

Prefrontal cortex damage abolishes brand-cued changes in cola preference

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Human decision-making is remarkably susceptible to commercial advertising, yet the neurobiological basis of this phenomenon remains largely unexplored. With a series of Coke and Pepsi taste tests we show that patients with damage specifically involving ventromedial prefrontal cortex (VMPC), an area important for emotion, did not demonstrate the normal preference bias when exposed to brand information. Both comparison groups (neurologically normal adults and lesion patients with intact VMPC) preferred Pepsi in a blind taste test, but in subsequent taste tests that featured brand information ('semi-blind' taste tests), both comparison groups' preferences were skewed toward Coke, illustrating the so-called 'Pepsi paradox'. Like comparison groups, the VMPC patients preferred Pepsi in the blind taste test, but unlike comparison groups, the VMPC patients maintained their Pepsi preference in the semi-blind test. The result that VMPC damage abolishes the 'Pepsi paradox' suggests that the VMPC is an important part of the neural substrate for translating commercial images into brand preferences.

Keywords: ventromedial prefrontal cortex; lesion; preference; brand; taste; emotion

INTRODUCTION

Television, radio, magazines, newspapers, internet, billboards, blimps, bus stops, sports arenas, park benches, subway platforms, sandwich boards, sides of buses, taxicab roof mounts and even the backs of supermarket receipts: commercial advertising is pervasive in modern societies, with considerable effects on human behavior. For example, adolescents' exposure to alcohol advertising is a significant predictor of subsequent alcohol use (Stacy *et al.*, 2004; Ellickson *et al.*, 2005; Collins *et al.*, 2007). Recent functional neuroimaging studies have begun to investigate how commercial brand information is processed in the brain (Paulus and Frank, 2003; McClure *et al.*, 2004; Deppe *et al.*, 2005; Schaefer *et al.*, 2006). Although the experimental designs vary, each of these studies report activity in ventral and/or medial prefrontal cortex during the contemplation or consumption of familiar brand-name products. Since lesion studies indicate ventromedial prefrontal cortex (VMPC) is critically involved in emotion, emotional regulation and decision-making (Damasio *et al.*, 1990; Bechara *et al.*, 1997; Anderson *et al.*, 2006; Koenigs and Tranel, 2007; Koenigs *et al.*, 2007), ventromedial prefrontal activations can be interpreted as evidence for emotion playing a pivotal role in brand preference (Paulus and Frank, 2003; Deppe *et al.*, 2005; Schaefer *et al.*, 2006). Psychological and sociological studies that document the use of emotional appeal in

advertisements further support the significance of emotion in brand preference formation (Gorn, 1982; Whissell and McCall, 1997; Shadel *et al.*, 2002; Anderson *et al.*, 2005). Here we provide a novel type of evidence on this issue, by testing the brand-related preference judgments of patients with VMPC lesions and defects in emotion processing. Patients with VMPC damage typically evince 'flattened' or 'blunted' affect, poorly modulated anger and diminished autonomic arousal to emotionally-charged images, despite largely preserved intellect (Damasio *et al.*, 1990; Grafman *et al.*, 1996; Anderson *et al.*, 2006). Each of the VMPC patients tested in the current study conforms to this characteristic profile (see Participants subsection of Methods). If aspects of emotional function mediated by VMPC are indeed critical for the biasing effect of commercial advertisement on brand preference, then it can be predicted that the emotionally impaired VMPC patients will demonstrate unbiased brand preferences, whereas healthy individuals will demonstrate biased brand preferences. More specifically, the prediction is that the manipulation of the availability of brand information will not alter the product preference of VMPC patients as it will for normal individuals.

