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How choice modifies preference: Neural correlates of choice justification

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ABSTRACT

When making a difficult choice, people often justify the choice by increasing their liking for the chosen object and decreasing their liking for the rejected object. To uncover the neural signatures of choice justification, we used functional magnetic resonance imaging to monitor neural activity when subjects rated their preference for chosen and rejected musical CDs before and after they made their choices. We observed that the trial-by-trial attitude change (i.e., increase of preference for chosen items and decrease of preference for rejected items) was predicted by post-choice activity in the ventral medial prefrontal cortex (MPFC), right temporal–parietal junction, anterior insula, and bilateral cerebellum. Furthermore, individual difference in choice justification (i.e., increased preference for chosen items minus decreased preference for rejected items) was predicted by post-choice neural activity in the dorsal MPFC, left lateral prefrontal cortex, and right precentral cortex positively. In addition, interdependent self-construal was correlated with decreased activity in the ventral MPFC in the post-choice than pre-choice sessions. These findings suggest that both negative arousal/regulation and self-reflection are associated with choice justification. This provides evidence for the self-threat theory of choice justification.

Introduction

Cognitive dissonance has been investigated using a wide variety of methodologies (see Harmon-Jones and Harmon-Jones, 2007 for a review). One of the most commonly used experimental paradigms involves a choice between two equally attractive objects (Brehm, 1956). Numerous behavioral studies have shown that, after making a difficult choice, people justify this choice by increasing their liking for the chosen item and decreasing their liking for the rejected item. The choice justification is believed to occur because people are motivated to reduce their cognitive conflict or dissonance (Brehm, 1956; Festinger, 1957). Researchers have hypothesized that this choice-induced conflict, and the resulting dissonance reduction, may be most likely to occur when the conflict poses a threat to a person's private sense of the self as rational and competent (Steele, 1988), the sense of the self as publicly recognized as rational and decent (Kitayama et al., 2004; Tedeschi and Reiss, 1981), or both.

Recent functional magnetic resonance imaging (fMRI) studies have provided some insight into the neural correlates of dissonance. In one study, van Veen et al. (2009) found that neural activity in the dorsal anterior cingulate cortex (dorsal ACC) and in the anterior insula increased to statements that conflicted with subjective feelings. This suggests that detection of cognitive conflict (dorsal ACC) and aversive somatic arousal (anterior insula) constitute important elements of cognitive dissonance, as implied by Festinger (1957) in his original formulation. Indeed, as would be predicted by the dissonance theory, the dissonance as indexed by the activity in these brain regions during the choice predicted subsequent attitude change in the form of justifying the dissonance-producing behavior (van Veen et al., 2009).

In another study, Jarcho et al. (in press) found that choice justification is reliably predicted by increased activations in the right inferior frontal gyrus and medial frontoparietal regions during the choice. The finding suggests that choice justification is mediated by regulation of negative arousal through inhibition of both competing information (right inferior frontal gyrus) and conscious attention (frontoparietal regions) to the chosen and rejected items. This study, however, scanned the brain only during the choice. Therefore, it is not clear whether and how representations of the chosen and rejected items might change as a consequence of choice.

A more recent study (Sharot et al., 2009) addressed this issue by testing choices among hypothetical vacation destinations. It was found that the attitude change involved in dissonance was mirrored by caudate activations in relation to the chosen and rejected items after the choice. However, this finding might not be applicable to difficult decisions involving objects one may actually be able to actually possess. Given this, much has yet to be learned about the neural mechanisms underlying *post-decisional* choice justification or dissonance reduction.

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To fill the gap of empirical knowledge on neural mechanisms underlying cognitive dissonance, we used a modified free-choice paradigm and scanned healthy young Chinese adults as they rated a set of CDs both before and after making a series of choices between these CDs. During the choice, the CDs were paired in such a way that the two CDs in each pair were equally attractive, as previous work shows that dissonance arises only when choices are difficult (Brehm, 1956; Sharot et al., 2009; Jarcho et al., in press). Moreover, in order to increase choice justification during the post-choice sessions, subjects were reminded which choice they had made earlier. We had two primary aims.

