



BRAND PREFERENCES MODULATE NEURAL
ACTIVITY DURING EXPECTATION AND
EVALUATION OF AN UNCERTAIN REWARD

*Andreas Pedroni, Susan Mérillat,
Anja Dieckmann, Volker Bosch, Lutz Jäncke*

WORKING PAPER /// NO. 4 / 2016

Copyright 2016 by Andreas Pedroni, Susan Mérillat, Anja Dieckmann, Volker Bosch, Lutz Jäncke & GfK Verein

Working papers are in draft form. This working paper is distributed for purposes of comment and discussion only and may not be reproduced or copied without permission of the copyright holder.

The views expressed are those of the authors and do not necessarily reflect the view of the GfK Verein.

An electronic version can be downloaded from the website of the GfK Verein: www.gfk-verein.org.

Brand preferences modulate neural activity during expectation and evaluation of an uncertain reward¹

Andreas Pedroni[†] Susan Mérrillat[‡] Anja Dieckmann^{*§}
Volker Bosch[¶] Lutz Jäncke[‡]

Abstract— *Humans may differ remarkably in their preferences for objectively similar rewards. Brand preferences, for instance, largely account for differences in shopping behaviour. In the present functional MRI study, we explore whether subjective brand preferences can be measured on the neural level. For this purpose, we implement a wheel-of-fortune game comprising a prospect phase and a subsequent outcome evaluation phase. Participants played for vouchers that they could redeem for sneakers of three differentially preferred brands. The results clearly demonstrate that neural activation in structures related to reward processing is linearly associated with the subjective brand preference hierarchy. Further, modulation of neural activity by preferred brands occurs in distinct neural regions during prospect and evaluation phases. Playing for more preferred compared to less preferred brands evokes an intensified state of wanting in the participant and facilitates action preparation—a mechanism that may underlie approach behaviour in real-life choice situations.*

Keywords— *Reward; Brand; Affect; Motivation; fMRI; Nucleus accumbens*

1 Introduction

Some people would kill for a Gucci handbag, others would not even bat an eye lid. To account for variance in people’s choices, social scientists have introduced the concept of preferences. Based on the idea of utility maximization, the concept of preferences allows for assigning individually different utility values to outcomes, and is thus used to explain why people can be motivated by different things. An economically highly relevant example are subjective preferences for branded, yet

otherwise often quite similar products: In 2006, the top 100 companies in terms of advertising expenditure spent almost 100 billion US dollars in worldwide media communication for their brands (Advertising Age, 2007). Besides increasing awareness, these efforts aim at highlighting the added value brands transfer to products as signals of trustworthiness, means of self-expression, status symbols, decision aids, and so forth (for an overview of psychological brand functions, see, e.g., Sommer, 1998). Sales data show that brands affect many of our purchase decisions (e.g., Ataman and Ülengin, 2003). Evidently, brands can exert a motivational force to guide buying actions, and consumers derive satisfaction from their consumption and ownership. Hence, branding strongly influences the incentive and hedonic values of consumer goods.

With the advent of modern brain imaging techniques, the neural underpinnings of motivational processes have received considerable interest in the neurosciences. In most studies, reward value was manipulated on an objectively quantifiable scale, like varying the magnitude of monetary rewards (Elliott et al., 2003). It is well explored how reward-value associations are learned and dynamically updated in nonhuman primates and humans (Schultz et al., 1997; O’Doherty et al., 2003). Also the

¹A slightly different version of this working paper has been published as chapter in the first author’s PhD thesis (Pedroni, 2011).

*Corresponding author, anja.dieckmann@gfk-verein.org

[†]University of Zurich, Institute of Psychology, Methods of Plasticity Research, Switzerland

[‡]University of Zurich, University Research Priority Program “Dynamics of Healthy Aging“, Switzerland

[§]GfK Verein, Fundamental Research, Nuremberg, Germany

[¶]GfK SE, Marketing and Data Sciences, Germany

Citation: Andreas Pedroni, Susan Mérrillat, Anja Dieckmann, Volker Bosch, Lutz Jäncke (2016). Brand preferences modulate neural activity during expectation and evaluation of an uncertain reward. GfK Working Paper Series, No. 4 / 2016.

neural underpinnings of contextual influences on reward values, like counterfactual reasoning (Coricelli et al., 2007), the effect of framing (Martino et al., 2006), satiety (James et al., 2004) and delay discounting (Kim et al., 2008) have been a matter of extensive research. However, the factor of subjectiveness of rewarding values—that is, subjectiveness of preferences—has rarely been investigated. In the current study, using branded products as an economically highly relevant example, we explore whether the factor of subjective preferences can explain differences in neural responses to rewarding events.

In a previous study we were already able to show that stimuli with objectively similar characteristics elicited hemodynamic responses in reward-related areas of the brain in dependency of the respective preference value (Koenke et al., 2008). Participants played a wheel-of-fortune (WOF) game, in which they could win or lose chocolate bars that differed in subjective value. Subjective value was operationalized in terms of brand preferences, which were a priori measured with state-of-the-art market-research tools. Given that brand preferences greatly differ between individuals and the objectively scaled values of related consumer goods (like price and quality) are often highly similar, we believe that such stimuli are ideal to investigate the variation of rewarding value on a subjective scale. Indeed, effects of branding on activity in reward-related brain areas have been reported before (Schaefer and Rotte, 2007). For example, it has been shown that the consumption of small amounts of soft drinks elicited stronger hemodynamic responses in reward-related areas of the brain when pre-cued by a logo of the market leader rather than by a logo of another soft drink manufacturer (McClure et al., 2004). However, to our knowledge this effect was not described for individual brand preference hierarchies before.

