Levitin & Menon, 2003). These cognitive functions are notably more complex than simple auditory processing and have been associated with activity in language regions of the lateral prefrontal cortex. We also observed this activation as a main effect of the stimulus (Koelsch, 2005; Koelsch

[5] Recent work in neuroeconomics has suggested that the price of a good modulates the neural response in orbitofrontal cortex. Using sips of wine as a stimulus, while manipulating the "retail" price, Plassmann et al. (Plassmann et al., 2008) observed increased activity in the orbitofrontal cortex when the price was higher. The orbitofrontal cortex is a region of the brain that has been frequently associated with both hedonic (experienced) pleasure and expected economic value (Padoa-Schioppa & Assad, 2006; Roesch, Taylor, & Schoenbaum, 2006; Rolls, 2000; Tremblay & Schultz, 1999). These results suggest that an exogenous effect, like market price, may change the experienced utility of a good at the most basic, biological level.

et al., 2005). We also observed activity of motor and premotor regions of the cortex. As others have noted, the perception of music is, in part, linked to the production of music (e.g. singing or tapping along), and it is common to observe a coupling between auditory streams and motor streams when listening to music (Grahn & Brett, 2007; Lahav, Saltzman, & Schlaug, 2007; Zatorre, Chen, & Penhume, 2007).

Compared to the main effect of listening to music, which resulted in multiple activations across different cortical systems, we observed a highly restricted network of regions that correlated with the rating assigned to the individual songs. The strongest correlations were observed in the head of the caudate nucleus bilaterally. This region of the caudate nucleus receives a dense dopaminergic projection from brainstem nuclei and is widely viewed as playing a key role in reward and valuation. The precise nature of this role is still debated (e.g. experienced utility or hedonic pleasure, decision utility, reward-prediction error), but its role in value-based decision making appears well-established (Camerer et al., 2005; Glimcher et al., 2005; Hampton & O'Doherty, 2007; Knutson et al., 2007; Knutson et al., 2005; Montague & Berns, 2002). In our study, the pattern is clear: the higher the individual rated a particular song, the greater the activity in the caudate nucleus.[6]

The effect of conformity was manifest solely in the anterior insula (bilaterally). This region is typically associated with internal arousal states, frequently observed during the anticipation and experience of noxious stimuli (Berns et al., 2008; Berns et al., 2006; Chandrasekhar et al., 2008; Craig, 2003; Koyama et al., 2005; Peyron et al., 2000; Ploghaus et al., 2003; Porro et al., 2002). Activation of this region has also been associated with processing of financial risk (Preuschoff, Bossaerts, & Quartz, 2006) as well as social signals like empathic responses to pain in others (Singer et al., 2004). The individuals who exhibited the most conformity in behavior were those individuals who had the largest responses to popularity in their insula. This suggests that a mismatch between one's rating and the popular ratings may

[6] Because subjects were both experiencing the song and making a decision about how to rate it, which would have determined the contents of the CD they took home from the experiment, we cannot separate the elements of experienced utility from decision utility. It is worth noting, however, that previous imaging studies have identified the same region as correlating with intensely pleasurable musical experiences (Blood & Zatorre, 2001; Koelsch, Fritz, Von Cramon, Muller, & Friederici, 2006), which suggests that experienced utility is likely a significant component of the striatal response to music.

trigger a cognitive/emotional dissonance. This interpretation is consistent with a growing body of data that suggests the role of the anterior insula in interceptive processing, especially with regard to threatening stimuli (Craig, 2002; Critchley, Wiens, Rotshtein, Ohman, & Dolan, 2004). In contrast, among those subjects who were affected by social information, we did not find significant changes in the striatum. This suggests that the effect of popularity on individuals' ratings was not reflective of a change in their intrinsic preferences.

Although there are very few imaging studies of conformity per se, our results seem, in part, consistent with others' findings. In a previous study, our group found evidence for conformity-related activity changes in occipital and parietal areas during a task of mental rotation, but we also found activation of the amygdala when individuals went against the group opinion (Berns et al., 2005). This study was quite different in both the task and the incentives, yet the amygdala is another key structure in the arousal circuits of the brain. Anterior insula activation has also been associated with Machiavellian personality traits when social norms are enforced by the threat of punishment during a financial transfer game (Spitzer, Fischbacher, Herrnberger, Gron, & Fehr, 2007), and when subjects received unfair offers during the ultimatum game (Sanfey, Rilling, Aronson, Nystrom, & Cohen, 2004).

