Negative bias of processing ambiguously cued emotional stimuli

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Daily we cope with upcoming potentially disadvantageous events. Therefore, it makes sense to be prepared for the worst case. Such a 'pessimistic' bias is reflected in brain activation during emotion processing. Healthy individuals underwent functional neuroimaging while viewing emotional stimuli that were earlier cued ambiguously or unambiguously concerning their emotional valence. Presentation of ambiguously announced pleasant pictures compared with unambiguously announced pleasant pictures resulted in increased activity in the ventrolateral prefrontal, premotor and temporal cortex, and in the caudate nucleus. This was not the case for the respective negative conditions. This indicates that pleasant stimuli after ambiguous cueing provided 'unexpected' emotional input, resulting in the adaptation of brain activity. It strengthens the hypothesis of a 'pessimistic' bias of brain activation toward ambiguous emotional events. ***NeuroReport*** **21:601–605 © 2010 Wolters Kluwer Health | Lippincott Williams & Wilkins.**

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Introduction

The emotional valence of an expected event provides the basis on which our brain develops behavioral strategies for quick and efficient adaptation to new circumstances. In daily life, we are often uncertain whether a future event will be pleasant or unpleasant. We then prepare ourselves mentally for the possible outcomes. From an evolutionary perspective, it is conceivable that we have come to prepare for, and thus, cope better with, a potentially threatening environment by anticipating the worst case [1]. Thus, one may assume a negative or 'pessimistic' bias of anticipating an event of ambiguous emotional valence, as reported earlier for the expectation period [2]. In contrast, optimistic biases toward the general personal future were reported [3]. For currently faced events with ambiguous emotional impact, either positive or negative, we hypothesized a negative/'pessimistic' bias. In that case, presenting negative stimuli after an ambiguous anticipation period should not serve as relevant new information. Thus, we expected no relevant emotion-specific cerebral activity changes compared with a condition of being prepared for a negative event known to be so, because the negative picture presentation would just confirm the negative presetting. In contrast, a positive event occurring after an ambiguously cued expectation of an emotional event should cause a mismatch between the hypothesized negatively biased anticipation and the pleasant presentation. Accordingly, in that case, we expected activation in structures involved in emotion processing, mismatch detection and behavior planning, because a 'remodeling' of the negative emotional presetting would have to take place. To test the hypothesis of a negative biased processing of ambiguous emotional impact, we carried out an experiment in the context of functional magnetic resonance imaging (fMRI) measurements in which a visual cue signaled forthcoming emotional stimuli. Participants were instructed to expect, and then to perceive visual stimuli with earlier unambiguous (pleasant, unpleasant/negative, neutral) or ambiguous (either unpleasant or pleasant) emotional valence. We compared brain activity during the presentation of pictures with the same valence (unpleasant and pleasant) after an ambiguous versus an explicitly precued unambiguous anticipation period.

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Materials and methods

Participants and experimental design

Sixteen healthy participants (mean age 27.6 years, standard deviation 3.6, right-handed, eight female) performed an emotion expectation task while being scanned with fMRI. This study was approved by the local ethics committee. The task comprised 56 trials in which emotional pictures were expected and then presented (Fig. 1). The trials consisted of two main conditions: unambiguously and ambiguously announced emotional pictures. For each trial of the unambiguously announced condition, a small cue was presented depicting either a smiling '∪' ['pleasant' (ps)], a nonsmiling '∩' ['negative' (ng)