In the present study we aimed to extend previous findings by using specific non-food rewards, for which it can be assumed that subjective value is independent of the degree of satiety as well as primary sensory qualities such as flavour. The chocolate reward used in the previous study represented a primary reinforcer, which has been shown to reliably elicit strong activations in reward-related brain regions (O’Doherty et al., 2002). But one potential drawback of investigating subjective values of primary reinforcers is that the rewarding value of food is highly dependent on satiety (James et al., 2004). It can be assumed that this effect applies even if no direct food intake occurs, as it was the case in our last study. Furthermore, the preferences for one particular brand of chocolate might be more influenced by the flavour of one specific bar of chocolate than by the brand itself. We therefore chose fashion products in the present study, for which we presume that subjective value is predominantly culturally transferred, and were interested in whether we can replicate the results found for chocolate brands. Also, the incentives used in the present study (a 150 SFr. voucher for a pair of sneakers of a particular brand) were monetarily much more valuable than what could be won in the initial study (on average around 10

bars of chocolate). By increasing the monetary incentive value, we aimed at also increasing the effects of subjective preferences for different brand versions of this incentive. Finally, besides changing the product class of the rewarding stimuli, modifications in the reward scheme were applied. In the previous study chocolate bars of three differentially preferred brands could be won or lost. This means that a once gained reward could be lost in any subsequent trial. Thus, the probability to acquire a reward only increased towards the very end of the experiment. In the present study subjects could increase the probabilities of winning differently valued rewards, rather than accumulating and losing rewards during the actual experiment. Therefore, reward values in every single trial were kept constant over the time-course of the experiment. With these refinements we aimed to replicate and strengthen the previously reported findings and extend insights to more abstract and culturally transformed subjectively valued rewards. Finally we were interested in comparing neural responses of the “accumulating probability“ reward scheme to results of commonly used reward schemes like gaining primary reinforcers or accumulating monetary rewards.

From a psychological perspective, the concept of reward has various facets. The reward theory by Kent Berridge and colleagues, for example, differentiates between at least two aspects of reward, namely “wanting“ and “liking“ (Berridge, 1996, 2004, 2007; Berridge and Robinson, 2003). Wanting corresponds to an anticipatory component that evolves after the presentation of a cue which signals the subsequent delivery of reward, and thus to an underlying motivational process that orients behavior towards the receipt of the reward. Liking, on the other hand, refers to a consummatory experience following the receipt of reward and reflects the experienced pleasantness or utility of the reward. The distinction of wanting and liking was introduced following the finding that the manipulation of neural dopamine circuits effectively alters motivated behavior (e.g., instrumental behavior and reward consumption) but not taste liking as measured via affective facial expressions in rodents. Later studies were able to show similar effects in humans (for a review see Berridge and Robinson, 2003). Similar distinctions, between reward expectancy or anticipation, and reward experience or outcome, have been made by other authors (Breiter et al., 2001; Knutson et al., 2001). The two components can be differentiated on a neural level: For instance, Knutson et al. (2003) found that the ventral striatum (incl. NAcc) was strongly active during the anticipation of monetary reward and that its activity was positively correlated with reward magnitude. In contrast, the mesial prefrontal cortex (MPFC), the parietal cortex and the posterior cingulum were active once participants received feedback indicating that the reward had been successfully obtained.

We used a wheel-of-fortune game that allowed for the differentiation between a prospect period (spinning of the wheel; wishing for a positive outcome) and an outcome period (processing the game outcome). During the fMRI

session, subjects could win lottery tickets in repeated rounds of the wheel-of-fortune game, thereby increasing their chance of winning in the subsequent lottery. In the lottery, subjects played for one voucher worth SFr. 150 for one of three different sneaker brands. Established market research instruments were used prior to the fMRI experiment to determine participants' individual preferences with respect to sneaker brands. Brands of high, intermediate and low subjective value were then selected for each participant and used as stimuli in the fMRI experiment. During the experiment, brands were represented by their logos. The rationale of our approach was that since the monetary value of each voucher was equal for the three brands, any elicited differences in neuronal activations could be exclusively attributed to differences in subjective value formed through individual brand preferences.

2 Method

2.1 Participants

Sixteen healthy adult participants (9 female and 7 male, mean age of 24 ± 4) were recruited from the University of Zurich and ETH Zurich, Switzerland. Participants were selected based on a two-stage selection procedure. At the first stage, a paper and pencil questionnaire was distributed to students in different courses of the Psychology Department of the University of Zurich. 200 students completed the questionnaire. Of those, 50 respondents who indicated that they (a) wore sneakers at least from time to time, (b) cared about sneakers, (c) cared about brands when it came to sneakers, and (d) who expressed differentiated brand preferences in a constant-sum point-allocation "chip game" between different sneaker brands, were invited to the second round. Twenty-seven of the pre-selected participants accepted the invitation and filled in a second, computer-based questionnaire that aimed at measuring individual brand preferences in more detail, consisting of the GfK Price Challenger (Wildner, 2003), a choice-based procedure with high predictive validity in terms of real sales data (Bosch, 2005), and again a constant-sum chip game. Of those, eighteen respondents were finally invited to the fMRI study. These participants expressed preferences that were consistent across the two measures and widely dispersed to allow for clear brand differentiation. Two participants dropped out due to private reasons. The local ethics committee approved the study and the participants gave written informed consent. The tasks and testing procedures were in accordance with institutional guidelines and the study conformed to the Declaration of Helsinki. Participation was compensated with SFr. 50 and a possible win of a voucher for a pair of sneakers, worth SFr. 150.

2.2 Design and Procedure

Participants played a virtual wheel-of-fortune game projected onto a translucent screen that participants viewed inside the scanner via a mirror. The experiment consisted of four runs with 25 trials each. Individual T1-weighted anatomic brain images were recorded after the actual experimental sessions. The total scanning time was approximately 50 minutes.