Our finding that conformity is not associated with striatal activation suggests that music popularity ratings do not affect adolescents' preferences over music. Clearly, we do not know whether a lack of a preference effect would be carried over to different consumption goods and age cohorts. However, based on our study and previous research mentioned above, it seems that one mechanism by which social influence affects behavior is through generating mismatch anxiety. There are at least two interesting implications of our neurobiological study of conformity that we believe may help economists in formulating models of conformity. The first is that mimicking others seems to be, at least in part, motivated by the need to avoid the disutility from being a contrarian rather than by the pursuit of a positive utility from doing the same thing as others. The second is that anxiety associated with conformity is a cost that perhaps economists should take into account when performing welfare calculations.

The effect of peer pressure has attracted the attention of economists and policy makers as a way to motivate people to change behaviors, and experimental evidence indicates that it can be a powerful force promoting cooperation (Masclet, Noussair, Tucker, & Villeval, 2003; Noussair

& Tucker, 2005; Rege & Telle, 2004). The existence of associated brain activation confirms that peer pressure is a physiological experience, which in principle could be measured; this can allow social scientists and policy makers to make economical and quick comparisons of the effectiveness of different sources of peer pressure before implementing them in the field. For example, one could potentially evaluate alternative social campaigns to reduce behavior viewed as socially suboptimal. Finally, for music or similar consumption goods that generate a hedonic reaction such as food and films, our research suggests that emphasizing the popularity of the product in addition to, or instead of, the intrinsic aspects of the product may be a powerful technique for promoting sales.

REFERENCES

Ariely, D., Loewenstein, G., & Prelec, D. (2006). Tom Sawyer and the construction of value. *Journal of Economic Behavior and Organization, 60*, 1-10.

Asch, S. E. (1951). Effects of group pressure upon the modification and distortion of judgements. In H. S. Guetzkow (Ed.), *Groups, Leadership and Men. Research in Human Relations* (pp. 177-190). Pittsburgh: Carnegie Press.

Asch, S. E. (1952). *Social Psychology*. New York: Prentice-Hall, Inc.

Bearden, W. O., & Rose, R. L. (1990). Attention to social comparison information: an individual difference factor affecting consumer conformity. *Journal of Consumer Research, 16*, 461-471.

Berns, G. S., Capra, C. M., Chappelow, J., Moore, S., & Noussair, C. (2008). Nonlinear neurobiological probability weighting functions for aversive outcomes. *NeuroImage, 39*, 2047-2057.

Berns, G. S., Chappelow, J. C., Cekic, M., Zink, C. F., Pagnoni, G., & Martin-Skurski, M. E. (2006). Neurobiological substrates of dread. *Science, 312*, 754-758.

Berns, G. S., Chappelow, J. C., Zink, C. F., Pagnoni, G., Martin-Skurski, M. E., & Richards, J. (2005). Neurobiological correlates of social conformity and independence during mental rotation. *Biol Psychiatry, 58*, 245-253.

Bettman, R. J., Luce, M. F., & Payne, J. W. (1998). Constructive consumer choice processes. *Journal of Consumer Research, 25*, 187-217.

Blood, A. J., & Zatorre, R. J. (2001). Intensely pleasurable responses to music correlate with activity in brain regions implicated in reward and emotion. *Proc Natl Acad Sci U S A, 98*(20), 11818-11823.

Camerer, C., Loewenstein, G., & Prelec, D. (2005). Neuroeconomics: how neuroscience can inform economics. *Journal of Economic Literature, XLIII*, 9-64.

Capra, C. M., & Li, L. (2008). Conformity in contribution games: gender and group effects. Emory University Working Paper.

Carpenter, J. (2004). When in Rome: conformity and the provision of public goods. *Journal of Socioeconomics, 33*(4), 395-408.

