The Identification of Sad Prosodies differentiates between High and Low Repressive Women

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Abstract

We investigated with fMRI whether different lateralization types of cortical activation in prosodic tasks are caused by different stress-related coping strategies. After classifying healthy women as high or low repressive they performed four different identification tasks with acoustically presented speech material while being in the MR scanner. The two materials presented in blocks were emotionally irrelevant CV syllables and adjectives with a mix of different prosodic intonations. Sad and happy intonations had to be targeted by two affective identification tasks in the same adjective mixtures. As controls for stimulus-material effects the phoneme /a/ had to be identified both in the syllables and in the adjectives. This design allowed to test influences of coping strategies and affective tasks on lateralization of cortical activation. Results showed no differences in global cortical lateralization as a function of high or low repressiveness and no global support for either the valence hypothesis or the right-hemisphere hypothesis of emotional processing. However, we observed differences in auditory and sensory speech cortex. In accordance to the construct of repression/sensitization, high repressive women showed larger left, low repressive women larger right hemisphere activation during the identification of sad intonations. Thus, differences in stress-related coping strategies may not lead to general differences in cortical lateralization, but may depend on specific elicitors and task-relevant brain areas. In contrast, the identification of happy intonations led to strong and right-lateralized global cortical activation independent of coping strategies which complies with the right-hemisphere hypothesis of emotional processing. In addition, this may reflect general cognitive and arousal effects of task difficulty as well as auditory cue-specific attentional effects.

1. Introduction

A previous functional magnetic resonance imaging (fMRI) study from our laboratory investigated in healthy humans the involvement of the two hemispheres during the perception of affective and linguistic prosodies in words [17]. Stimulus material consisted of mixtures of differently intonated adjectives (declarative, interrogative, imperative, happy and sad intonations) and of neutral consonant-vowel (CV) syllables on which four different identification tasks had to be performed. Subjects should either detect sad or interrogative intonations in the adjectives, whereas in the control tasks they should detect the phoneme /a/ in the adjectives and in the CV syllables. No lateralization differences of cortical activation as a function of tasks involving the adjectives was observed across the cohort. However, a post hoc analysis revealed two groups with either a stable left or right hemisphere dominance of cortical activation in all three tasks involving the adjectives, i.e. an effect of stimulus material. As a possible reason for these results with mixed prosodic stimuli, the valence hypothesis of emotion processing (left frontal dominance of brain activity for positive emotions, right frontal dominance for negative emotions) [6] in combination with interindividual differences in emotional reactivity to the mixed material was discussed [19].

For a reevaluation of these data it seems relevant that the valence hypothesis of emotion processing has been extended amongst others to individual differences in stress-related coping style [9]. Specifically with respect to stress-related coping the constructs of repression and sensitization as personality traits may be considered as fruitful. They characterize two opposite coping strategies with stressful events or threatening stimuli. While sensitizers attend to threatening stimuli, repressors avoid attention to threatening stimuli. According to Kohlmann [10], a repressive coping style is well operationalized by the scale "cognitive avoidance" of the "Angstbewältigungs-Inventar" (anxiety-coping inventory) [12]. Therefore in the present study the scale "cognitive avoidance" was assumed to be adequate for classifying subjects on their repressive coping style.

On the other hand, the results obtained by Stiller et al. [17] might be partially explained by the right-hemisphere hypothesis of emotional processing [4]. One subgroup of subjects could have attended mainly to the emotional content resulting in a right-hemisphere lateralization of cortical activation, while the other subgroup attended mainly to the verbal content of the adjectives resulting in a left-hemisphere lateralization. The study of Stiller et al. [17] cannot decide on the right-hemisphere hypothesis or on the valence hypothesis of emotional processing because the identification of happy intonations was not tested. Therefore in the present study, in addition to the anxiety-coping inventory, we explicitly included the identification of happy intonations as the second affective identification task to test these hypotheses.