Before being scanned, participants were informed with respect to the MRI / fMRI method. Following this, each participant had to (1) complete a questionnaire that checked for individual MR-suitability and (2) to give his / her written informed consent. Then, participants were requested to read a short instruction manual, which explained the procedures of the experiment, and played two trials of the wheel-of-fortune game outside the scanner to assure that they had understood the task correctly. The overall prize that could be won in our experiment was a voucher (worth 150 SFr.) for a pair of sneakers of a particular brand. The subjects played for this voucher in a lottery subsequent to the scanning session. During the scanning session, the subjects were able to win lottery tickets that increased the chance of winning in the subsequent lottery. In other words, a won trial in the wheel-of-fortune game increased the probability of winning the voucher for a certain sneaker brand.

Based on the preference data gathered in the second stage of the selection procedure (see Participants section) 3 sneaker brands were determined for each subject: (1) her / his favourite brand, (2) her / his least preferred yet still acceptable brand, as well as (3) one intermediate brand that ranked between the top and the bottom brand. In each wheel-of-fortune trial one of 25 lottery tickets per brands could be won (i.e., 75 lottery tickets in total). Trials were brand-specific meaning that a won trial increased the chance to win a voucher for one specific brand. Across the scanning session, the number of won lottery tickets for each brand was accumulated. After the scanning session, the subjects were presented with three pots (one for each brand), each containing 25 lottery tickets, with one lot being the joker. The subjects then drew the amount of won lottery tickets separately for each brand. If the joker was drawn, participants received the voucher for the particular brand. If more than one voucher was won, they could freely choose one to take home. The chance to win was pseudorandomly varied at a chance of 50 percent per brand. Thus, participants had the cumulative chance to win one of the three vouchers of 87.5 percent. The sequence of the brands the participants played for were pseudo-randomly distributed to ensure enough trials of every possible combination (brand, outcome) for the analysis. In addition, 25 trials where no lottery tickets could be won were randomly interspersed in the experiment to detect brain areas responding to the wheel-of-fortune game itself, resulting in a total of 100 trials.

As illustrated in Figure 1, a trial consisted of a brand-announcement phase (0.5–2 s), a response phase (placing the bet on green or red; 1–2 s), a prospect phase (wheel

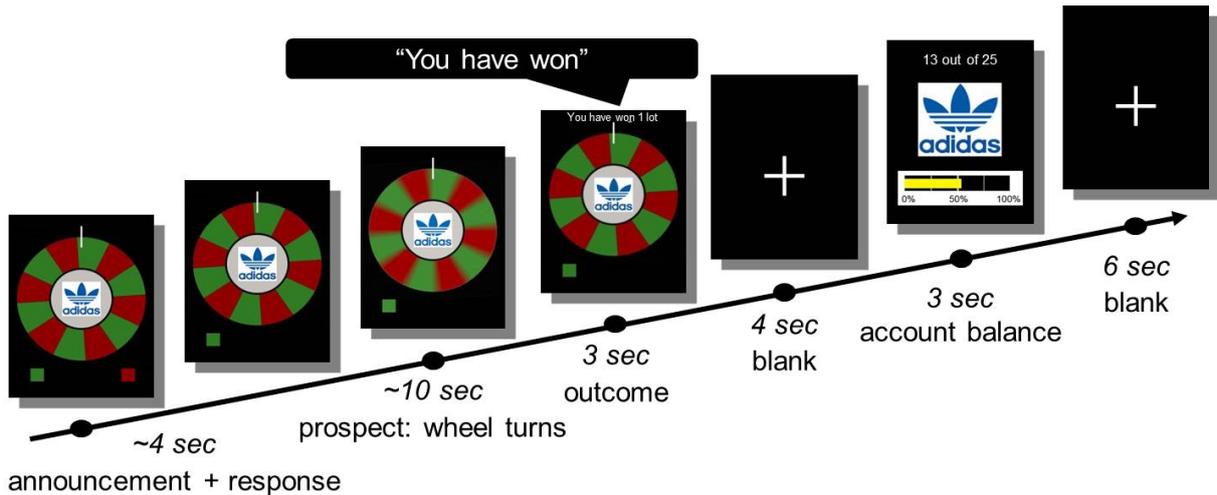


Figure 1: Experimental design of the wheel-of-fortune game.

of fortune spins; 8–12 s), an outcome phase (outcome is presented; 3 s), a blank screen with a fixation cross (4–5 s), a picture of the actual account balance (2 s), and another blank screen with a fixation cross (6 s). In the announcement phase the logo of the brand subjects played for in the current trial was presented in the center of a wheel-of-fortune with twelve colored (6 green and 6 red) fields. During the response phase, participants could choose one color by pressing a button. The chosen color field remained visible underneath the wheel while the other color field disappeared so that participants did not have to memorize their choice. The prospect phase started with the wheel-of-fortune rotating and slowing down to halt after 8–12 seconds. The ensuing outcome phase started after the wheel had stopped. The outcome was indicated by the field that came to a halt under a pin at the top of the wheel and by a text box (i.e., “You have won 1 lot / You have not won“). A trial was won when the color chosen by the subject was consistent with the color of the field that came to a halt under the pin. To prevent participants from memorizing account balances, the the number of already acquired lottery tickets for the respective brand was indicated in each trial. This number was also translated into the probability of winning a voucher and represented as bar chart. A blank screen with a fixation cross was presented for six seconds before the next trial started to ensure that the fMRI signal could level back to a task-unspecific baseline.

