Anterior cingulate reflects susceptibility to framing during attractiveness evaluation

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Human cognitive decisions can be strongly susceptible to the manner in which options are presented (‘framing effect’). Here we investigated the neural basis of response adjustments induced by changing frames during intuitive decisions. Evidence exists that the anterior cingulate cortex plays a general role in behavioral adjustments. We hypothesized, therefore, that the anterior cingulate cortex is also involved in the ‘framing effect’. Our hypothesis was tested by using a binary attractiveness judgment task (‘liking’ versus ‘nonliking’) during functional magnetic resonance imaging. We found that the framing-related anterior cingulate cortex activity predicted how strongly susceptible an individual was to a biased response. Our results support the hypothesis that paralimbic processes are crucial for predicting an individual’s susceptibility to framing. 

Keywords: decision-making, fMRI, framing effect, neuroeconomics, prefrontal cortex, prejudgments, uncertainty

Introduction

In decision science, the term ‘framing’ characterizes the manner in which a problem of choice is presented. For example, the judgment of whether a certain newsmagazine headline is regarded as true or as false strongly depends on the credibility of the magazine in which the headline is presented [1]. In this example, the magazine brand can be regarded as ‘framing information’ that frames a cognitive plausibility decision. The dependence of the answers during a choice task on framing has been denoted as ‘framing effect’. Tversky and Kahneman’s work on the perceptual principles of human cognitive-decision problems has demonstrated that economic decisions can strongly depend on framing [2].

Recent studies provide evidence that framing-induced judgment biases are associated with emotional information integrated into the cognitive-decision process [1,3]. In particular, it was shown that during rational decision-making activations in the prefrontal cortex correlated with the participants’ susceptibilities to framing effects [1]. From a phylogenetic point of view, the development of adaptive behavior requires that all kinds of environmental stimuli be evaluated with respect to their behavioral relevance. Thus, framing effects might occur not only during rational decision-making with a purely cognitive context, but also during intuitive behavior, even if no obvious relationship exists between the framing information and the judgment material.

The anterior cingulate cortex is a central node in a neural network responsible for the integration of information about positive or negative reinforcements. This node thus relates actions to consequences, and is central to conflict monitoring and cognitive control [4–6]. Evidence from human and animal studies is available about the role of the anterior cingulate cortex in assessing the need for behavioral adaptations [7–10].

In this study we tested the hypothesis that the anterior cingulate cortex also has a central function for the integration of framing information into response behavior during intuitive decision making. When being investigated by functional magnetic resonance imaging (fMRI), participants had to evaluate the attractiveness (‘liking’, ‘nonliking’) of print advertising. The framing information consisted of the logos and style elements of four German newsmagazines and was concomitantly presented with the advertisements during the judgment task.

Methods

Stimulus material

We employed 46 current print advertisements taken arbitrarily from a well known German newsmagazine (Focus Magazin Verlag, Hubert Burda Media GmbH, München, Germany). In a pilot study, 100 randomly selected participants of both sexes had to judge their liking of these advertisements. The advertisements had to be rated on a
bias

namely 10 advertisements each in the groups rated highest
fMRI experiments we selected 30 of these advertisements,
Attractive' (see Fig. 1). As stimulus material for the following
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We provided high-quality image presentation with

scale ranging from 1 = 'very attractive' to 7 = 'absolutely not
attractive' (see Fig. 1). As stimulus material for the following
fMRI experiments we selected 30 of these advertisements,
namely 10 advertisements each in the groups rated
highest (group '++'), the 10 most nonliking (group '−−')
and 10 indifferent ads (group '0') were selected for our experiment.

by using this kind of 'normalization,' it was expected that the statements
of the three groups would mainly be judged as 'liking,' 'ambiguous'
and 'nonliking,' respectively.

Participants undergoing fMRI
Thirteen healthy men and eight healthy women (these participants
did not belong to the pilot study) participated in the core trial (mean age 29, range 25–35 years).
Standard exclusion criteria for MR imaging were applied. Participants with strong
myopia or other relevant constraints of vision were also excluded. All participants provided
informed consent before the scanning sessions. The participants did not belong to the pilot study
and were also informed that the examination could reveal potentially medically significant findings and were asked if
they would like to be notified in this case. The study was
approved by the local ethics committee.

Judgment task
During fMRI the 30 advertisements were presented in
combination with each of four logos of well known German
newsmagazines, here denoted as A, B, C, and D (Fig. 2). Thus
4 × 30 judgments had to be made. For data analysis, these
logos were used as the four levels of the framing factor.
The interstimulus interval between all 120 stimuli was standard-
dized to 10 s. In a forced-choice task, the participants were
requested to judge whether they liked the presented
advertisement or not by pressing the corresponding button
('liking' or 'nonliking') on a response box compatible with the
MR scanner. The responses were recorded by the stimulation
software that was used for visual presentation (ShowPics,
Department of Neurology, University of Münster, Germany).