The 'Pepsi paradox' is a microcosm of the effectiveness of commercial advertising. In blind taste tests subjects tend to prefer Pepsi over Coke or have no reliable preference for one cola over the other, but yet Coke consistently outsells Pepsi. The paradox is that people exhibit a reliable preference for Coke when brand information is available (e.g. in the supermarket), but no reliable preference for Coke when no brand information is available (e.g. in blind taste tests). The Pepsi paradox can be modeled experimentally

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with a series of three taste tests (McClure *et al.*, 2004). A simple ‘Blind’ taste test (subject samples one unmarked cup of Coke and one unmarked cup of Pepsi) reveals the subject’s preference in the absence of brand information, while two ‘Semi-blind’ taste tests (one for Coke and one for Pepsi) reveal the extent to which the availability of brand information biases preference. In the Semi-blind Coke taste test, the subject chooses between two cups of Coke. One cup is labeled with the Coke brand logo, while the other cup is unlabeled. Subjects are told that the labeled cup is labeled accurately, but the unlabeled cup could contain either Coke or Pepsi. The Semi-blind Pepsi test has the same format, except Pepsi and the Pepsi brand logo are used instead of Coke and the Coke brand logo. By comparing the number of selections of labeled Coke to the selections of labeled Pepsi, one can determine the strength of a subject’s bias toward one brand or the other (when brand information is available). In terms of these tests, the Pepsi paradox would be modeled by the following result: a preference for Pepsi in the Blind taste test, but a stronger preference for labeled Coke than for labeled Pepsi in the Semi-blind taste tests. In short, the Pepsi paradox exists if subjects’ Blind taste preferences are not consistent with their Semi-blind taste preferences—that is, when the availability of brand information ‘changes’ subjects’ cola preference.

Against this background, we hypothesized that normal healthy participants and neurological patients with lesions outside VMPC would show the Pepsi paradox (Blind preference for Pepsi but Semi-blind preference for Coke), whereas patients with VMPC lesions would not show the Pepsi paradox (Pepsi preference in both Blind and Semi-blind tests).

METHODS

Participants

Three groups participated: 1) patients with VMPC lesions and documented defects in emotional processing (VMPC group; $n = 12$; Table 1), 2) Brain-Damaged Comparison patients whose lesions did not include VMPC (BDC group; $n = 16$) and 3) Normal Comparison subjects with no brain lesion (NC group; $n = 16$). For patient classification, VMPC was defined as the medial one-half of the orbital surface and the medial surface of prefrontal cortex at or below the level of the genu of the corpus callosum, including the subjacent white matter. The emotional processing defects of ten of the VMPC patients (0318, 1584, 1768, 1983, 2352, 2391, 2577, 2748, 2837, 2990) have been described extensively in previous publications (Eslinger and Damasio, 1985; Tranel *et al.*, 2005; Anderson *et al.*, 2006; Koenigs and Tranel, 2007; Koenigs *et al.*, 2007). In brief, each of these patients exhibit generally blunted affect, poorly modulated anger/frustration and inappropriate social conduct. The remaining two VMPC patients (1986 and 2553) exhibit a similar profile, with severely impaired emotional processing and emotional regulation and major disturbances of social conduct. Since

Table 1 Participant data

Subject	Sex	Age	VMPC lesion	Etiology
0318	M	66	Bilateral	Meningioma resection
1584	M	63	Bilateral	SAH; ACoA aneurysm
1768	M	68	Right	ACA stroke
1983	F	43	Bilateral	SAH; ACoA aneurysm
1986	F	66	Right	SAH; ACoA aneurysm
2352	F	57	Bilateral	SAH; ACoA aneurysm
2391	F	60	Bilateral	Meningioma resection
2553	M	39	Bilateral	Trauma
2577	M	66	Bilateral	SAH; ACoA aneurysm
2748	F	34	Left	Cyst
2837	M	30	Right	Cyst ^a
2990	M	17	Right	Trauma ^a
VMPC group	5F/7M	50.8 (17.4)		
BDC group	4F/12M	51.9 (12.8)		
NC group	6F/10M	51.1 (11.6)		

^aDenotes a childhood-onset lesion; all other lesions were acquired in adulthood. SAH, subarachnoid hemorrhage; ACoA, anterior communicating artery; ACA, anterior cerebral artery. VMPC, BDC and NC groups did not differ in age ($P = 0.97$) or sex ratio ($P = 0.61$).

all VMPC patients have similar emotional processing defects and we do not have any a priori hypothesis about the laterality of brain areas important for brand preference, we include both unilateral and bilateral VMPC lesions in our target group.