First, we aimed to investigate the brain regions recruited when subjects justified their choices. Previous research has found that choice justification is eliminated when one's sense of the self is affirmed after making a difficult choice (Hoshino-Browne et al., 2005; Steele, 1988). This supports the proposal that individuals justify their choice in order to eliminate a threat to the self. On the basis of this literature, we predicted that self-related brain areas such as the ventral MPFC (Kelley et al., 2002) and the dorsal/ventral lateral prefrontal cortex (Liberman, 2010) would be engaged in *post-decisional* choice justification. Furthermore, because the public sense of the self involves taking the perspectives of others (Imada and Kitayama, 2010; Kitayama et al., 2004), we anticipated that brain areas implicated in mind reading such as temporal–parietal junction (TPJ, e.g., Saxe and Kanwisher, 2003) and dorsal MPFC (e.g., Gallagher et al., 2000) might also be related to choice justification. In addition, since individuals justify their choices by inhibiting choice-inconsistent information while augmenting choice-consistent information (Jarcho et al., in press), we predicted that the brain areas implicated in regulation, such as the dorsal MPFC (Venkatraman et al., 2010), the dorsal LPFC (Ochsner and Gross, 2008), and the inferior frontal gyrus (Jarcho et al., in press), would also be involved.

Second, we aimed to examine whether, similar to the Sharot et al. (2009) study, choice justification might be tracked by neural activity that is related to subjectively experienced preferences. We expected that neural activities reflecting subjects' preferences, such as caudate (Sharot et al., 2009), ventral MPFC (McClure et al., 2004), and/or OFC (Kawabata and Zeki, 2008), would be altered by choice justification. In addition, given cultural differences in cognitive dissonance (Hoshino-Browne et al., 2005; Imada and Kitayama, 2010) and considerable variation within cultures in the extent to which they endorse their cultural norms, we assessed the relationship between change in the neural signatures related to subjects' preference and individual differences in independent self-construals (i.e., the view the self as an autonomous entity separate from others) and interdependent self-construals (i.e., the view of the self as interconnected with others as well as the social contexts; Markus and Kitayama, 1991).

Materials and methods

Subjects

Sixteen undergraduate and graduate students from Peking University, China (5 males, 11 females; 19–26 years of age, mean 22.3 ± 1.91, values are given as mean ± SD throughout), participated in this study as paid volunteers. All subjects were right-handed, had normal or corrected-to-normal vision, and had no neurological or psychiatric history. Informed consent was obtained prior to scanning. This study was approved by a local ethics committee.

Stimuli

Stimuli consisted of 60 popular music CDs, including 48 Chinese CDs and 12 European/American CDs. The artists of the CDs were known to college students. The cover of each CD was scanned and saved as a .jpg file.

Pre-scanning procedure

Subjects were asked to rank 60 CDs according to their degree of liking by categorizing the CDs into10 boxes with 6 CDs in each box. The ten boxes were marked with numbers from 1 to 10 (1 = slightly like the CD, 10 = extremely like the CD).

fMRI Scanning sessions and "free-choice" session

After the pre-scanning CD categorization task, subjects were scanned to get anatomical structures. This was followed by eight functional scanning sessions and intervened by a "free-choice" session.

Pre-choice session

The pre-choice session consisted of four event-related functional scanning sessions. On each trial, subjects were presented with a picture of a CD cover. They were then asked to either indicate "How much do you like the CD?" (preference judgment task) or "How new is the CD?" (recency judgment task) on a 4-point scale (1 = slightly like/slightly new; 2 = somewhat like/somewhat new; 3 = like/new; 4 = extremely like/extremely new). Subjects responded to each stimulus by pressing one of the four buttons as accurately and quickly as possible using the index and middle fingers of their left and right hands. Thirty preference judgments and 15 recency judgments were conducted in a random order in each scanning session.