Separately for each magazine M, we calculated the response
bias $B_M$ according to [1]

$$B_M = \frac{N_{\text{Liking}} - N_{\text{Nonliking}}}{N_{\text{Liking}} + N_{\text{Nonliking}}}$$

where $N_{\text{Liking}}$ and $N_{\text{Nonliking}}$ are the number of ratings judged
as 'liking' or 'nonliking', respectively ($−1 < B_M < 1$). Owing to

the preceding normalization of the stimulus material, we
assumed an average bias $\bar{B}$ of around 0 for representative
participants, whereas 'ad-liking' participants would obtain
positive and 'ad-aversive' persons negative values for $B$.

Additionally, a susceptibility index $SI$ was calculated as a
measure for the variability of the responses with regard to the
randomly changed magazine logos $M = A, B, C, \text{and } D$:

$$SI = \sqrt{\frac{1}{4} \sum_{M=A,B,C,D} (\bar{B}_M - \bar{B})^2}$$

Mathematically the $SI$ is the standard deviation of the
response biases $B_A, B_B, B_C$ and $B_D$ for each individual using
the mean bias

$$\bar{B} = (B_A + B_B + B_C + B_D)/4.$$  

Accordingly, if the magazine brand had no influence on the
perception and processing of the advertisements, there
would be no differences between the four $B_M$ values, that is,
$B_A = B_B = B_C = B_D$, and thus $SI = 0$. $SI$ can range between 0
and 1. $SI = 1$ indicates that the response variability is
entirely due to framing manipulation, that is, the visual
content of all advertisements is completely ignored.

Image presentation
A dedicated fMRI projection system (Covilex, Magdeburg,
Germany) provided high-quality image presentation with
the images covering about 50% of the participant's whole
field of view. Even small details of the visual stimulus could
be recognized easily. Care was taken to present the different
advertisements and logos in equal size, position, background,
and luminance to prevent such potential confounders.
The volunteers were asked to press the corresponding
button on the response box immediately after they had
made their decisions. They were informed that 120 decisions
had to be made. Head fixation was achieved with foam pads
and a soft headband. Earplugs and headsets were employed
to protect against scanner noise and to permit communication
with the participants.
Magnetic resonance image acquisition
All data were acquired on a 3.0-T whole-body scanner (Intera T30, Philips, Best, The Netherlands). An isotropic T1w dataset of the whole head with a reconstructed voxel size of 0.5-mm edge length was acquired for anatomical identification and coregistration into the Talairach space [11]. For functional images blood oxygenation level dependent (BOLD) contrast images were acquired using a T2*-weighted single shot gradient echo-planar imaging (EPI) sequence, which covered nearly the whole brain. The dataset consisted of 36 transversal slices of 3.6-mm thickness without gap, field of view 230 × 230, matrix 64 × 64. Slices were oriented parallel to the ac–pc line. Imaging parameters were repetition time = 3000 ms, echo time = 50 ms, flip angle = 90° and EPI-factor (echo train length) 63. Before each fMRI was run, 10 dummy scans were acquired to allow for the equilibration of magnetization.

Data analysis
Data analysis was performed using Statistical Parametric Mapping (SPM2; Wellcome Department of Cognitive Neurology, London, UK; http://www.fil.ion.ucl.ac.uk/spm). All EPI volumes were spatially normalized to the Montreal Neurologic Institute EPI standard template and resampled to 2 × 2 × 2 mm³ resolution [12]. All normalized functional volumes were smoothed with an isotropic Gaussian kernel (4 mm full width at half-maximum). Global changes in fMRI response from scan to scan were removed by proportional filtering with a cutoff frequency of 0.008 Hz. The hemodynamic responses were modeled into an event-related statistical design based on the general linear model. The temporal events were defined by the time points when the visual stimuli appeared. The events were categorized according to the four different levels of the implicit stimulation, that is, the occurrence of the advertisements in one of the four different newsmagazine brands A, B, C, and D. According to these four levels of the factor magazine type M, a one-factorial analysis of variance (ANOVA) was calculated for each examined participant to assess individual cortical-activity modulations caused by the framing factor (single-participant analysis). For the group analysis, we employed linear regression by using the F maps from the one-factorial single-participant ANOVA as the dependent variable and the participants’ SI as the independent variable. Correlations of P < 0.001 (uncorrected, extent threshold = 50 voxels) between SI and cortical-activity modulations were regarded as being significant.