Cason, T. N., & Mui, V.-L. (1998). Social influence in the sequential dictator game. *Journal of Mathematical Psychology, 42*, 248-265.

Chandrasekhar, P. V., Capra, C. M., Moore, S., Noussair, C., & Berns, G. S. (2008). Neurobiological regret and rejoice functions for aversive outcomes. *NeuroImage, 39*(3), 1472-1484.

Childers, T., & Rao, A. (1992). The influence of familial and peer-based reference groups on consumer decisions. *Journal of Consumer Research, 19*(2), 198-211.

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

Cooper, D., & Rege, M. (2008). Social interaction effects and choice under uncertainty: an experimental study. Florida State University Working Paper.

Craig, A. D. (2002). How do you feel? Interoception: the sense of the phsyiological condition of the body. *Nature Reviews Neuroscience, 3*, 655-666.

Craig, A. D. (2003). Pain mechanisms: labeled lines versus convergence in central processing. *Annual Review of Neuroscience, 26*, 1-30.

Critchley, H. D., Wiens, S., Rotshtein, P., Ohman, A., & Dolan, R. J. (2004). Neural systems supporting interoceptive awareness. *Nature Neuroscience, 7*, 189-195.

Deutsch, M., & Gerard, H. B. (1955). A study of normative and informational social influences upon individual judgment. *Journal of Abnormal and Social Psychology, 51*, 629-636.

Escalas, J., & Bettman, J. R. (2005). Self-construal, reference groups, and brand meaning. *Journal of Consumer Research, 32*(3), 378-389.

Galvan, A., Hare, T. A., Parra, C. E., Penn, J., Voss, H., Glover, G., et al. (2006). Earlier development of the accumbens relative to orbitofrontal cortex might underlie risk-taking behavior in adolescents. *J Neurosci, 26*, 6885-6892.

Glimcher, P. W., Dorris, M. C., & Bayer, H. M. (2005). Physiological utility theory and the neuroeconomics of choice. *Games and Economic Behavior, 52*(2), 213-256.

Grahn, J. A., & Brett, M. (2007). Rhythm and beat perception in motor areas of the brain. *Journal of Cognitive Neuroscience, 19*(5), 893-906.

Gullone, E., Moore, S., Moss, S., & Boyd, C. (2000). The adolescent risk-taking questionnaire: development and psychometric evaluation. *Journal of Adolescent Research, 15*(2), 231-250.

Hampton, A. N., & O'Doherty, J. P. (2007). Decoding the neural substrates of reward-related decision-making with functional MRI. *Proc Natl Acad Sci U S A, 104*, 1377-1382.

Harbaugh, W. T., Krause, K., & Vesterlund, L. (2002). Risk attitudes of children and adults: choices over small and large probability gains and losses. *Experimental Economics, 5*, 53-84.

Janata, P., Birk, J. L., van Horn, J. D., Leman, M., Tillman, B., & Bharucha, J. J. (2002). The cortical topography of tonal structures underlying western music. *Science, 298*, 2167-2170.

Knutson, B., Rick, S., Wimmer, G. E., Prelec, D., & Loewenstein, G. (2007). Neural predictors of purchases. *Neuron, 53*, 147-156.

Knutson, B., Taylor, J., Kaufman, M., Peterson, R., & Glover, G. (2005). Distributed neural representation of expected value. *Journal of Neuroscience, 25*(19), 4806-4812.

Koelsch, S. (2005). Neural substrates of processing syntax and semantics in music. *Current Opinion in Neurobiology, 15*, 207-212.

Koelsch, S., Fritz, T., Schulze, K., Alsop, D., & Schlaug, G. (2005). Adults and children processing music: an fMRI study. *NeuroImage, 25*, 1068-1076.

Koelsch, S., Fritz, T., Von Cramon, D. Y., Muller, K., & Friederici, A. D. (2006). Investigating emotion with music: an fMRI study. *Human Brain Mapping, 27*, 239-250.

Koyama, T., McHaffie, J. G., Laurienti, P. J., & Coghill, R. C. (2005). The subjective experience of pain: where expectations become reality. *Proceedings of the National Academy of Science, USA, 102*(36), 12950-12955.