1.1 Aims

In accordance to the above mentioned hypotheses on emotional processing and coping style, the influences of stress-related coping style and task on cortical activation were investigated in the present fMRI study using the same stimulus material as in Stiller et al. [17] but introducing the anxiety-coping inventory and as tasks the identification of happy intonations beside sad intonations. (1) We tested for lateralization differences in cortical activation by the adjectives in high and low repressive subjects, i.e. for an interaction between the factors coping style and hemisphere independent of task. In analogy to EEG data [9], cortical activation should be lateralized to the left hemisphere in high repressive subjects by avoiding negative and focusing on positive affective intonations. Conversely, cortical activation should be lateralized to the right hemisphere in low repressive subjects. (2) We tested for different influences of the four tasks on cortical lateralization when subjects attended to either positive or negative intonations of adjectives or to the emotionally irrelevant phoneme /a/ in adjectives or syllables (interaction between the factors hemisphere and task). The valence hypothesis would predict right-lateralized cortical activation for the identification of sad intonations and left-lateralized cortical activation for the identification of happy intonations. The right-hemisphere hypothesis, however, would predict right-lateralized cortical activation during the identification of sad and happy intonations. (3) We tested for combination effects of subject's emotional reactivity and coping style on cortical lateralization, i.e. an interaction between the factors coping style, hemisphere and task. Here we expected lateralization differences between subjects with different coping styles (anxiety-coping inventory) with respect to negative emotions, i.e. sad intonations.

2. Methods and Materials

2.1 Subjects

24 right-handed women with normal hearing participated in this study (mean age 22.7 years).

According to their coping style, subjects were classified as being high or low repressive. In a separate test session before the fMRI session, they performed the subtest "self-confidence threat" of the anxiety-coping inventory (ABI-E-R) [12] concerning their coping style with stressful events.

2.2 Stimuli

The prosodic material consisted of 40 adjectives intonated in five different ways by a male speaker (200 differently intonated words). The intonations were declarative, interrogative, imperative, happy, and sad. The neutral stimulus material consisted of 80 CV syllables spoken by the same male speaker. For each task (see below) there was a stimulus file composed of 30 percent targets and 70 percent non-targets. Stimulus presentation was done in a typical fMRI block design with eight stimulus and eight silence blocks of 34 s each (total length of each task was 9 min 4 s). Stimulation followed binaurally through fMRI-compatible headphones [3] with an individually adjusted loudness level of 60 to 75 dB SPL.

2.3 Task

Subjects had to perform four different identification tasks. In the control tasks, the phoneme /a/ should be detected in the CV syllables (task A) or in the mixture of the differently intonated adjectives (task B). In contrast to Stiller et al. [17], there were two affective tasks in the present study. In task C, sad intonations, and in task D happy intonations had to be detected in the adjective mixture. While each subject began with the control task A, tasks B, C, and D were counterbalanced across subjects.

2.4 Data Acquisition

Subjects were scanned in a BRUKER BIOSPEC 3T/60cm system with a birdcage head-coil and an asymmetric gradient system (30 mT/m). Functional images of four contiguous axial slices parallel to the AC/PC line were collected using a noise-reduced gradient echo sequence (58 dB SPL) [16]. (For further details see Ref. [15].)

2.5 Data Analyses

Functional data were controlled for motion artifacts, spatially smoothed by a gaussian filter to reduce in-plane noise, and linearly trend corrected.

As region of interest (ROI) prefrontal, frontal, insular, temporoparietal, and occipital cortical regions of both hemispheres were analyzed by correlation analysis to obtain statistical parametric maps. The ROIs were defined individually for each subject according to anatomical landmarks. Functional data analysis was carried out with the custom-made software package KHORFu [7]. Activated voxels ($P<0.01$ over all cycles) were attributed to each ROI and subject in each of the four tasks. The basis for further data analyses were intensity weighted volumes (IWV) in each ROI. They are the product of the absolute number of significantly activated voxels and their mean change in signal intensity.

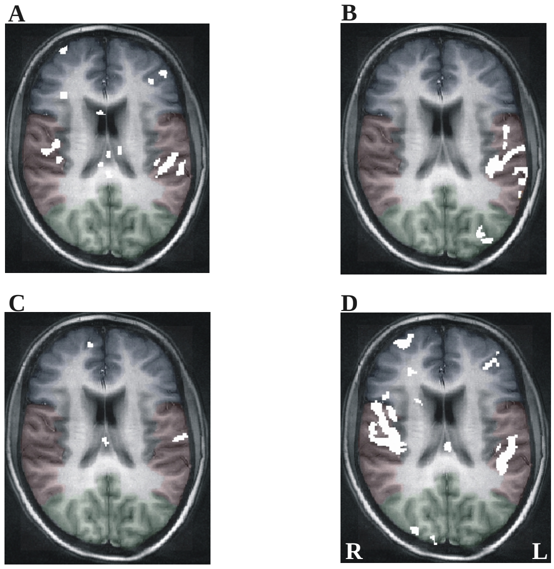

Figure 1: The effect of task on the strength of cortical activation (P<.01) is shown exemplary for one participant. A Task A phoneme identification in CV syllables, B task B phoneme identification in the adjective mixture, C task C identification of sad, and D task D identification of happy intonations in the adjective mixture. Task D led to a larger activation than tasks A, B and C, and more strongly in the right hemisphere. Cortical activation is shown on slice number 3. R right, L left hemisphere.