The chemical senses (smell, taste) can be affected by VMPC damage, so it was important to rule out a basic confound on this level. The Blind test condition effectively does so, because the results indicated a clear preference (Pepsi > Coke) in the VMPC group that was as strong (actually slightly stronger) than that evidenced by the NC and BDC groups (see Results section). Such a result would not be expected if the VMPC subjects had severe anosmia/ageusia and this finding allows a straightforward interpretation of the Semi-blind test results.

Patients were selected from the Patient Registry of the Division of Cognitive Neuroscience at the University of Iowa. All patients conformed to the inclusion criteria of the Patient Registry. They had focal, stable lesions that could be clearly identified on MR or CT scans and they were free of dementia, psychiatric disorder and substance abuse. All participants were free of significant intellectual impairments and were capable of comprehending the test instructions, co-operating with the experiment and providing taste preference decisions. Neuropsychological, neuro-anatomical and experimental studies were all conducted in the chronic phase of recovery. The average time since lesion onset for collection of the experimental data was 12.4 years (SD = 8.1 years) for VMPC patients and 7.9 years (SD = 11.1 years) for BDC patients ($t = 1.18$; $P = 0.25$). Normal participants were recruited from the surrounding community through advertisement and they were compensated for their participation. Participant groups were matched for age and sex distribution (Table 1). All participants gave informed consent before completing the study,

which was approved by the Human Subjects Committee of the University of Iowa.

Experimental tests

Participants completed a series of three taste tests modified from a previous study of brand-related cola preference (McClure *et al.*, 2004).

Blind taste test. The participant was presented with two unlabeled cups, one containing Coke and the other Pepsi. Each cup contained ~20–50 ml of cola. The participant was asked to take a sip from each cup (as much as s/he wished) and state a preference (right or left cup). Each participant completed 20 trials of this taste test. Individual trials were separated by 10–40 s. Coke and Pepsi were presented in the right and left cups in a fixed random order.

Semi-blind taste tests. The participant was presented with two cups, both containing the same cola (both Coke or both Pepsi). One cup was unlabeled, while the other cup's content was denoted by a can of that cola placed beside the cup. The participant was told that the unlabeled cup could contain Coke or Pepsi. Each cup contained ~20–50 ml of cola. The participant was asked to take a sip from each cup (as much as s/he wished) and state a preference (right or left cup). Trials were separated by 10–40 s. Each participant completed 40 trials of this taste test. In one block of 20 trials both cups contained Coke and one was marked with the Coke can beside it. In the other block of 20 trials both cups contained Pepsi and one was marked with the Pepsi can beside it. The location of the can was switched between the right or left in a fixed random order.

Order of tests. The tests were ordered as follows: (1) Blind taste test, (2) Semi-blind taste test block #1, (3) Semi-blind taste test block #2. The order of the Semi-blind taste tests (Coke block or Pepsi block) was counterbalanced among participants within each group.

Data analysis. Blind taste test data were analyzed with a one-way ANOVA, with Group (NC, BDC, VMPC) as the independent variable and number of Pepsi selections as the dependent variable. Semi-blind taste test data were analyzed with a 3×2 mixed ANOVA, with Group (NC, BDC, VMPC) as a between-subjects factor, Brand Label (Coke or Pepsi) as a within-subjects factor and number of selections for the labeled cup as the dependent variable.