Lahav, A., Saltzman, E., & Schlaug, G. (2007). Action representation of sound: audiomotor recognition network while listening to newly acquired actions. *Journal of Neuroscience, 27*(2), 308-314.

Lascu, D. N., & Zinkhan, G. (1999). Consumer conformity: review and applications for marketing theory and practice. *Journal of Marketing Theory & Practice, 7*(3), 1-12.

Levitin, D. J., & Menon, V. (2003). Musical structure is processed in "language" areas of the brain: a possible role for Brodmann Area 47 in temporal coherence. *NeuroImage, 20*(2142-2152).

Masclet, D., Noussair, C., Tucker, S., & Villeval, M. C. (2003). Monetary and non-monetary sanctions in the voluntary contributions method. *American Economic Review, 93*, 366-380.

Montague, P. R., & Berns, G. S. (2002). Neural economics and the biological substrates of valuation. *Neuron, 36*, 265-284.

Noussair, C., & Tucker, S. (2005). Combining monetary and social sanctions to promote cooperation. *Economic Inquiry, 43*, 649-660.

Padoa-Schioppa, C., & Assad, J. A. (2006). Neurons in the orbitofrontal cortex encode economic value. *Nature, 441*, 223-226.

Peyron, R., Laurent, B., & Garcia-Larrea, L. (2000). Functional imaging of brain responses to pain. A review and meta-analysis. *Neurophysiologic Clinics, 30*, 263-288.

Plassmann, H., O'Doherty, J., Shiv, B., & Rangel, A. (2008). Marketing actions can modulate neural representations of experienced pleasantness. *Proc Natl Acad Sci U S A, 105*(3), 1050-1054.

Ploghaus, A., Becerra, L., Borras, C., & Borsook, D. (2003). Neural circuitry underlying pain modulation: expectation, hypnosis, placebo. *Trends in Cognitive Sciences, 7*(5), 197-200.

Porro, C. A., Barardi, P., Pagnoni, G., Serafini, M., Facchin, P., Maieron, M., et al. (2002). Does anticipation of pain affect cortical nociceptive systems? *Journal of Neuroscience, 22*(8), 3206-3214.

Preuschoff, K., Bossaerts, P., & Quartz, S. R. (2006). Neural differentiation of expected reward and risk in human subcortical structures. *Neuron, 51*, 381-390.

Rangel, A., Camerer, C., & Montague, P. R. (2008). A framework for studying the neurobiology of value-based decision making. *Nature Reviews Neuroscience, 9*, 545-556.

Rege, M., & Telle, K. (2004). The impact of social approval and framing in public good situations. *Journal of Public Economics, 88*, 1625-1644.

Roesch, M. R., Taylor, A. R., & Schoenbaum, G. (2006). Encoding of time-discounted rewards in orbitofrontal cortex is independent of value representation. *Neuron, 51*, 509-520.

Rolls, E. T. (2000). The orbitofrontal cortex and reward. *Cerebral Cortex, 10*, 284-294.

Sanfey, A. G., Rilling, J. K., Aronson, J. A., Nystrom, L. E., & Cohen, J. D. (2004). The neural basis of economic decision-making in the Ultimatum Game. *Science, 300*, 1755-1758.

Singer, T., Seymour, B., O'Doherty, J., Kaube, H., Dolan, R. J., & Frith, C. D. (2004). Empathy for pain involves the affective but not sensory components of pain. *Science, 303*, 1157-1162.

Slovic, P. (1995). The construction of preference. *American Psychologist, 50*, 364-371.

Spitzer, M., Fischbacher, U., Herrnberger, B., Gron, G., & Fehr, E. (2007). The neural signature of social norm compliance. *Neuron, 56*, 185-196.

Sridharan, D., Levitin, D. J., Chafe, C. H., Berger, J., & Menon, V. (2007). Neural dynamics of event segmentation in music: converging evidence for dissociable ventral and dorsal networks. *Neuron, 55*(3), 521-532.

Steinberg, L., & Monahan, K. C. (2007). Age differences in resistance to peer influence. *Developmental Psychology, 43*(6), 1531-1543.