3. Results

3.1 Subject classification and behavioral data

13 subjects were classified by median cutting as being high and 11 subjects as being low cognitive avoiding (scale "cognitive avoidance", median = 8.5; "high" group mean = 12.4, S.D. = 3.6; "low" group mean = 5.2, S.D. = 2.4). In the following, we refer to the high cognitive avoiding group as the "cognitive avoiders" (CA), to the low cognitive avoiding group as the "non-avoiders" (NA).

The mean percent correct target identifications were relatively high in the phoneme identification tasks in CV syllables (task A, 78%) and in the adjective mixture (task B, 76%) as well as in the sad intonation identification task (task C, 82%), but low in the happy intonation identification task (task D, 45%). This was in good correspondence with the mean difficulty ratings of the four tasks. While the mean ratings of tasks A, B, and C indicated that these tasks were not very difficult (1.7, 3.1, and 2.7, respectively), task D yielded the highest mean score of 6.6 on a scale ranging from 1 (not at all difficult) to 8 (very difficult). Two-factorial ANOVAs conducted separately on the identification rates and difficulty ratings showed for both measures significant main effects of task ($F_{(3,7)}=4.86$, $P=0.042$ and $F_{(3,7)}=26.417$, $P<0.0001$ both Greenhouse-Geisser corrected). But there was no main effect of coping style (CA and NA) and no interaction between the two factors coping style and task. Bonferroni corrected paired T-tests as posthoc-tests showed that the differences in identification rates between tasks B and D (P=0.001), and C and D were significant (P<0.0001), and that task D was significantly rated more difficult than tasks A, B, and C (for all comparisons P<0.001). Exclusively in task D, subjects' identification rates and difficulty ratings were negatively correlated, i.e. low identification rates were accompanied by high difficulty ratings (Spearman's rho = -.653, P=0.029 two-tailed). Thus, the identification of happy intonations in the adjective mixture was evidently the most difficult task which was corroborated by subjects' mean score of difficulty ratings after the experiment.

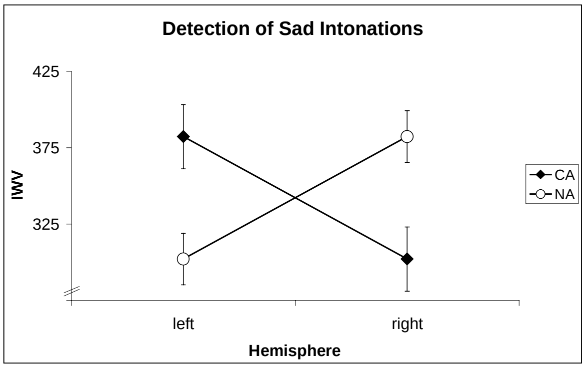

Figure 2: In the temporoparietal ROI, a significant three-way interaction of coping style by hemisphere by task was observed for the identification of sad intonations (task C) (P=0.044). The non-avoiders (NA) showed a significantly larger cortical activation in the right (P=0.002), the cognitive avoiders (CA) in the left hemisphere (P=0.004). Differences between CA and NA in both hemispheres were also significant (for both comparisons P=0.003). IWV (± S.E.M.).

3.2 fMRI Results

The focus of statistical analyses of cortical activation was on interaction effects between the factors coping style (CA, NA), hemisphere (left, right) and task (A, B, C, D), but we also analyzed main effects of these factors. Here we report only two of our most prominent results, with respect to the complete results confer to Sander et al. [15].

3.2.1 Effect of Task

In four of the five ROIs the main effect of task across coping styles and hemispheres was significant (P<0.05). The identification of adjectives with a happy intonation (task D) led to significantly more activation than the identification of the phoneme /a/ in the CV syllables (task A) in prefrontal, frontal, insular and temporoparietal ROIs (for all ROIs P<0.01). Task D also led to significantly more activation than the phoneme identification in the prosodic material (task B) in frontal, insular and temporoparietal ROIs (for all ROIs P<0.01). In addition, task D led to significantly more activation than the identification of sad intonations (task C) in frontal and insular cortex (for both ROIs P<0.01). Taken together, the identification of adjectives with a happy intonation led to the largest cortical activation in all ROIs with a significant main effect of task (Figure 1).