Each trial started with the presentation of an instruction for 1000 ms, which defined the task (i.e., preference or recency judgments). Then the cover of a CD was presented for 3000 ms followed by an inter-stimulus interval that varied randomly among 1500, 2000, 2500 ms. Sixty CDs were used for the preference judgment task and, of those, 30 CDs were randomly selected for the recency judgment task. In order to collect enough data, these tasks consisted of two functional scanning sessions and were repeated once in an additional two scanning sessions.

Free choice

After the pre-choice session, subjects engaged in 30 free-choice trials. On each trial, two CD covers were presented on either side of the screen (i.e., right or left). Each CD was shown only once. Subjects were instructed to indicate which CD they wanted more by pressing one of the two buttons using the left or the right index finger. Prior to this, subjects were informed that one CD would be randomly selected from the CDs they chose and given to them as a token of appreciation for their participation at the end of the study. CDs pairs were determined by each subject's ranking of the CDs during the pre-scanning categorization task. That is, each pair was randomly selected from one of the 10 boxes so that each pair was equal in liking. Choices made during the free-choice session were used to classify the 60 CDs into the chosen and rejected items in the post-choice sessions.

Post-choice session

The post-choice session also consisted of four functional scanning sessions. All aspects of the post-choice session were identical to those in the pre-choice session except that each CD was shown with a color frame (i.e., red = chosen; green = rejected; gray = used in the recency judgment task) to indicate the status of the CD.

Post-scanning procedure

After the scanning procedure, each subject was asked to rate his/her independent/interdependent self-construal (Singelis, 1994) on a 7-point Likert-type scale (1 = strongly disagree to 7 = strongly agree).

fMRI Data acquisition

Scanning was performed at Peking University First Hospital on a GE 3-T scanner with a standard head coil. Thirty-two transverse slices of functional images covering the whole brain were acquired using a

$p<0.001$), suggesting that the preference for chosen over rejected CDs was larger during the post-choice than pre-choice sessions. Post hoc analysis confirmed that the rating scores for chosen CDs were higher in the post-choice than pre-choice sessions ($t(15)=2.93$, $p<0.05$), whereas rating scores for rejected CDs did not differ significantly between the post-choice than pre-choice sessions ($t(15)=2.03$, $p=0.06$).

fMRI Results

To identify neural activities associated with post-choice attitude change, we calculated the change in preference rating by subtracting the rating score of each CD in the pre-choice sessions from the rating score of the same CD in the post-choice sessions. We then conducted parametric modulation analysis during post-choice session using the change in preference rating as a regressor. We found that attitude change was associated with activations in the ventral MPFC ($x=-12/y=54/z=0$, $Z=3.53$; cluster size = 165 voxel), right temporal–parietal junction (TPJ) ($x=48/y=-60/z=12$, $Z=3.02$; cluster size = 205 voxel), anterior insula ($x=42/y=-2/z=6$, $Z=3.05$; cluster size = 66 voxel), and bilateral cerebellum ($x=28/y=-64/z=-30$, $Z=3.42$; cluster size = 131 voxel; $x=-38/y=-66/z=-30$, $Z=3.12$; cluster size = 121 voxel) (Fig. 2a).

We also conducted a regression analysis using the individual attitude change score (increase of preference for the chosen items minus decrease of preference for the rejected items) as the regressor. We found that activities in left LPFC($x=-24/y=56/z=8$, $Z=3.73$; cluster size = 133 voxel), dorsal MPFC ($x=-4/y=14/z=54$, $Z=3.23$; cluster size = 111 voxel), and right precentral cortex ($x=54/y=-8/z=44$, $Z=3.09$; cluster size = 212 voxel) positively correlated with subjects' attitude change scores (Fig. 2b).