RESULTS AND DISCUSSION

On the Blind test all three groups exhibited similar cola preference: Pepsi was preferred over Coke in a majority of the choices in each group (55, 57 and 63% of selections were for Pepsi in the NC, BDC and VMPC groups, respectively) (Figure 1A). There were no significant differences in Blind taste preference among groups ($F=0.30$; $P=0.74$), indicating that, in the absence of brand information, all groups preferred Pepsi to a similar extent. The Semi-blind test yielded a markedly different pattern of results. NC and BDC groups exhibited similar cola preference: for both groups,

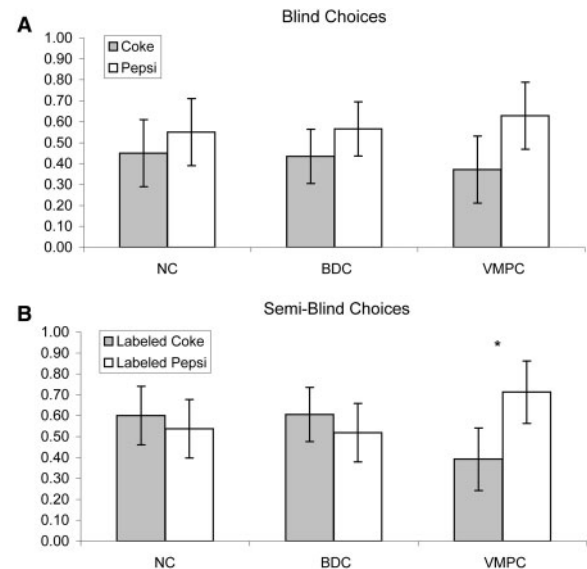


Fig. 1 Group choices on the Blind and Semi-blind taste tests. Error bars represent 95% confidence intervals. (A) In the Blind test subjects sampled two unmarked cups: one Coke and one Pepsi (20 trials). All groups preferred Pepsi to a similar extent. (B) In the Semi-blind tests subjects sampled two cups of the same cola. One cup was accurately marked with the cola's brand logo and the other was unmarked. Subjects completed 20 trials of a Semi-blind Coke test and 20 trials of a Semi-blind Pepsi test. NC and BDC groups made more selections for labeled Coke than for labeled Pepsi; VMPC patients showed the opposite pattern.

labeled Coke was selected in greater proportions than was labeled Pepsi (60% labeled Coke to 54% labeled Pepsi in the NC group, 61% labeled Coke to 52% labeled Pepsi in the BDC group). But the VMPC group exhibited the reverse pattern, selecting greater proportions of labeled Pepsi than labeled Coke (71% labeled Pepsi to 39% labeled Coke). A 3×2 ANOVA of the Semi-blind test data revealed a significant interaction of Group and Brand Label ($F=4.41$; $P=0.015$), indicating significant between-group differences in cola preference in the presence of brand information. Specifically, the VMPC group differed from both the NC group ($F=6.11$; $P=0.017$) and the BDC group ($F=7.08$; $P=0.010$) in selecting a greater proportion of labeled Pepsi than labeled Coke, while NC and BDC groups made nearly identical patterns of choices ($F=0.035$; $P=0.85$). So whereas all groups similarly preferred Pepsi to Coke in the Blind test (Figure 1A), only the VMPC group demonstrated a stronger preference for the Pepsi brand than the Coke brand in the Semi-blind tests (Figure 1B). Taken together, these findings suggest that the comparison groups were biased by the presence of brand information and changed their cola preference, whereas the VMPC group demonstrated consistent cola preference regardless of whether brand information was available or not. This conclusion is supported by a supplemental analysis of individual participants' data, which show that the correlation between Blind and Semi-blind preferences was substantially higher in VMPC patients ($r=0.47$) than in comparison subjects ($r=0.13$) (Figure 2).