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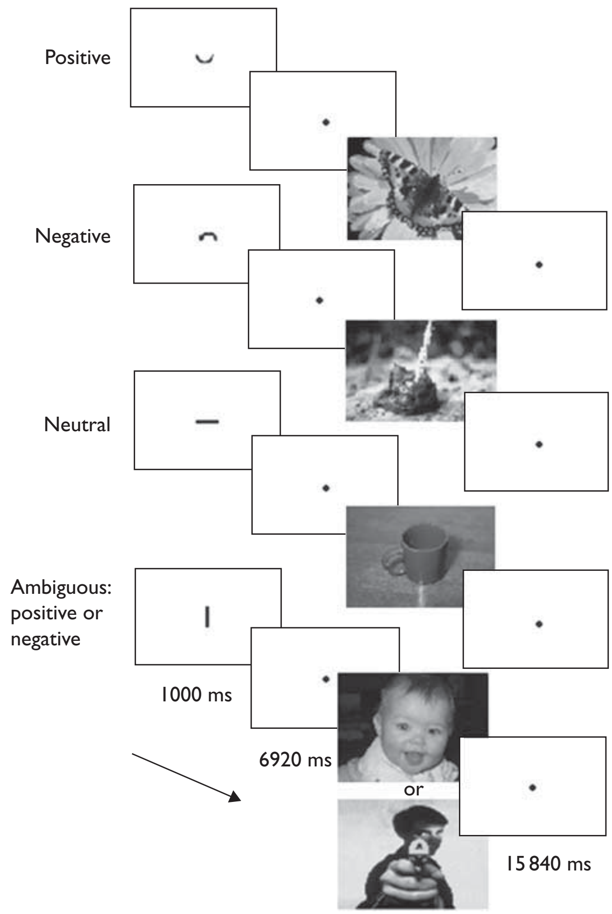
Fig. 1



Experimental task. The four conditions with the respective cues and the durations. Here, the cues are relatively enlarged for presentation reasons. In the experiment, they were about 1/40 of screen height.

or 'unpleasant'], or a neutral (nt) '–' symbol, and indicating the emotional valence of the pictures presented after a delay period. In the ambiguously announced condition (amb) '|', either pleasant or unpleasant pictures appeared randomly. The cues were presented for 1000 ms followed by an anticipation period of 6920 ms (cue and anticipation together 7920 ms = four repetition time; TR), during which a blank screen with a small fixation point was shown. Subsequently, emotional pictures of the International Affective Picture System [4] were presented for 7920 ms (4 TRs). A baseline of 15840 ms (eight TRs) followed, to allow the BOLD signal to level off before a new trial started. Altogether, 56 precued pictures were shown in a randomized order, 14 for each condition: unambiguous positive, negative, neutral, and ambiguous (seven positive and seven negative). The participants were instructed to expect the emotional stimuli after the cue, and to be aware of the emotional valence signaled, and to subsequently look at the following picture. The stimuli were matched for complexity, content of faces, scenery, food and nature, and intensity of positive and negative valence with the same difference in valence ratings from neutral [2]. The task was programmed with Presentation (Neurobehavioral Systems, USA).

FMRI acquisition and data analysis

Imaging was carried out with a 1.5 Tesla Siemens Sonata whole-body scanner (Erlangen, Germany) equipped with a head coil. The detailed general imaging parameters and the basic standard fMRI preprocessing procedures using BrainVoyager QX 1.10.1 (Brain Innovation, Maastricht, the Netherlands) were reported [2]. Nine predictors were used to build the design matrix of the experiment: four for the expectation (exp) conditions ng, ps, nt, amb, and five for the presentation (pres) conditions ng after ng exp, ng after amb exp, ps after ps exp, ps after amb exp, nt after nt exp. Expectation periods and picture presentation periods were modeled as epochs, using the standard two-γ-hemodynamic response function. Three-dimensional statistical parametric maps were calculated for the groups with separate subject predictors using a general linear model and a random effects analysis (rfx). We used a cluster threshold of 135 voxel a $1 \times 1 \times 1$ mm, for the analysis, corresponding to five voxel a $3 \times 3 \times 3$ mm and set at P value of less than 0.005.

We examined whether brain areas react differentially to the presentation of positive or negative pictures, depending on whether the pictures were ambiguously or unambiguously announced. We calculated the following contrasts to test our hypothesis that only the perception of ambiguously cued positive pictures requires additional brain processes to adapt to the new (better than expected) situation:

(1) (Presentation of positive pictures after an ambiguous cue) versus (positive pictures after unambiguous positive cue); briefly: [(pres-amb-ps > pres-ps-ps)];

versus

(2) (Presentation of negative pictures after an ambiguous cue) versus (negative pictures after unambiguous negative cue); briefly [(pres-amb-ng > pres-ng-ng)].