Tremblay, L., & Schultz, W. (1999). Relative reward preference in primate orbitofrontal cortex. *Nature, 398*, 704-708.

Zatorre, R. J., Chen, J. L., & Penhume, V. B. (2007). When the brain plays music: auditory-motor interactions in music perception and production. *Nature Reviews Neuroscience, 8*, 547-558.

TABLES

Table 1. Columns in the first-level fMRI model.

Stage 1			Stage 2					Ratings
All trials	x pop	x lik_1	Trials where popularity was *shown*	x pop	x lik_1	Trials where popularity was *blocked*	x lik_1	Familiarity, Stage one likability, Stage two likability

Table 2. Brain regions correlating with likability during listen 1 (*P*<0.001 and cluster size ≥ 5).

		MNI			Talairach				
Label	**BA**	**x**	**y**	**Z**	**x**	**y**	**z**	**T**	**Size**
R Caudate	Caudate Body	12	6	9	12	6	8	6.80	68
L Caudate	Caudate Body	-12	3	12	-12	3	11	5.73	44
R Inferior Frontal/Middle Frontal	9	57	21	27	56	22	24	5.26	80
R Inferior Frontal	47	51	21	-12	50	20	-11	4.71	24
R Thalamus		6	-12	15	6	-11	14	4.58	43
R Precentral	6	54	6	48	53	8	44	4.48	7
R Middle Frontal	9	39	3	39	39	5	36	3.95	9
R Middle Temporal	21	60	-30	-3	59	-29	-1	3.92	10
R Superior Temporal		63	-39	12	62	-37	13	3.71	8

Table 3. Brain regions with a significant interaction between popularity during the listen 2 and the subjectwise conformity score (negative component 2 of the PCA) (*P*<0.001 and cluster size ≥ 5).

		MNI			Talairach				
Label	**BA**	**x**	**y**	**Z**	**x**	**y**	**z**	**T**	**Size**
R Insula	13	42	9	-9	42	8	-8	4.39	33
L Insula	13	-30	18	15	-30	18	13	4.36	10

FIGURE LEGENDS

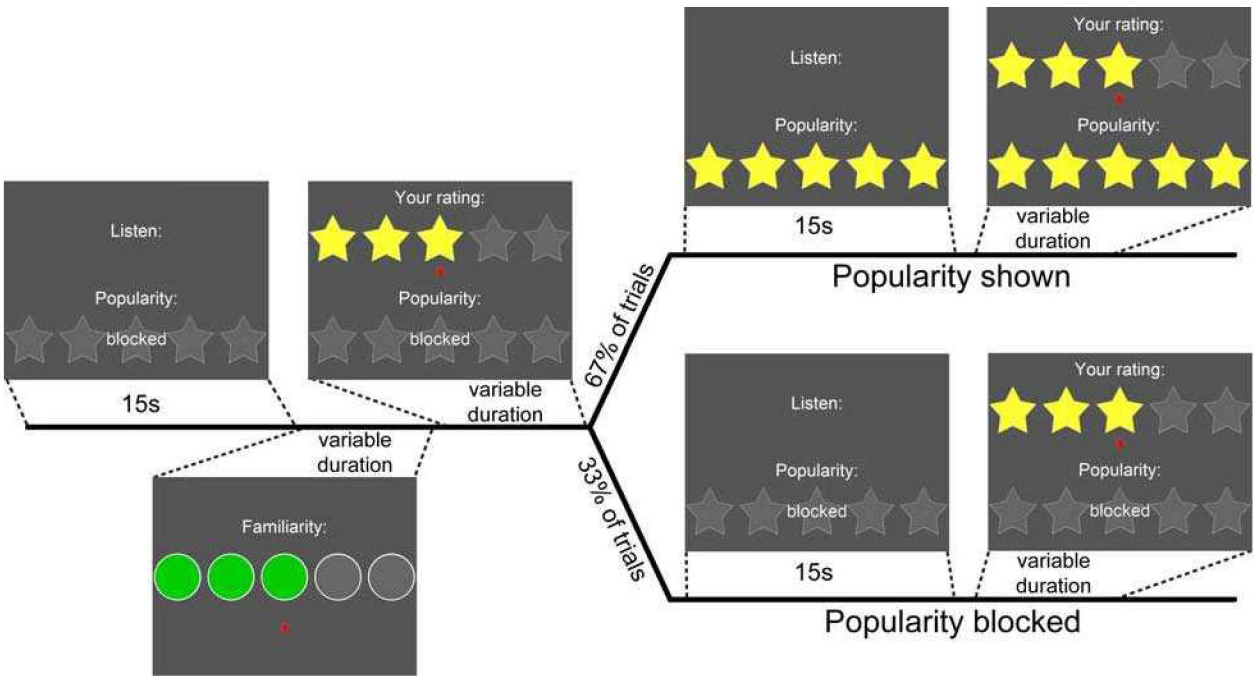
Figure 1. Trial design. Each trial began with a 15-second clip from a song downloaded from MySpace.com. Following the clip, the participant rated the song for both familiarity and likability on a 5-star scale. After the ratings, the participant heard the clip a second time, after which they rerated the song. There were a total of 60 trials. On 2/3 of the trials the popularity of the song was displayed during the second listen. On 1/3 of the trials, the popularity was not shown (blocked).