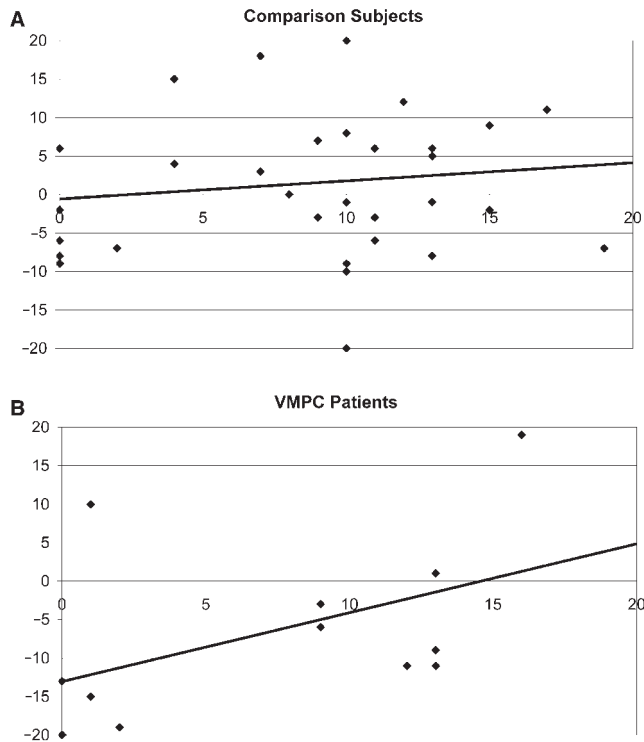


Fig. 2 Relationship between Blind and Semi-blind choices. X-axis is the number of selections of Coke in the Blind taste test. $X = 20$ represents maximal blind preference for Coke; $X = 0$ represents maximal blind preference for Pepsi. Y-axis is the difference between the number of selections of labeled Coke and the number of selections of labeled Pepsi in the Semi-blind tests. $Y = 20$ represents maximal preference for the Coke brand label; $Y = -20$ represents maximal preference for the Pepsi brand label. **(A)** Among comparison participants, there is almost no correlation between Blind and Semi-blind cola preference ($r = 0.13$). **(B)** Among VMPC patients, there is a moderate positive correlation between Blind and Semi-blind cola preference ($r = 0.47$). Taken together, these data corroborate the averaged group data in Figure 1: Blind and Semi-blind preferences were consistent among VMPC patients, but not among comparison subjects.

In agreement with previous results (McClure *et al.*, 2004), the finding that Blind and Semi-blind preferences were not consistent among comparison participants indicates that normal brand preference is the product of factors unrelated to the taste of the soft drink. The key finding of this study—that Blind and Semi-blind preferences were ‘abnormally’ consistent among VMPC patients—provides direct evidence for the notion that the VMPC is an important part of the neural substrate for taste-independent processes involved in brand preference.

There is an alternative explanation of the main result that is important to acknowledge—perhaps VMPC has nothing to do with the taste-independent factors associated with brand preference and we happened to obtain *by chance* a group of 12 individuals (the VMPC group) who are abnormally fond of the Pepsi brand¹. To address this possibility, we calculated the probability of obtaining, by chance, the observed number

of Pepsi-brand-lovers in the VMPC group. For this analysis, we defined a ‘Pepsi-brand-lover’ as an individual who made at least 15 selections for the labeled Pepsi in the Semi-blind Pepsi test. (‘At least 15’ is the smallest number of labeled Pepsi selections [out of 20] that is statistically significantly different from a ‘chance’ or ‘random’ selection of one cup or the other.) Among comparison groups, only 10 out of 32 subjects met the criterion for a ‘Pepsi-brand-lover,’ whereas 9 out of 12 VMPC patients met the criterion. Fisher’s exact test reveals that the probability of this distribution of individuals occurring by chance is 1%. A similar result ($P < 0.05$) is obtained whether we set the criteria for ‘Pepsi-brand-lover’ as ‘at least 13,’ ‘at least 14,’ ‘at least 15,’ ‘at least 16,’ ‘at least 17,’ or ‘at least 18’ selections for labeled Pepsi. In other words, it is extremely unlikely that we obtained this sample of individuals in the VMPC group by chance. Rather, we conclude that the sample of VMPC patients is different from the comparison groups with respect to brand-related decision-making *because of* the VMPC damage. One possible explanation is that in comparison subjects there is some emotional/affective association with the Coke brand label that drives their Semi-blind preference towards Coke, despite their Blind preference for Pepsi. Lacking the normal affective processing, VMPC patients may base their brand preference primarily on their taste preference.