Similar to the previous research (Sharot et al., 2009), we assessed whether neural activities can predict individual differences in eference l723eviois,l723242sessed6209(neura28.11110TD-158/F21Tf61170TD(

Table 1
Brain activities differentiating preference judgment of chosen CDs and that of rejected CDs during pre-choice and post-choice sessions.

	Brain region	*X*	*Y*	*Z*	*Z* value	Voxel no.
Pre-choice	**Preference$_{Chosen}$ > Preference$_{Rejected}$**					
	Posterior cingulate cortex/precuneus	0	−64	28	3.89	455
		2	−62	18	3.48	
	Middle cingulate cortex	2	−16	28	4.36	146
	Preference$_{Rejected}$ > Preference$_{Chosen}$					
	Postcentral/paracentral cortex (R)	30	−40	60	5.04	7356
		20	−44	60	4.59	
	Paracentral cortex/precuneus (L)	−8	−44	60	3.45	327
		−10	−44	48	3.39	
	Superior temporal cortex (L)	−46	−32	4	3.20	290
	Insula (R)	32	−28	10	3.00	183
Post-choice	**Preference$_{Chosen}$ > Preference$_{Rejected}$**					
	Cuneus/precuneus	−2	−70	30	3.50	538
		6	−60	48	3.23	
	Preference$_{Rejected}$ > Preference$_{Chosen}$					
	Insula (R)	40	−20	8	3.77	1158
	Postcentral cortex (R)	44	−28	56	3.46	380
Conjunction	**Preference$_{Chosen}$ > Preference$_{Rejected}$**					
	Posterior cingulate/precuneus	0	−68	32	3.95	429
		6	−54	28	3.34	
	Preference$_{Rejected}$ > Preference$_{Chosen}$					
	Insula (R)	40	2	4	3.86	725
	Postcentral cortex (R)	44	−28	56	3.76	1115

R: right hemisphere; L: left hemisphere. Voxels survived an uncorrected p value of 0.005, cluster size > 100, $p < 0.001$ uncorrected.

activity was linked to preference judgment for the chosen CDs, whereas the right insula and postcentral cortex were associated with preference judgment for the rejected CDs (Fig. 4a; Table 1: Conjunction). The neural activity linked to preference judgments was assessed by contrasting preference and recency judgment tasks. These revealed activations in the precuneus as well as the right PCC in the pre-choice session and in the ventral MPFC in the post-choice session (Fig. 4b; Table 1: Conjunction).

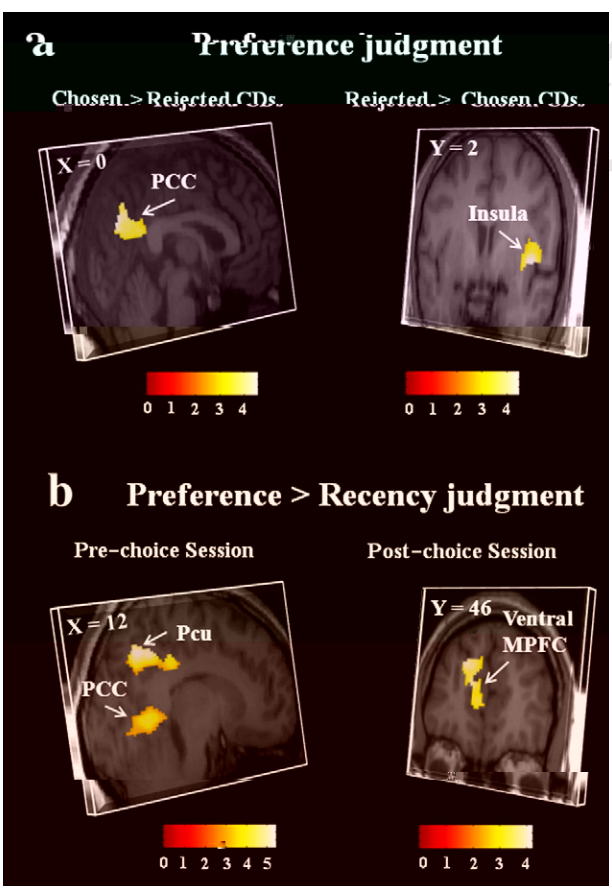

Fig. 4. (a) Brain activities differentiating preference judgment of chosen CDs and preference judgment of rejected CDs. (b) Brain activities linked to preference judgment during pre-choice and post-choice sessions. PCC = posterior cingulate cortex; Pcu = precuneus; MPFC = medial prefrontal cortex.