Figure 2. Behavioral results. The popularity treatment had a significant effect on the percentage of trials in which the participant changed their likability rating. Without popularity, participants changed their ratings on 11.6% of the trials, but with popularity shown, they changed their ratings in that direction 21.9% of the time (*top*, P=0.0006, paired t-test, 31 d.f.). When expressed as a fraction of the trials in which they changed their ratings, without popularity, they changed in that direction 38.3% of the time versus 79.9% of the time when popularity was present (*bottom*, P<0.00001).

Figure 3. Brain regions with significant activation during the 1st listen (P<0.001, k≥5). A broad network of activations was observed with the strongest activity in auditory cortex (bilateral superior temporal gyri) and sensory association areas (superior parietal cortex). These activations are consistent with auditory stimulation (the music) as well as visual stimulation (the rating screen).

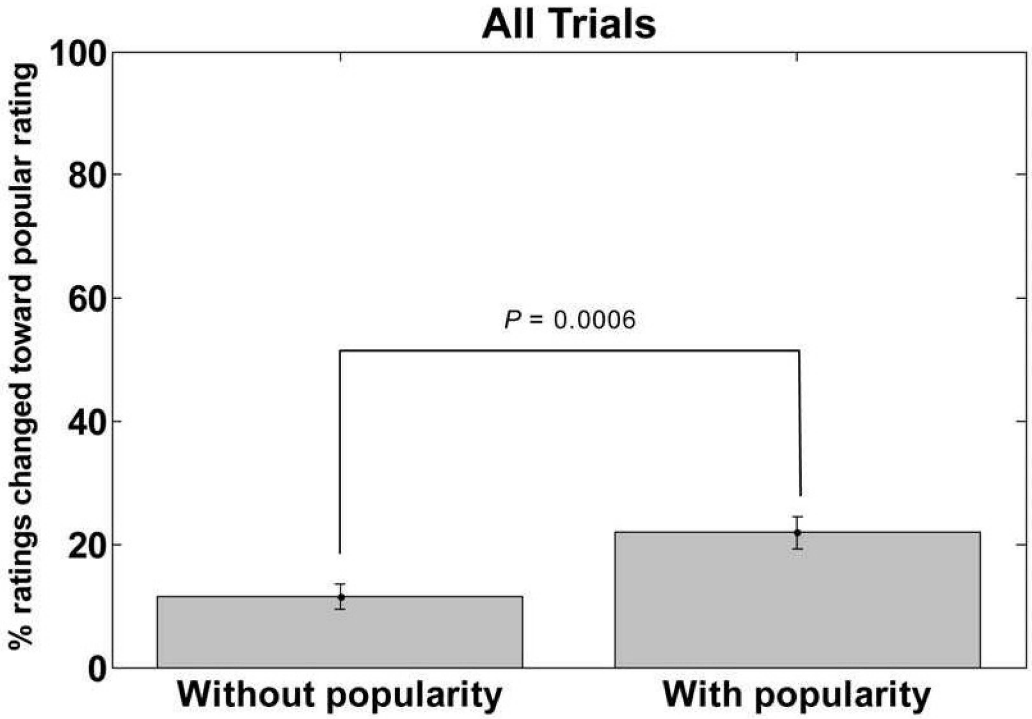
Figure 4. Brain regions with significant correlations to likability ratings during the 1st listen (*orange/yellow*) and interaction of popularity during the 2nd listen with subjectwise 2nd PCA score (*violet, circled*). All thresholds at P<0.001, k≥5. Likability correlated with activity strongly in bilateral caudate nucleus (*above left* and *lower right*) and right lateral prefrontal cortex (middle and inferior gyri, *upper right*). The effect of popularity was strongest in subjects who exhibited conformity behavior, and this was manifest only in the anterior insula (bilaterally). The relationship to the 2nd PCA score indicates a V-shaped relationship to the difference between *pop* and lik_1, suggesting that conforming behavior is driven by mismatch anxiety in those subjects sensitive to popularity information.