2.3 Functional Imaging

A Philips Intera 3T whole-body MR unit (Philips Medical Systems, Best, The Netherlands) equipped with an eight-channel Philips SENSE head coil was used to acquire magnetic resonance images. Anatomical images of the whole brain were obtained by using a T1-weighted three-dimensional, spoiled, gradient echo pulse sequence (repetition time (TR) = 20 ms, echo time (TE) = 2.30 ms, flip angle = 20°, field of view (FOV) = 220 mm, ac-

quisition matrix = 224 x 224, voxel size = 1.00 x 1.00 x 0.75 mm, 180 slices, slice thickness = 0.75 mm). Functional data for the behavioural tasks were obtained from 310 whole-head scans per run using a Sensitivity Encoded (SENSE) single-shot echoplanar imaging technique (TR = 2500 ms, TE = 35 ms, flip angle = 78°, FOV = 220 mm, acquisition matrix = 80 x 80, voxel size = 1.72 x 1.72 x 4.00 mm, 33 transverse slices).

2.4 Data Analysis

Artefact elimination and MRI data analysis were performed using MATLAB 2006b (Mathworks Inc., Natick, Massachusetts, USA), and the SPM5 software package (Institute of Neurology, London, UK). The first three images were discarded to allow for steady-state magnetization. All images were realigned to the first image of the first run, slice time corrected and spatially normalized into standard stereotactic MNI space (EPI template provided by the Montreal Neurological Institute), interpolated to a voxel size of 2.00 x 2.00 x 2.00 mm and spatially smoothed using a 8-mm full-width-at-half-maximum Gaussian kernel.

Activated voxels were identified by the general linear model approach implemented in SPM5. At the first level of analysis, we adopted a parametric analysis according to Büchel et al. (1998). After highpass-filtering (cut off 128 s), an individual statistical model was computed for each participant with separate regressors for the announcement phase (1 s), response phase (1–2 s), prospect phase (8–12 s), the two types of outcome phases (3 s) and the presentation of the actual account balance (2 s). The announcement, response and prospect phases and the blank screen between outcome and balance had variable durations. Also, the time-lag between motor response for choosing a color and the onset of the prospect phase (the start of the spinning of the wheel-of-fortune) was temporally jittered. This was implemented to (1) induce a dephasing of stimuli onsets with respect to scan onsets

to optimize sampling of the hemodynamic response and (2) to temporally de-correlate regressors of interest. The resulting regressors were convolved with SPM's canonical difference of gammas hemodynamic response function.

The main focus of the analysis was to identify regions whose hemodynamic response was modulated by individual brand ranking. Thus, the individual rankings of the brands were introduced into the statistical model as first and second order modulatory parameters of the regressors of the announcement, prospect, outcome and balance phases. Subsequently, linear contrasts of the first and second order terms against a baseline (blank screens) were performed. This was applied to the announcement, prospect, outcome, and actual balance phases. In order to dissociate task-specific effects of the wheel-of-fortune game and brand preference specific effects, neutral trials were implemented (see Design and Procedure), which were modelled as separate regressors for each phase.

To permit population-level inferences, maps of contrast coefficients for each of the first level contrasts were collectively submitted to one-sample t-tests against the null hypothesis of no increase in hemodynamic response, while controlling for random effects. Despite de-correlation of the prospect and outcome phase through temporal jittering of the duration of the prospect phase it was still possible that clusters of activation found in the outcome phase could be due to continuing activity elicited during the prospect phase. Taking this possible confound into account, the search area for activations in the outcome phase was reduced to the areas activated by the preceding prospect phase in an additional analysis. No clusters of activation remained.

To explore a wide range of effects in the data, voxels surviving significance thresholding at $p < .001$, uncorrected for multiple comparisons, with a spatial extent threshold at $k = 10$ voxels were reported. For specific regions, a-priori hypotheses were derived from previous reward paradigms (O'Doherty et al., 2002; Breiter et al., 2001; Elliott et al., 2003; Knutson et al., 2001). Within these regions, small volume corrections (SVC) were applied to correct the false positive error probability for the number of made comparisons. SVCs were applied with a sphere of 8 mm, chosen to be equal to the spatial smoothing kernel (Rolls et al., 2008). Peaks surviving $p < .05$ family-wise-error (FWE) correction were considered significant.

3 Results

The primary goal of this study was to identify areas of the brain showing stronger hemodynamic responses when playing for more preferred brands. We further examined whether distinct neural networks process reward information in the prospect phase and the outcome phase of won trials. The following results represent the first order term in the parametric analyses.

3.1 Regions exhibiting preference-modulated neural responses during prospect phase

In the prospect phase, hemodynamic responses linearly increasing with higher subjective preference were identified in right anterior insula / lateral orbitofrontal cortex (OFC), left pallidum / nucleus accumbens, bilateral premotor cortex, supplementary motor area, right supra-marginal gyrus, primary somatosensory cortex and bilateral precuneus (see Figure 2 and Table 1).

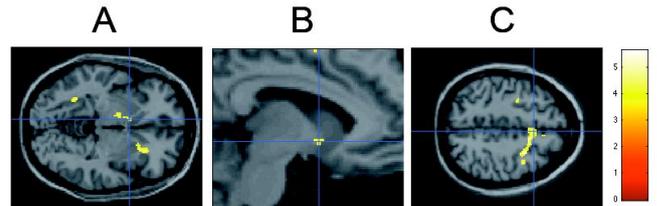


Figure 2: Neural activity in brain regions linearly modulated by brand preference (i.e., showing greater activity for more preferred brands) during prospect phase ($p < .001$ uncorrected): (A) right hemispheric anterior insula. (B) Left nucleus accumbens. (C) Predominantly right hemispheric premotor cortex and supplementary motor area.