Results
Judgments
Owing to the ‘normalization’ of the advertisements’ attractiveness (Fig. 1) in the pilot study, we found balanced decisions in total. The actual judgments averaged over the four journals were mainly ‘liking’ for the ‘+’ group, ‘nonliking’ for the ‘−’ group, and were nearly equally distributed within the ‘0’ group. According to equation 1, this led to an overall mean bias for all 21 examined participants close to zero. Response times typically varied between 2 and 4 s with significantly longer times for decisions of the ‘0’ group. Our behavioral results expressed by the SI [equation (2)] indicate a violation of representa-

tional invariance in response behavior due to the framing by the magazine logos. SI varied between 0.0 and 0.32, indicating an interindividual difference in the degree of susceptibility for framing information (Fig. 3).

Cortical activity
The fMRI analysis performed at the single-participant level (one-factorial ANOVA) revealed significant blood oxygenation level dependent signal modulations by framing for about half the participants. In participants with significant effects, these changes occurred consistently in the right-sided higher visual areas in the parietal cortex (Brodmann area BA 19), in the inferior frontal gyrus (BA 46), the right middle frontal gyrus (BA 10), and bilaterally within the anterior cingulate cortex, in correspondence with our hypothesis (Fig. 4a–c).

Regression analysis demonstrated that the degree of the participants’ susceptibilities to judgment biases, expressed by the SI, and their corresponding brain-activity modulations in the anterior cingulate cortex, induced by the varying magazine brands, correlated highly significantly (R = 0.69, P = 0.0005) (Fig. 4d).

Discussion
In two recent studies employing (i) a preference-choice task [13] and (ii) a cognitive plausibility-evaluation task [1], it was shown that the ventral parts of the medial prefrontal cortex play a key role in the integration of implicit, decision-relevant framing information during rational decision making. These structures have been found to be particularly involved in processing emotions. Further, it has been demonstrated that framing effects correlated with activity modulations in emotionally associated brain structures during economical decisions [3].

In this study, we used the same framing stimulus as in the previously published plausibility-evaluation task [1], but we
changed the type of material that had to be evaluated. Instead of semantic stimuli, we used visual stimuli here, which had to be intuitively evaluated on a participant-specific intrinsic scale. We further assessed the event-related hemodynamic responses immediately associated with the occurrence of the visual stimulus instead of those at the point in time when the responses were given.

The main finding of this study was that anterior cingulate cortex activity predicted the individual’s susceptibility to framing information. If the magazine brand had no influence on the perception and processing of the advertisements in the sense of a framing effect, there would have been no significant differences between the four $B_M$ values, that is $B_A = B_B = B_C = B_D$, and thus $SI = 0$ (according to equation 2), because the visual contents to be evaluated were exactly the same in all four magazines. Quite the contrary was true. We found highly significant intraindividual variations in $B_M$ (expressed by $SD$), reflecting a strong influence of the confounding framing stimuli, that is, the magazine brands. The strong correlation between an individual’s $SI$ score, representing a participant’s susceptibility to framing, and the activity modulation in the anterior cingulate cortex supports our hypothesis that this paralimbic structure is involved in assessing the behavioral relevance of framing stimuli. These results are in agreement with recent findings that underline the role of the dorsal anterior cingulate cortex in stimulus assessment and in the general regulation of response behavior beyond conflict monitoring [14].

**Conclusion**

We conclude that, corresponding to its fundamental role in behavioral adjustments, the anterior cingulate cortex is involved in the assessment of environmental (framing) information during decision making. Our results support the hypothesis that an individual’s susceptibility to framing is at least partly regulated by presemantic assessment processes in a phylogenetically old brain structure. These results may explain why it is so hard to fulfill an important

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**Fig. 4** Stimulus-onset-locked brain-activity changes. (a–c) We found significant correlations ($P < 0.001$, uncorrected, extent threshold 50 voxels) between individuals’ susceptibility for a framing effect ($SI$) and the effect size of the framing stimulus on the hemodynamic response bilaterally in the anterior cingulate cortex (red arrow, a) and the inferior frontal gyrus, Brodmann area (BA) 46 (b). Further correlations were found in higher-order visual cortices in the right occipital lobe (BA 19), and the right middle frontal gyrus, BA 10 (c). (d) Linear regression between the response effect in the anterior cingulate cortex (ACC; red arrow in a) and $SI$. Each point reflects data from a single participant ($N = 21$).
Axiom in rational decision-making theory, namely the representational invariance in human decision behavior [15].

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