The comparison between (1) and (2) represented the main analysis [(pres-amb-ps > pres-ps-ps) < > (pres-amb-ng > pres-ng-ng)].

The regions that showed the first contrast (1) were regarded exploratory and reported in the supplemental digital content, if they complied with the hypothesized functions and if they did not get activated in the second contrast (2).

Furthermore, we calculated a conjunction analysis to show the brain regions that are important for the adaptation process, after an ambiguous cue for both the emotional valences (positive and negative):

(3) (Presentation of positive pictures after an ambiguous cue) versus (positive pictures after unambiguous positive cue) and (presentation of negative pictures after an ambiguous cue) versus (negative pictures after unambiguous negative cue); in brief: [(pres-amb-ps > pres-ps-ps) ∩ (pres-amb-ng > pres-ng-ng)].

The identification of the anatomical regions was based on the Talairach and Tournoux system [5]. An analysis restricted to the expectation period was reported earlier [2].

Results

Fourteen of the 16 participants were included in the analysis. Two participants were excluded because of drowsiness in the scanner and lack of concentration.

Identification of those regions that differ in activity during the perception of ambiguously cued positive pictures in comparison with ambiguously cued negative pictures [(contrasting (1) minus (2)], showed increased activity in the right ventrolateral prefrontal cortex (VLPFC; Fig. 2a), the right premotor cortex (Fig. 2b), the caudate/hippocampus and the middle temporal gyrus in both hemispheres, the right precuneus, the left gyrus lingualis, and the left putamen (Table 1). Calculation of the reversed contrast [(2) minus (1)], for identifying those regions that react differentially to ambiguously announced negative pictures, showed no increased activity in any brain region.

The conjunction analysis aimed at uncovering those regions that differ in activity depending on whether positive and negative pictures were ambiguously or unambiguously cued [contrast (3); $P < 0.005$], showed no activity in any brain region.

An exploratory analysis aimed at uncovering those regions that differ in activity depending on whether positive pictures were ambiguously or unambiguously cued [contrast (1), Table S1, Supplemental digital content 1, *http://links.lww.com/WNR/A38*], showed activation in the anterior cingulate cortex (Fig. S1) and in the dorsolateral prefrontal cortex [(Fig. S2), Supplemental digital content 2, *http://links.lww.com/WNR/A39*], which was not the case for the perception of ambiguously announced negative pictures [contrast (2)].