3.2 Regions exhibiting preference-modulated neural responses during outcome phase

In the outcome phase of won trials, clusters of voxels in the anterior prefrontal cortex and anterior cingulate cortex (subgenual part) showed a linear increase in their hemodynamic response with higher subjective preference for the reward (see Figure 3 and Table 2).

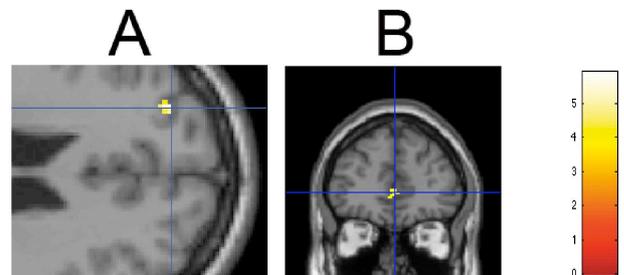


Figure 3: Neural activity in brain regions linearly modulated by brand preference (i.e., showing greater activity for more preferred brands) during outcome phase of won trials ($p < .001$ uncorrected). (A) dorsolateral prefrontal cortex (DLPFC), (B) mesial prefrontal cortex (VMPFC).

Neural activity in regions	Right / Left	Cluster size (Voxels)	Coordinates			t-value
			X	Y	Z	
increasing linearly with subjective preference:						
Anterior insula	R	161	28	26	-2	4.98
Superior frontal gyrus	R	41	38	44	26	5.21
Middle frontal gyrus	R	28	42	34	34	4.4
Nucleus accumbens / ventral pallidum	L	121	-14	-4	-2	5.51
Premotor cortex	R	656	30	2	46	5.91
Premotor cortex	L	340	-28	-4	56	5.41
Premotor cortex, pre-SMA	R	137	12	8	64	4.83
pre-SMA, paracingulate gyrus	L	53	-10	6	52	4.95
Supramarginal gyrus	R	100	56	-36	22	4.82
Supramarginal gyrus	R	32	48	-30	32	4.84
Broca area	L	36	-50	4	14	4.23
Superior parietal lobe	R	83	12	-54	66	4.82
Primary somatosensory cortex	R	112	32	-44	64	4.64
Lingual gyrus	L	51	-30	-56	-4	4.88
Precuneus	L	103	-8	-46	58	5.93
Precuneus	R	53	10	-74	42	3.84

Table 1: Clusters showing brand-preference-dependent activity during the prospect phase. Clusters with an error probability of $p < .001$ uncorrected for multiple comparisons are reported. The coordinates and t-values are at the peak voxels in each cluster (coordinates refer to MNI-space). All clusters written in bold letters are within a priori hypothesized regions and survive a significance threshold of $p < .05$ family-wise error corrected for small volumes.

Neural activity in regions	Right / Left	Cluster size (Voxels)	Coordinates			t-value
			X	Y	Z	
increasing linearly with subjective preference:						
Dorsolateral prefrontal cortex	L	163	-26	50	24	5.64
Mesial prefrontal cortex	R	16	2	44	2	4.27

Table 2: Clusters showing brand-preference-dependent activity during the prospect phase. Clusters with an error probability of $p < .001$ uncorrected for multiple comparisons are reported. The coordinates and t-values are at the peak voxels in each cluster (coordinates refer to MNI-space). All clusters written in bold letters are within a priori hypothesized regions and survive a significance threshold of $p < .05$ family-wise error corrected for small volumes.

4 Discussion

One aim of this study was to replicate and strengthen the findings of our previous study (Koenke et al., 2008) that explored brain areas responding to rewards differing in subjective value. For this purpose, we used sneaker brands as rewards that differed in subjective attractiveness, following the hypothesis that brands have the power to modulate the subjectively perceived value. In line with the results of our former study, we were able to demonstrate that playing for more preferred rewards compared to less preferred rewards induces increased neural activation in structures commonly linked to reward processing. Thus, results seem to generalize across different reward categories. Results furthermore support the proposed distinction between anticipatory and evaluative aspects of reward processing (Berridge, 1996, 2004, 2007; Berridge and Robinson, 2003; Knutson et al., 2001). In addition, we could show that increasing one's chance of obtaining rewards that differ in terms of subjective preference elicits neural activity comparable to winning different amounts of primary reinforcers or accumulating monetary rewards.

4.1 Prospect phase

“The anticipation of a reward is thought to lead to motivated behaviour through a series of steps originating in the limbic system and terminating in the motor system“ (see Roesch and Olson, 2003, p. 1766). Our results revealed neural structures along this pathway. Thus, the increase of the incentive value of the sports shoes induced by more preferred compared to less preferred brands is reflected by enhanced activity of neural structures commonly associated with reward processing.

While participants were waiting for the outcome of the spinning wheel-of-fortune, hemodynamic responses in the left ventral striatum were linearly associated with subjectively perceived reward value. The ventral striatum is known to be involved in the prediction of rewards in terms of expected reward value and expected reward probability (Schultz, 1998). Given that in this study, between-trials reward probability was held constant across trials ($p = 0.5$), the preference-modulated activation of the ventral striatum likely reflects the augmented value that a more favoured brand adds to an expected reward. In a majority of studies that have used monetary reinforcers, a similar relation between neural activity and reward magnitude has been reported (Knutson and Cooper, 2005). In contrast, a study of Elliott et al. (2003) showed a non-graded striatal response to varying monetary rewards. This contradictory finding might be due to the fact that reward anticipation and reward outcome were not modelled as separate conditions but analyzed in a blocked design. It was shown previously that this distinction is important: Using single cell recordings in primates' midbrain dopaminergic neurons, Tobler et al. (2005), for example, demonstrated that the spiking response to a reward cue is sensitive to the magnitude of the expected reward value but not the

response to the reward outcome. In line with this finding, Cromwell and Schultz (2003) reported a monotonic relationship between discharge rates of primate striatal neurons and expected reward magnitudes. Thus, we assume that the activation in the ventral striatum in our study reflects expectancies concerning the predicted, forthcoming reward value and clearly indicates that this value is modulated by the subjective value associated with specific brands.