Discussion

Neural mechanisms of choice justification

Our behavioral measurements showed, consistent with the previous studies (Brehm, 1956; Kitayama et al., 2004), that after making choices between two similarly likable CDs, subjects increased their liking for chosen CDs and tended to decrease their liking for rejected CDs. The increase of liking for chosen CDs was highly significant, but the decrease of liking for rejected CDs was rather weak possibly due to a simple floor effect on rejected CDs. Given the data reported by Shultz et al. (1999), who found that choice justification is realized by boosting the preference of chosen items when the relevant items are relatively unattractive, the present finding might mean that the CDs we used were not highly attractive for the subjects we tested.

Our fMRI results uncovered neural activities associated with the trial-by-trial attitude change in the ventral MPFC, right TPJ, anterior insula, and bilateral cerebellum. The ventral MPFC was activated in studies involving self-reference processing (Kelley et al., 2002; Han et al., 2008; Zhu et al., 2007), whereas the right TPJ is commonly recruited when perspective taking is required during mental attribution (Frith and Frith, 2006; Decety and Lamm, 2007; Carrington and Bailey, 2009). Thus our fMRI results suggest that self-reflection resulting from taking others' perspectives (i.e., an appraisal of the public self) was possibly involved during choice justification in our Chinese subjects. This evidence converges with recent behavioral data that participants from Asian cultural groups tend to show a choice justification effect when the self is experienced as "being seen" by others (Imada and Kitayama, 2010; Kitayama et al., 2004). In line with the previous fMRI studies (van Veen et al., 2009; Jarcho et al., in press), we also found anterior insula activation in association with choice justification, suggesting that negative somatic arousal might be generated when individuals justify their choices.

In addition, we found that activations in the dorsal MPFC, left LPFC, and right precentral cortex positively correlated with each subject's overall attitude change score. These findings are consistent with the hypothesis that choice justification may require regulation processes that are mediated by the dorsal MPFC and left LPFC (Venkatraman et al., 2010; Ochsner and Gross, 2008). However, the activations in the dorsal MPFC, left LPFC, and right precentral cortex did not overlap with regions that correlated with the trial-by-trial attitude change score. It is possible that there is a relatively stable individual difference in the degree to which the self-regulatory processes are engaged across all trials throughout the entire experimental session. The overall degree of choice justification may be expected to be greater for those who engage self-regulatory processes to justify their choices than those who do not. At the same time, however, across the 30 choices, people may engage their self-appraisals (vMPFC) mediated by perspective tasking (TPJ) to varying extent. They may do so more on some trials than on some other trials. This may be expected to result in a trial-by-trial variation in choice justification. The two processes (i.e., self-regulation that varies across individuals and self-referential processing that varies within each individual) are distinct and, yet, we suspect within the specific experimental setting of the present study that they result in the same behavioral outcome of choice justification.

During the post-choice rating session of the present study, subjects were given an explicit marker of whether they had chosen or rejected each CD. This procedure might have resulted in top–down modulation of preference related brain response (de Araujo et al., 2005; Plassmann et al., 2008; Kirk et al., 2009). However, the brain areas that were associated with attitude changes in the present study included left LPFC (−24, 56, 8), dorsal MPFC (−4, 14, 54), and right precentral cortex (54, −8, 44). These brain regions are different from those involved in the top–down modulation of preference responses. For example, Kirk et al. (2009) found that neural activity in the right medial orbitofrontal cortex (12, 48, −20) and the ventral medial prefrontal cortex (−10, 60, 2) correlated with aesthetic ratings. Accordingly, it is unlikely that the present results were influenced by the top–down modulation of preference responses (Table 2).