Discussion

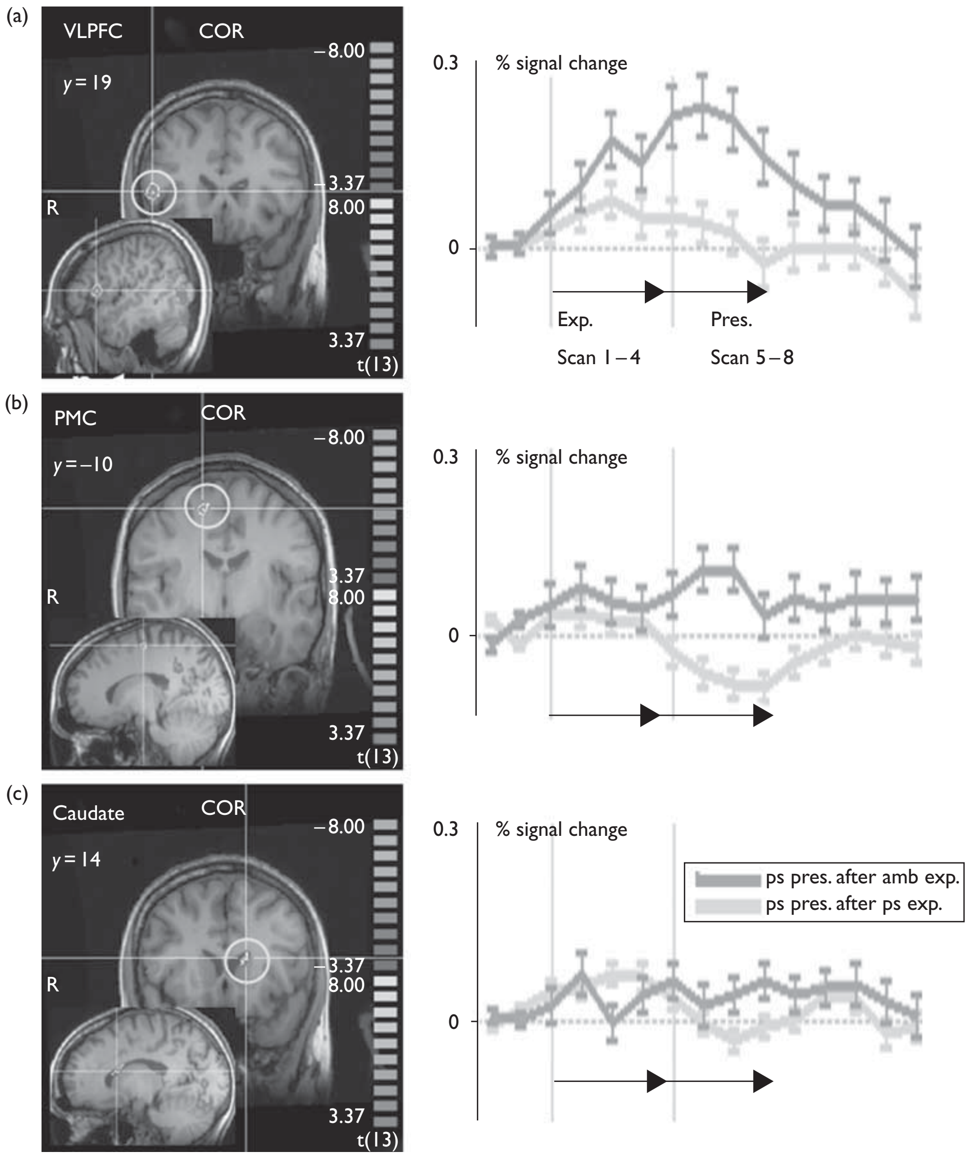
Perceiving ambiguously cued positive pictures in comparison with unambiguously cued positive pictures resulted in prominent changes in various hypothesized brain areas. In contrast, perceiving ambiguously cued negative pictures in comparison with unambiguously cued negative pictures did not change brain activation. This implicates, that in case of ambiguity, the positive valence of the pictures may have meant ‘unexpected’ information, which was not prepared for and onto which brain activation had to then adapt. In contrast, the negative stimuli appeared to be ‘expected’ as no adaptive brain activity occurred. This provides neurobiological evidence for a ‘pessimistic’ bias in brain activation in response to events with ambiguous emotional impact, implicating that ambiguous expectation is associated with a preparation for the worse case [6].

The presentation of ambiguously announced positive pictures leads to brain activity changes in the VLPFC, a central region within emotion processing. The VLPFC was earlier reported to be involved in the integration of cognitive and emotional information [7], in processes of inner monitoring of emotions [8], in working memory [9,10], stimulus evaluation and perceptual and conceptual processing [11]. These functions are reasonably involved in resetting a negative bias to deal with a positive event. Furthermore, the mid-VLPFC, in which the activity was observed, is involved in active controlled judgments leading to the disambiguation of information in memory and perceptual processing [12]. Accordingly, one may interpret our finding in a way that the information provided with the pleasant pictures after ambiguous cueing could require more disambiguation than when being presented the negative pictures because these were implicitly expected. Furthermore, we found bilateral activations in the middle temporal gyrus, which was earlier reported to be involved in higher order stimulus-processing and emotion-processing (e.g. [13,14]).