Our analysis further revealed a cluster in the right anterior insula to respond to the subjective value of the rewards played for. While activity in the insula has been traditionally associated with negative emotional states, arising in response to aversive stimuli such as facial expressions of disgust (Phillips et al., 2004), pain (Peyron et al., 2000) or monetary losses (Paulus et al., 2003), it is also reliably responding to monetary gains (Izuma et al., 2008) and appetitive processing (Craig, 2004). In addition, results of recent lesion studies demonstrated that smokers with damage to the insular cortex no longer experience conscious urges to smoke after quitting, suggesting that the insular cortex is a key structure in the perception of bodily needs that provides direction to motivated behaviours (Naqvi et al., 2007). Taking the above mentioned findings of previous studies into account we cannot definitely answer the question whether reward-value-dependent insular activity can be attributed to positive emotions in the prospect phase. It is equally conceivable that the preference-modulated activity in the anterior insula may be due to the potential risk of reward omission which probably is regarded as more negative in case of more preferred brands. But regardless of valence of the emotional state indicated by the insula activity, its strength is clearly dependent on the subjective preference for the uncertain reward.

In addition to the ventral striatum and the insula, a monotonic reward-value-dependent increase of the hemodynamic responses was registered bilaterally in the premotor cortex and pre-SMA. Given that reward delivery did not depend on an instrumental motor response (such as grasping for a reward), processes of motor preparation or motor execution (Picard and Strick, 2001) cannot explain this finding. Instead, premotor activity and pre-SMA activity may represent an increased state of motor preparedness, which may be the result of action-inducing characteristics of incentive stimuli. It is likely that the premotor cortex activity and pre-SMA activity reflect motivational modulation of motor signals corresponding to the value of a reward (i.e., increased motor preparedness for more desired rewards), as previously shown in primate single cell studies (Roesch and Olson, 2003) and human brain imaging studies (Koenke et al., 2008; Elliott et al., 2003; Knutson and Cooper, 2005).

4.2 Outcome phase

In each trial, when the wheel of fortune game stopped, the participants were informed whether they had won or not. In trials in which participants won, hemodynamic responses in the dorsolateral prefrontal cortex (DLPFC)

were stronger for more preferred brands. This is in line with the findings of McClure et al. (2004), showing that participants' previously expressed brand preferences influenced neural activity in the DLPFC during subsequent consumption of soft drinks. The DLPFC is understood to play an integrative role in cognitive control (Miller, 2000) and short-term memory processing (Levy and Goldman-Rakic, 2000). Additionally, results from studies with patients with major depressive disorders and patients with DLPFC lesions (Davidson et al., 2002) suggest an involvement in affective and motivational processing.

Hemodynamic responses in the mesial prefrontal cortex (VMPFC) also correlated with brand preferences in the outcome phase. A large number of studies reported increased hemodynamic responses in the VMPFC when participants received information about gains compared with no gains or losses. This holds for primary reinforcers, such as drinks (McClure et al., 2004), and for secondary reinforcers, such as money (Knutson et al., 2001). Knutson and Peterson (2005) therefore propose that the MPFC tracks the experienced utility of rewards. Furthermore, MPFC activations were found irrespective of whether the rewards were consumed immediately (e.g., liquid food, O'Doherty et al., 2002) or obtained after the experimental procedure (e.g., monetary rewards, Breiter et al., 2001). It should be noted that participants in our study did not accumulate money over trials, but could only increase the probability of winning a voucher for a particular brand. Thus, the reward value perceived in each winning trial of our study is affected by the subjective brand preference but also by reward probability defined as the number of lottery tickets won so far at a given point in time. To overcome the problem that people often experience difficulties with cognitively processing probabilities (Tversky and Kahneman, 2003), probabilities were represented by frequencies (of lottery tickets) in our study, which are easier to understand (Gigerenzer and Hoffrage, 1995). Despite the more abstract reward scheme, our results are comparable to those of studies in which guaranteed monetary rewards were collected (Knutson et al., 2003). Thus, the results seem to hold regardless of whether expected reward value is manipulated by changing the value of the outcome or by changing its probability. Besides its prominent role in processing the value of obtained rewards, MPFC activation has also been observed in the context of emotional arousal and introspection (Critchley et al., 2000; Lane et al., 1998; Price, 1999). Overall, findings of past research and of the current study indicate that the MPFC is involved in the evaluation of reward magnitude and reward valence, largely independent from sensory modality and the degree of abstraction.

4.3 Differences to the findings of the study of Koeneke et al. (2008)

One major goal of the present study was to replicate and extend previously reported findings of a study of our group (Koeneke et al., 2008). The foremost mod-

ifications of the present study compared to the former implied an altered reward scheme (participants could increase reward probabilities rather than gain—as well as lose—rewards) and the use of different rewards (vouchers for sneakers rather than chocolate bars). Overall, similar structures were inferred from the analysis, suggesting reliable activation of reward-related brain structures to differentially valued rewards.