The finding we report here extends previous correlative work from functional neuroimaging and has important implications for neurobiological mechanisms of conditioning, persuasion and attitude change. Future studies will aim to specify the factors that contribute to brand preference, as well as the role of VMPC in processing these factors. One factor undoubtedly affecting brand preference is commercial advertisement. Since advertisements typically feature emotionally engaging or arousing images in the absence of substantive product information, one might assert that emotional associations are the driving force behind the ability of commercial advertisements to influence consumers’ decision-making. Psychological and sociological studies documenting the role of emotional appeal in advertisements support this claim (Gorn, 1982; Whissell and McCall, 1997; Shadel *et al.*, 2002; Anderson *et al.*, 2005).

If the power of commercial advertising lies in the ability of emotional associations to influence decision-making, there is a reason to believe that VMPC would play a central role. Lesion studies indicate that VMPC is a critical neural substrate for successfully associating an emotional event with a subsequent behavioral choice (Damasio, 1994; Bechara *et al.*, 1997). Also, VMPC damage diminishes concern for others (Anderson *et al.*, 2006; Koenigs *et al.*, 2007) and this could contribute to VMPC patients resisting socially dominant preferences. Further work will be needed to establish direct evidence for defective emotional processes contributing to the VMPC patients’ abnormal brand-related behavior, but the current results are consistent with this interpretation, as are previous studies reporting abnormal

¹ Note that this abnormal fondness would only pertain to the Pepsi ‘brand’ (as opposed to the Pepsi ‘taste’), since the VMPC group was no different from comparison groups on the Blind test.

emotion-related decision-making following VMPC damage (Bechara *et al.*, 1997; Camille *et al.*, 2004; Shiv *et al.*, 2005; Koenigs and Tranel, 2007; Koenigs *et al.*, 2007). Building on this line of work, we would predict that normal healthy individuals would demonstrate significant emotional responses to certain brand images or during brand-related decision-making, whereas VMPC patients would have diminished emotional responses in such circumstances. Although data on the VMPC patients' 'real-life' brand-related behavior were not collected for this study, it will be interesting to determine whether VMPC patients evince real-life abnormalities in brand-related behavior following their brain injury, as the results reported here would suggest. The limited scope of the present study invites further experimentation along these lines.

The findings from this study relate to a large body of psychological research demonstrating that subjective judgments are often not the product of accurate introspection about the actual underlying influences (reviewed in Nisbett and Wilson, 1977). For example, in this study, some of the comparison subjects who had a Blind preference for Pepsi would offer unsolicited justifications of their Semi-blind preference for Coke, such as 'Coke just has a better fizz,' or 'Coke goes better with pizza,' even though their Blind test data indicate a preference for the taste of Pepsi. These results are in line with Nisbett and Wilson's conclusion that subjective judgments may be based largely on non-conscious biases. We propose that the implicit biases related to commercial brand preference are at least in part affective and mediated by VMPC. Furthermore, we speculate that affective, implicit biases mediated by VMPC may underlie subjective preference in domains other than commercial brand behavior, such as affinity for certain political candidates or partiality in art and music.

The present results also bear on the neural basis of taste processing. Studies in macaques identify a primary taste cortical region in the anterior insula and adjoining frontal operculum, with a secondary taste area in the caudolateral orbitofrontal cortex (Scott *et al.*, 1986; Rolls *et al.*, 1990; Baylis *et al.*, 1994). In humans, areas of orbitofrontal cortex respond to sweet tastes (O'Doherty *et al.*, 2001) and activity in VMPC scales with subjective preference for sweet drinks (McClure *et al.*, 2004). The target patients in this study all had damage involving VMPC (including medial orbitofrontal cortex), but almost never in frontal operculum/anterior insula or caudolateral orbitofrontal cortex. Thus, it is perhaps not surprising that the VMPC patients demonstrated intact taste preference; this result stands in stark contrast to the VMPC patients' abnormal brand preference.

In sum, we show that the normal influence of brand information on cola preference (the so-called 'Pepsi paradox') is not present among patients with VMPC damage and defects in emotional processing. This result suggests that VMPC is a critical neural substrate for

the effect of commercial brand information on human decision-making.

Conflict of Interest

None declared.

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