The premotor cortex is involved in the planning of voluntary motor action [15]. Hence, its involvement could be because of the hypothesized ‘remodeling’ of brain activity, as potentially prepared motor reaction as ‘flight-or-fight strategies’ have to be skipped with the appearance of an ‘unexpectedly’ positive picture. The same reason could explain the activation of the caudate, as part of the basal ganglia, showing visuomotor associations [16]. The caudate was shown to be part of dopamine-rich areas associated with reward and motivation [17], both functions that gain a new significance in case of occurrence of a positive picture after a negatively biased ambiguous expectation. What is more, activity in the head of the caudate was shown to be linked to executive functions related to feedback receiving [18], and was associated with probabilistic classification [19] and information integration [20]. Altogether, the caudate may be involved in adapting brain activity when perceiving an ‘unexpected’ emotional event and in preparing the executive level to deal with the ‘new’ circumstances.

When further regarding those regions with differing activity during the perception of ambiguously cued positive and negative pictures (in comparison with unambiguously cued positive and negative pictures; conjunction analysis), to show brain regions that are important for the adaptation process in general, we found no region to be activated, meaning that there are no common regions modulating the adaptation process regardless of the emotional valence.

Fig. 2



Brain activation resulting from the contrast 'presentation of positive pictures after ambiguous (amb) expectation versus positive (ps) pictures after unambiguous positive expectation' compared with 'presentation of negative pictures after ambiguous expectation versus negative pictures after unambiguous negative expectation'. The vertical gray bars represent the beginning of the expectation and presentation periods comprising each four volumes. Consider the time courses of BOLD signal changes showing differing activations in the presentation period of conditions with ambiguous (darker line) and obvious positive cueing (lighter line), despite both represented the perception of positive pictures: (a) right (radiological convention) ventrolateral prefrontal cortex (VLPFC), (b) right premotor cortex (PMC) and (c) caudate body. Exp, expectation; pres, presentation.

We expected an activation in the anterior cingulate cortex, known for conflict monitoring and mismatch detection [21], or/and the dorsolateral prefrontal cortex (executive functions and behavior planning [22]). This was only the case when regarding those regions with differing activity during the perception of ambiguously cued positive pictures (in comparison with unambiguously cued positive pictures, see Supplemental digital content, *http://links.lww.com/WNR/A39*); these regions were not activated in the respective negative condition, although the difference between both contrasts was not significant.

Conclusion

Although participants viewed pictures with the same positive emotional content, different activation patterns were observed depending on whether emotional valence was announced ambiguously or unambiguously. This presumably adaptive activation in case of ambiguity, not

Table 1 Activated regions in the contrast 'presentation of positive pictures after ambiguous expectation versus positive pictures after unambiguous positive expectation' compared with 'presentation of negative pictures after ambiguous expectation versus negative pictures after unambiguous negative expectation'

Anatomical region	Brodmann area	Cluster size (mm^3)	Talairach coordinates			t-max
			x	*y*	*z*	
(pres-amb-ps > pres-ps-ps) > (pres-amb-ng > pres-ng-ng)						
VLPFC R (Fig. 2a)	45	635	49	19	9	4.89
PMC R (Fig. 2b)	6	140	15	−10	55	5.26
Caudate L (Fig. 2c)		198	−15	14	18	5.05
Hippocampus/caudate tail R		222	38	−26	−7	4.63
Putamen L		138	−25	−2	14	4.52
Middle TG R	37	850	49	−64	6	4.19
Middle TG R	22	278	49	−39	0	4.19
Middle TG L	37	163	−49	−64	9	4.17
Middle TG L	22	188	−61	−44	4	4.69
Precuneus R	31	580	13	−46	35	5.64
Gyrus lingualis L	18	723	−12	−77	4	6.18

Indicated are the cluster sizes in mm^3, their central Talairach coordinates (*x*, *y*, *z*), and the maximal t value of the voxels within each region.
L, left; PMC, premotor cortex; R, right; TG, temporal gyrus; VLPFC, ventrolateral prefrontal cortex.

occurring with negative stimuli, confirms assumptions about a principal 'pessimistic' attitude toward upcoming events of ambiguous emotional impact for the individual.

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