In extension of the previous findings, we found value-related activity in the ventral striatum. This result did not emerge in the former study, in which participants could win *and* lose rewards. Thus, the expected reward value might have been minimized because the probability to keep a once gained reward over the whole experiment was small. Supporting this notion, a recent fMRI study demonstrated that neural activity in the ventral striatum correlates with the expected probability for a reward (Abler et al., 2006). In contrast, the reward scheme applied in the present study implied an irreversible accumulation of the chance to win one out of three differentially preferred rewards. Each lot to be won represented an increase in chance over the whole experiment and therefore the perceived reward value was likely higher than in the previous study. Also, the monetary value of the likely reward was higher (a voucher worth 150 SFr., won with a probability of $p = 0.5$ per brand, resulting in an overall win probability of $p = 0.875$). Compared to the average gain of 10 chocolate bars in the previous study, the stakes were higher in the current study, which may have further contributed to strengthening the effects.

In the present study participants could win vouchers for a pair of sneakers of a specific brand. Marketing in this product category mainly focuses on associating the brands with a certain lifestyle rather than advertising concrete product features (Niebuhr, 1998). In addition, up-market sneakers are similar in price, appearance and quality. Thus, we believe that the subjective values for the differentially preferred vouchers are predominantly culturally transferred. In contrast, chocolate bars of different brands employed in the previous study possibly represented a less culturally influenced reward category. Preferences for chocolate might be more influenced by preferences for taste than for brand. Given that in both studies highly similar structures of the brain (besides the ventral striatum) responded to differences in subjective value, it is conceivable that brain areas of the reward system generally respond according to perceived subjective values of rewards, irrespective of the reward stimulus category (eg. primary reinforcers such as tasty food, monetary rewards, or other secondary reinforcers with culturally transferred meaning) and the degree of abstraction of a reward (e.g., accumulating rewards or accumulating chances to gain a reward).

5 Conclusion

In summary, this study provides evidence that the modulating effect of branding on the rewarding value of objectively similar goods can be demonstrated in specific

patterns of brain activation. While opting for a desired reward, activity in the ventral striatum, anterior insula and premotor cortex correlates with subjective preference, whereas winning a preferred reward elicits preference-dependent activation in the medial and dorsolateral prefrontal cortex. The findings are consistent with the hypothesis that brand attractiveness, similar to the attractiveness of other rewarding stimuli, is mediated by at least two components: a motivational component to guide future behavior, and an evaluative component monitoring the conscious feeling of pleasure. From an applied perspective, the distinction of different facets of brand attractiveness on a neural level may help marketing practitioners attain a better understanding of how brands are processed, and provides guidance for tailoring marketing activities.

References

- Abler, B., Walter, H., Erk, S., Kammerer, H., and Spitzer, M. (2006). Prediction error as a linear function of reward probability is coded in human nucleus accumbens. *Neuroimage*, 31(2):790–795.
- Advertising Age (2007). Top 100 Global Marketers. Advertising Age’s 21st Annual Global Marketers Part 1: Global Ad Spending by Marketer. Technical report, Advertising Age.
- Ataman, B. and Ülengin, B. (2003). A note on the effect of brand image on sales. *Journal of Product and Brand Management*, 12(4):237–250.
- Berridge, K. (1996). Food reward: Brain substrates of wanting and liking. *Neuroscience and Biobehavioral Reviews*, 20(1):1–25.
- Berridge, K. (2004). Motivation concepts in behavioral neuroscience. *Physiology and Behavior*, 81(2):179–209.
- Berridge, K. (2007). The debate over dopamine’s role in reward: The case for incentive salience. *Psychopharmacology*, 191(3):391–431.
- Berridge, K. and Robinson, T. (2003). Parsing reward. *Trends in Neurosciences*, 26(9):507–513.
- Bosch, V. (2005). Validation of the GfK Price Challenger. Technical report, GfK White Paper.
- Breiter, H., Aharon, I., Kahneman, D., Dale, A., and Shizgal, P. (2001). Functional imaging of neural responses to expectancy and experience of monetary gains and losses. *Neuron*, 30(2):619–639.
- Büchel, C., Holmes, A., Rees, G., and Friston, K. (1998). Characterizing stimulus-response functions using nonlinear regressors in parametric fMRI experiments. *Neuroimage*, 8(2):140–148.
- Coricelli, G., Dolan, R., and Sirigu, A. (2007). Brain, emotion and decision making: the paradigmatic example of regret. *Trends in Cognitive Sciences*, 11(6):258–265.
- Craig, A. (2004). Human feelings: why are some more aware than others? *Trends in Cognitive Sciences*, 8(6):239–241.
- Critchley, H. D., Corfield, D., Chandler, M., Mathias, C., and Dolan, R. (2000). Cerebral correlates of autonomic cardiovascular arousal: A functional neuroimaging investigation in humans. *Journal of Physiology*, 523:259–270.
- Cromwell, H. and Schultz, W. (2003). Effects of expectations for different reward magnitudes on neuronal activity in primate striatum. *Journal of Neurophysiology*, 89(5):2823–2838.
- Davidson, R., Pizzagalli, D., Nitschke, J., and Putnam, K. (2002). Depression: Perspectives from affective neuroscience. *Annual Review of Psychology*, 53:545–574.
- Elliott, R., Newman, J., Longe, O., and Deakin, J. (2003). Differential response patterns in the striatum and orbitofrontal cortex to financial reward in humans: a parametric functional magnetic resonance imaging study. *Journal of Neuroscience*, 23(1):303–307.
- Gigerenzer, G. and Hoffrage, U. (1995). How to improve Bayesian reasoning without instruction: Frequency formats. *Psychological Review*, 102(4):684–704.
- Izuma, K., Saito, D., and Sadato, N. (2008). Processing of social and monetary rewards in the human striatum. *Neuron*, 58(2):284–294.
- James, G., Gold, M., and Liu, Y. (2004). Interaction of satiety and reward response to food stimulation. *Journal of Addictive Diseases*, 23(3):23–37.
- Kim, S., Hwang, J., and Lee, D. (2008). Prefrontal coding of temporally discounted values during intertemporal choice. *Neuron*, 59(1):161–172.
- Knutson, B. and Cooper, J. (2005). Functional magnetic resonance imaging of reward prediction. *Current Opinion in Neurology*, 18(4):411–417.
- Knutson, B., Fong, G., Adams, C., Varner, J., and Hommer, D. (2001). Dissociation of reward anticipation and outcome with event-related fMRI. *Neuroreport*, 12(17):3683–3687.
- Knutson, B., Fong, G., Bennett, S., Adams, C., and Hommer, D. (2003). A region of mesial prefrontal cortex tracks monetarily rewarding outcomes: Characterization with rapid event-related fMRI. *Neuroimage*, 18(2):263–272.
- Knutson, B. and Peterson, R. (2005). Neurally reconstructing expected utility. *Games and Economic Behavior*, 52(2):305–315.
- Koeneke, S., Pedroni, A., Dieckmann, A., Bosch, V., and Jäncke, J. (2008). Individual preferences modulate incentive values: Evidence from functional MRI. *Behavioral and Brain Functions*, 4(1):55.