3.2.2 Interaction of Coping Style with Hemisphere and Task

A significant three-way interaction of coping style with hemisphere and task was only observed in the temporoparietal ROI including auditory and sensory speech cortex (P=0.044). Figure 2 shows that during the identification of adjectives with a sad intonation there was a significantly larger left hemisphere activation for the cognitive avoiders (P=0.004), and a larger right hemisphere activation for the non-avoiders (P=0.002). The differences between the CA and NA in each hemisphere were also significant (for both comparisons P=0.003). This result is in accordance to the hypothesis that cortical activation lateralization would differ in cognitive avoiders and non-avoiders with respect to negative emotions.

No differences in global cortical lateralization as a function of high or low repressiveness and no global support for either the valence hypothesis or the right-hemisphere hypothesis of emotional processing were observed.

4. Discussion

4.1 The identification of sad intonations differentiates between high and low repressive coping strategies

Our first question concerned the influence of stress-related coping strategies (cognitive avoidance) on the general lateralization of cortical activation, whereby global left–lateralized activation was expected in high repressive subjects ("cognitive avoiders"), right-lateralized in low repressive subjects ("non-avoiders") as a consequence of avoiding or focusing attention to negative stimuli, respectively. In the present study, there was apparently no relationship between coping style, i.e. high or low cognitive avoiding, and global lateralization of brain activity. With respect to the two different, task-independent lateralization types observed by Stiller et al. [17] (and in tendency in the present study, data not shown) one may conclude that they do not depend on differences in stress-related coping strategies. It, therefore, still remains open by which influence this general cortical lateralization during the identification of prosodies was induced.

In contrast, at a more specific level of subjects' coping style and task performance there was a lateralization of cortical activation: the three-way interaction of the factors coping style, hemisphere and task in the temporoparietal ROI was significant. In accordance with assumptions on stress-related coping, this interaction was only observed for the identification of sad intonations (task C). The cognitive avoiders showed in task C larger left hemisphere activation, the non-avoiders larger right hemisphere activation. In addition, there were significant differences between the two groups in each hemisphere. In line with stress-related coping strategies [11], differences in cortical lateralization between cognitive avoiders and non-avoiders may thus occur only when attention is directed specifically towards negative emotional stimuli. Thus, these different coping styles may instead lead to different lateralization patterns of cortical activation only in the presence of adequate elicitors as, for example, specific task demands and in areas relevant to the task.

In contrast to EEG studies which showed left-lateralized baseline activity in women (right-lateralized in men) in frontal brain regions due to a CA coping style [9], we exclusively observed such a lateralization pattern in the temporoparietal region during acoustic stimulation, i.e. at the level of auditory and sensory speech cortex. This may reflect meaning-related processing of the acoustically presented speech material in the temporal lobe.

4.2 Cortical activation enhancement by task difficulty and arousal

An additional prominent result was that the identification of happy intonations led to the strongest cortical activation. This effect was accompanied by a right-hemisphere lateralization independent of coping style and was observed from frontal to temporoparietal brain regions, but not in the occipital cortex. These results obviously do not comply with considerations on coping style, neither from the hypothesis which focuses on stress-related events nor from the results since the whole group showed the right hemisphere effects. Second, the results are not compatible with the valence hypothesis which suggests a left hemisphere dominance for positive emotions. It is, however, compatible with the right-hemisphere hypothesis. Nevertheless, additional effects beside right hemisphere emotional processing may be postulated.

It does not seem plausible that the strong and right-lateralized cortical activation during the identification of happy prosodies (task D) depended simply on some general acoustic cue because the same speech material was presented in the three tasks with prosodic material, and only the task performed on the stimulus material varied. One reason for this might be an enhanced focusing of attention because of the difficulty of task D which was reflected by the low identification rate and the subjective difficulty ratings. The identification of happy prosodies seems generally more difficult than the identification of other affective prosodies [2]. Such an enhancement effect of attention on neural activity is long known to exist as demonstrated by numerous animal and brain imaging studies [1,8,13]. On the other hand, one cannot rule out that each task itself directed attention to specific acoustic cues implicit in the task which in turn might have caused this strong and right-lateralized cortical activation. For example, it is discussed that specific prosodic cues might be processed either in the left or in the right hemisphere [18]. An influence of specific acoustic cues on cortical lateralization was also demonstrated by Papanicolaou et al. [14] using the same speech material with either a phonetic task or an affective prosodic task. Since attentional mechanisms directed towards specific acoustic cues of the prosodies most probably involve the same auditory centers in which these cues are processed it is likely that the right hemisphere effect found in the temporoparietal ROI is the cue-specific attentional effect, for instance the direction of frequency modulations in voice fundamental frequency [5]. The pronounced difficulty of identifying the happy prosodies might have caused arousal and additional cognitive effects that could be a reason why activities in all other ROIs (except the occipital) were also increased.

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