Neural markers of preferences

Parametric modulation analysis showed that PCC activity was positively correlated with subjects' preference. Consistent with this, the previous studies have shown that activation in the PCC is positively correlated with the perceive desirability of objects (Kawabata and Zeki, 2008) or the subjective value of delayed monetary rewards (Kable and Glimcher, 2007). Because the PCC is also implicated in self-referential processing and autobiographic memory (Rameson et al., 2010; Sajonz et al., 2010), this brain region might play a significant role in indexing preferences that are grounded in the personal self.

It is important to note, however, that the PCC activation did not relate to the choice justification effect in our study. This might indicate that there are multiple neural bases for expressed preferences. The choice justification effect we observed might be based on preferences that are tied to appraisals of the public self (vMPFC and TPJ). Both the public self (vMPFC and TPJ) and the personal self (PCC) could inform expressed preferences.

Neural activations that predicted choices

Because PCC activation is related to personal preferences and, moreover, personally preferred CDs are more likely to be chosen than personally less preferred CDs, it should not come as any surprise that activation in the PCC/precuneus was linked to preference judgment of chosen CDs. Moreover, previous studies have linked anterior insula to negative somatic arousal. It would therefore seem reasonable that activations in the right insula were associated with preference judgment of rejected CDs during post-choice session. Importantly, however, these brain activations were observed during the pre-choice scanning session, meaning that in our studies, the PCC activity predicted selection of CDs and the anterior insula activity predicted rejection of CDs during the subsequent choice session.

Table 2
Brain activities linked to preference judgment during pre-choice and post-choice sessions.

	Brain region	*X*	*Y*	*Z*	*Z* value	Voxel no.
Pre-choice	**Preference$_{Chosen}$ > Recency**					
	Middle cingulate cortex/precuneus	4	−66	12	4.42	3244
		0	4	36	4.12	
	Posterior cingulate (R)	6	−38	22	4.03	160
	Preference$_{Rejected}$ > Recency					
	Precuneus/paracentral cortex	10	−52	48	4.19	5214
		−12	−40	58	3.87	
	Lingual cortex/posterior cingulate (R)	12	−70	0	4.23	3048
		8	−40	8	4.18	
	Temporal/fusiform cortex (R)	38	−48	−4	4.27	434
		46	−34	−20	3.35	
	Superior temporal cortex/insula (L)	−42	4	−8	4.16	245
	Insula/precentral cortex (R)	44	−2	4	3.25	187
	Conjunction					
	Precuneus	12	−60	48	4.49	2335
	Posterior cingulate (R)	10	−60	4	3.70	1587
Post-choice	**Preference$_{Chosen}$ > Recency**					
	Medial prefrontal/anterior cingulate cortex	6	54	0	3.96	5944
		−6	48	2	3.83	
		−4	36	12	3.23	
	Precuneus/posterior cingulate (R)	2	−66	34	3.73	406
		10	−64	14	2.92	
	Middle cingulate cortex	0	−36	12	4.42	163
	Preference$_{Rejected}$ > Recency					
	Medial prefrontal cortex	−14	60	4	4.24	831
		8	58	6	3.91	
		20	58	6	3.82	
	Superior temporal cortex (R)	52	−58	14	3.16	189
	Precuneus (R)	6	−66	28	3.47	137
	Conjunction					
	Medial prefrontal cortex	−14	58	2	3.71	488

R: right hemisphere; L: left hemisphere. Voxels survived an uncorrected p value of 0.005, cluster size > 100, p < 0.001 uncorrected.

One previous study (Sharot et al., 2009) found a similar effect, but the brain area that was implicated was very different. In this study, activity in the caudate nucleus predicted subsequent choices. Whereas