Figure 1.

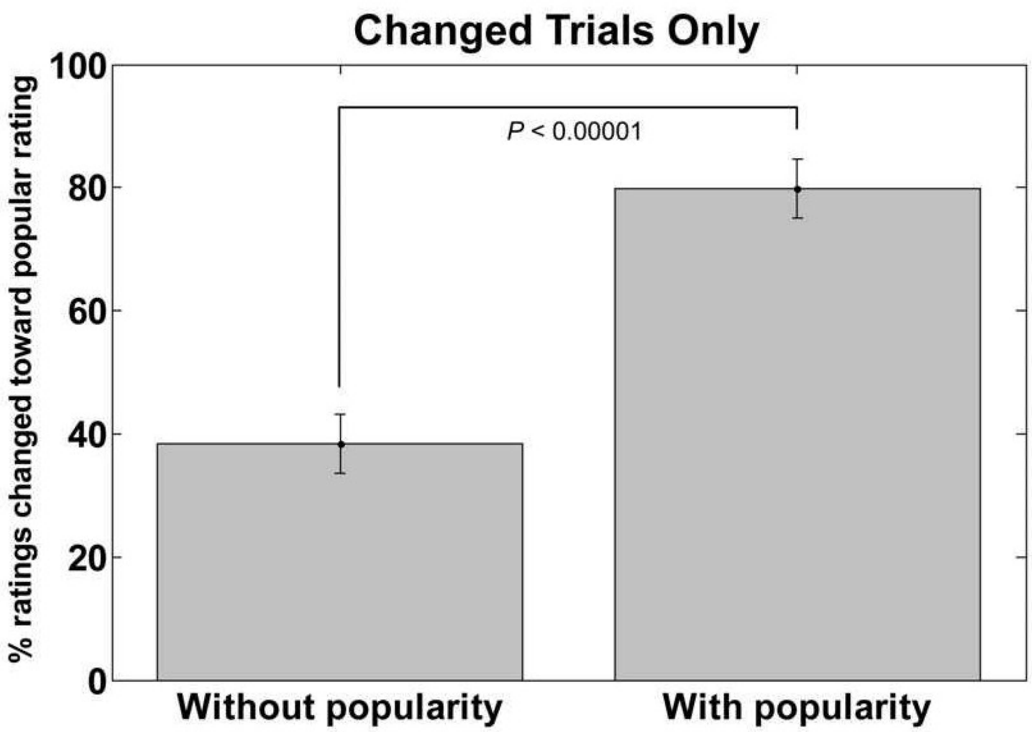


Listen:
Popularity:
blocked
15s
Your rating:
Popularity:
blocked
variable
duration
variable
duration
Familiarity:
67% of trials
33% of trials
Listen:
Popularity:
15s
Your rating:
Popularity:
variable
duration
Popularity shown
Listen:
Popularity:
blocked
15s
Your rating:
Popularity:
blocked
variable
duration
Popularity blocked

Figure 2.