- Lane, R., Reiman, E., Axelrod, B., Yun, L., Holmes, A., and Schwartz, G. (1998). Neural correlates of levels of emotional awareness. Evidence of an interaction between emotion and attention in the anterior cingulate cortex. *Journal of Cognitive Neuroscience*, 10(4):525–535.
- Levy, R. and Goldman-Rakic, P. (2000). Segregation of working memory functions within the dorsolateral prefrontal cortex. *Experimental Brain Research*, 133(1):23–32.
- Martino, B. D., Kumaran, D., Seymour, B., and Dolan, R. (2006). Frames, biases, and rational decision-making in the human brain. *Science*, 313(5787):684–687.
- McClure, S., Li, J., Tomlin, D., Cypert, K., Montague, L., and Montague, P. (2004). Neural correlates of behavioral preference for culturally familiar drinks. *Neuron*, 44(2):379–387.
- Miller, E. (2000). The prefrontal cortex and cognitive control. *Nature Reviews Neuroscience*, 1(1):59–65.
- Naqvi, N., Rudrauf, D., Damasio, H., and Bechara, A. (2007). Damage to the insula disrupts addiction to cigarette smoking. *Science*, 315(5811):531–534.
- Niebuhr, J. (1998). Target group: Poor neighbourhood. The ethical implications of lifestyle marketing in low income residential neighbourhoods. *Business Ethics: A European Review*, 7(3):182–185.
- O’Doherty, J., Dayan, P., Friston, K., Critchley, H., and Dolan, R. (2003). Temporal difference models and reward-related learning in the human brain. *Neuron*, 38(2):329–337.
- O’Doherty, J., Deichmann, R., Critchley, H., and Dolan, R. J. (2002). Neural responses during anticipation of a primary taste reward. *Neuron*, 33(5):815–826.
- Paulus, M., Rogalsky, C., Simmons, A., Feinstein, J., and Stein, M. (2003). Increased activation in the right insula during risk-taking decision making is related to harm avoidance and neuroticism. *Neuroimage*, 19(4):1439–1448.
- Pedroni, A. (2011). *The Neural Representation of Subjective Reward Valuation*. PhD thesis, University of Zurich.
- Peyron, R., Laurent, B., and Garca-Larrea, L. (2000). Functional imaging of brain responses to pain. A review and meta-analysis (2000). *Neurophysiologie Clinique / Clinical Neurophysiology*, 30:263–288.
- Phillips, M., Williams, L., Heining, M., Herba, C., Russell, T., Andrew, C., Bullmore, E., Brammer, M., and S.C. Williams, M. Morgan, A. Y. J. G. (2004). Differential neural responses to overt and covert presentations of facial expressions of fear and disgust. *Neuroimage*, 21(4):1484–1496.
- Picard, N. and Strick, P. (2001). Imaging the premotor areas. *Current Opinion in Neurobiology*, 11(6):663–672.
- Price, J. (1999). Prefrontal cortical networks related to visceral function and mood. *Annals of the New York Academy of Sciences*, 877:383–396.
- Roesch, M. and Olson, C. (2003). Impact of expected reward on neuronal activity in prefrontal cortex, frontal and supplementary eye fields and premotor cortex. *Journal of Neurophysiology*, 90(3):1766–1789.
- Rolls, E., McCabe, C., and Redoute, J. (2008). Expected value, reward outcome, and temporal difference error representations in a probabilistic decision task. *Cerebral Cortex*, 18(3):652–663.
- Schaefer, M. and Rotte, M. (2007). Favorite brands as cultural objects modulate reward circuit. *Neuroreport*, 18(2):141–145.
- Schultz, W. (1998). Predictive reward signal of dopamine neurons. *Journal of Neurophysiology*, 80(1):1–27.
- Schultz, W., Dayan, P., and Montague, P. (1997). A neural substrate of prediction and reward. *Science*, 275(5306):1593–1599.
- Sommer, R. (1998). *Psychologie der Marke [Psychology of the Brand]*. Deutscher Fachverlag, Frankfurt.
- Tobler, P., Fiorillo, C., and Schultz, W. (2005). Adaptive coding of reward value by dopamine neurons. *Science*, 307(5715):1642–1645.
- Tversky, A. and Kahneman, D. (2003). Availability: A heuristic for judging frequency and probability. In Baars, B., Banks, W., and Newman, J., editors, *Essential Sources in the Scientific Study of Consciousness*, pages 163–178. MIT Press, Cambridge.
- Wildner, R. (2003). Using market research to set prices. *Yearbook of Marketing and Consumer Research*, 1:12–16.