All Trials
% ratings changed toward popular rating
100
80
60
40
20
0
P = 0.0006
Without popularity
With popularity



Changed Trials Only
% ratings changed toward popular rating
100
80
60
40
20
0
P < 0.00001
Without popularity
With popularity

Figure 3.

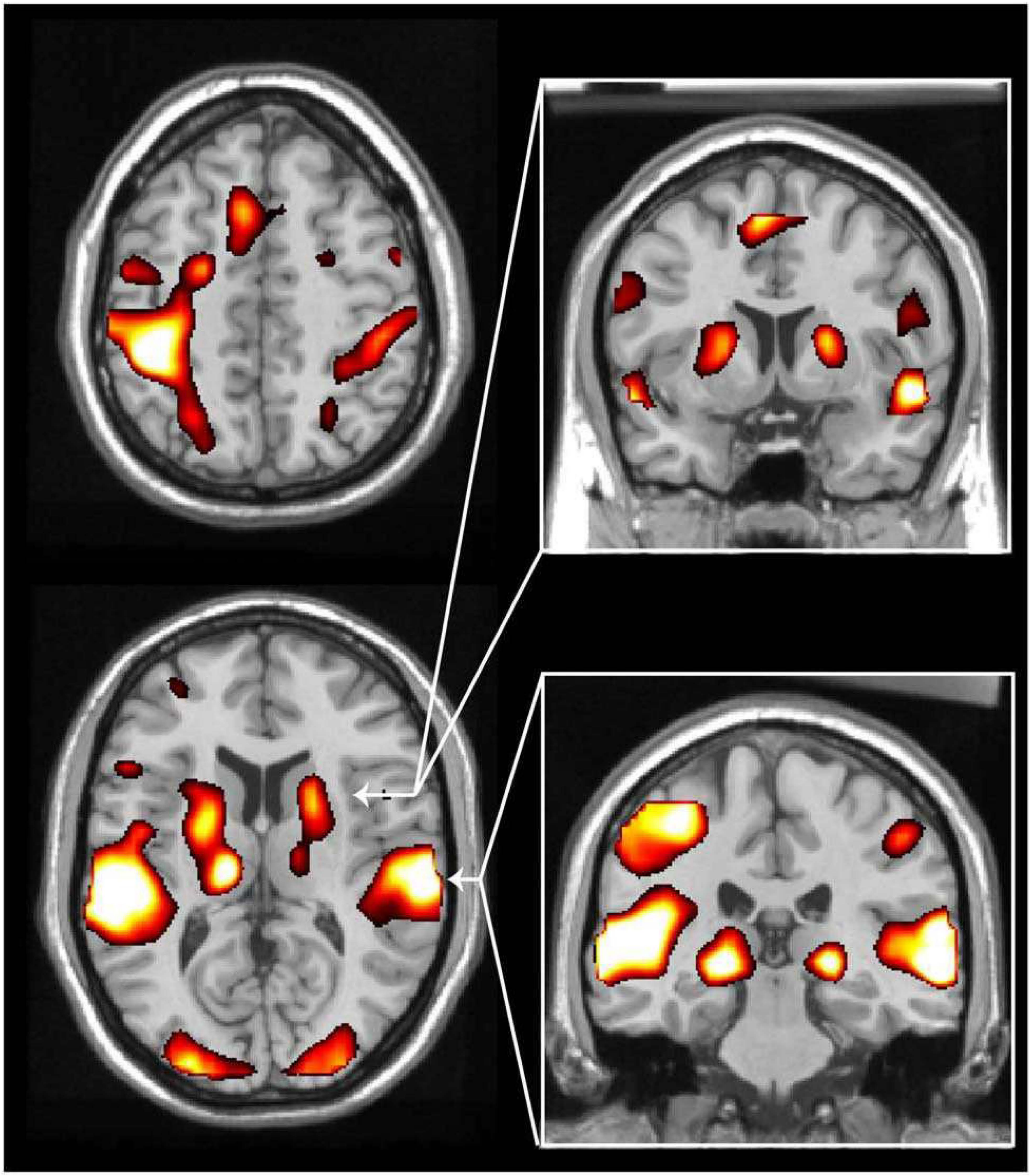


Figure 4.