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ORIGINAL PAPER

Attention to emotion: auditory-evoked potentials in an emotional choice reaction task and personality traits as assessed by the NEO FFI

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Abstract Several studies suggest that attention to emotional content is related to specific changes in central information processing. In particular, event-related potential (ERP) studies focusing on emotion recognition in pictures and faces or word processing have pointed toward a distinct component of the visual-evoked potential, the EPN ('early posterior negativity'), which has been shown to be related to attention to emotional content. In the present study, we were interested in the existence of a corresponding ERP component in the auditory modality and a possible relationship with the personality dimension extraversion–introversion, as assessed by the NEO Five-Factors Inventory. We investigated 29 healthy subjects using three types of auditory choice tasks: (1) the distinction of syllables with emotional intonation, (2) the identification of the emotional content of adjectives and (3) a purely cognitive control task. Compared with the cognitive control task, emotional paradigms using auditory stimuli evoked an EPN component with a distinct peak after 170 ms (EPN 170). Interestingly, subjects with high scores in the personality trait extraversion showed significantly higher EPN amplitudes for emotional paradigms (syllables and words) than introverted subjects.

Keywords Attention · Emotion · EEG · Early posterior negativity · EPN · Event-related potential

Introduction

Recent studies in neuroscience have examined the neuronal correlates of perception and processing of emotional stimuli and the role of emotional states for the regulation of cognition and action [1]. Generally, emotional states are thought to be critically involved in the control of behavior in complex environments [2]. Many different stimuli reach the sensory system at any time competing with each other for neuronal representation in the brain. Using frightened, happy and neutral facial expressions, it was demonstrated that emotional stimuli are processed preferentially when competing with neutral stimuli. Moreover, the authors observed that brain regions only responded differentially to emotional faces when sufficient attentional resources were available to process the faces. Thus, the processing of facial expression appears to be under top-down control [3]. The visual presentation of faces has become an established method for examining the perception of emotions because an average person seeing a face is able to identify the so-called 'basic emotions' (happiness, surprise, fear, anger, disgust and sadness) very quickly. Such processing of emotional information requires the cooperation of a large number of brain structures interacting with each other at different times in order to form a perceptual representation of emotional stimuli (higher order sensory cortices), classify their emotional significance (e.g. orbitofrontal cortex

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or amygdala) and generate conscious representations of emotional states (e.g. anterior cingulate cortex) [4].

Studies using electroencephalography (EEG) event-related potentials (ERP) also often focus on the process of recognizing emotional faces and on the successive steps necessary for processing emotional information [5]. EEG studies have identified a posterior-lateral negative peak at a latency of approximately 170 ms (the so-called N170) that was elicited by visual presentation of faces [6]. Different emotional expressions of faces are known to modify the N170 [7, 8] and the activity of involved generators, e.g. the fusiform gyri [9]. However, there are also reports of absent systematic differences in ERP responses to specific facial expressions [10]. Another specific electrophysiological component related to emotional stimuli is the early posterior negativity (EPN). The visually evoked EPN is reported to demonstrate a temporo-occipital maximum and peaks between 200 and 350 ms after stimulus onset [11]. It is modulated by emotional contents [12]. Furthermore, an additive relationship of attention and emotion is discussed with regard to the EPN if subjects are attended to emotional stimuli [12]. Using silently read streams of words varying in their emotional significance, an enhancement of the EPN was found after pleasant and unpleasant words compared to neutral words [13]. Kissler et al. [14] showed an enhanced EPN during both reading and counting of emotionally arousing words (pleasant and unpleasant). Regarding later components of visually evoked ERPs, there are reports on the 'late positive potential' (LPP, starting approximately 300 ms after stimulus onset), which is larger following the presentation of emotional pictures than following neutral ones [15].

Hillyard et al. [16] showed that selective attention to auditory stimuli enhances the amplitude of the N100-component of the auditory-evoked potential (AEP). This effect of selective attention to different AEP components and their generators was examined in various studies using a cognitive auditory discrimination paradigm [17–21]. In this study, an emotional version of this paradigm was used in order to find out whether there is also an emotion-specific component for the AEP. Generally, it seems to be more difficult to perceive emotions via acoustic stimuli than to recognize effect in the visual representation of faces. The number of available indicators (such as rhythm, intonation, stressing, etc.) allowing the identification of emotion is large and requires complex interactions [22]. Schirmer et al. [23] reported smaller auditory-evoked N400 amplitudes for congruent stimuli compared to emotionally incongruent stimuli in female listeners in a semantic task. A study by Erhan et al. [24] testing subjects while they were asked to identify emotions hidden in nonsense syllables (such as ba, pa) containing different emotional intonations found no specific effects of emotional perception in either the N100 or P300 AEP component.

According to the personality type classification developed by Eysenck [25], persons with similar characteristics belong to the same personality type. Personalities can be defined by high or low levels of certain character dimensions, e.g. the Big Five (neuroticism, extraversion, agreeableness, conscientiousness, openness). In the context of the Big Five model, Eysenck's temperament theory essentially considers all temperamental attributes to be the expression of a pair of two-poled dimensions, such as extraversion (E, extroverted–introverted) and neuroticism (N, stable–unstable). The character traits E and N influence external relationships in a significant manner. Eysenck held the view that there is a biological basis for these two dimensions and that they can be recognized in neurophysiological, stimulatory and inhibitory processes. Various connections between the auditory P300 potential and the personality trait extraversion were found using non-emotional tasks [26–28]. Extraverted and introverted individuals engaged in emotional face processing were found to show differential cortical activations [29]. In a fMRI study, extraversion was positively correlated with an increased activity in bilateral frontal, right temporal and subcortical regions, whenever subjects were looking at positive pictures [30]. These results suggest a connection between the personality dimension extraversion–introversion and the attention-regulating system for the perception of emotions.

Accordingly, this study was addressing the following questions: (1) Is there a specific neural correlate related to auditory emotional stimuli to which attention is directed in AEPs according to the reports on the visually evoked EPN? (2) Are there differences between negative and positive emotional stimuli in the AEPs? (3) Is there a specific relationship between AEPs evoked by emotional stimuli and the personality dimension extraversion–introversion?

Methods

Subjects

Twenty-nine healthy volunteers (mean age 28.7, SD = 9.8, 14 women, 15 men, 27 right handed, 2 left handed) with no history of neurological or psychiatric disorders or reduced hearing were recruited and paid for their participation. The study was approved by the local ethics committee of the Ludwig-Maximilians-University, Munich. Each subject received all relevant information and signed a declaration of consent.

All subjects completed the Eysenck Personality Inventory. Subgroups were created based on median splits for each personality dimension. In all five personality dimensions, there was no significant difference between the subgroups concerning age and gender (see Table 1).

Table 1 Personality trait subgroups

Personality trait	Low-scoring subgroup (14 persons)	High-scoring subgroup (15 persons)
Neuroticism	Mean value: 1.0 (SD: 0.3)	Mean value: 2.0 (SD: 0.5)
	6 women, 8 men	8 women, 7 men
	Average age: 32.0 (SD: 12.4)	Average age: 25.5 (SD: 5.3)
Extraversion	Mean value: 2.2 (SD: 0.2)	Mean value: 2.9 (SD: 0.2)
	6 women, 8 men	8 women, 7 men
	Average age: 28.8 (SD: 10.5)	Average age: 28.5 (SD: 9.6)
Openness	Mean value: 2.5 (SD: 0.3)	Mean value: 2.9 (SD: 0.2)
	6 women, 8 men	8 women, 7 men
	Average age: 27.8 (SD: 7.5)	Average age: 29.5 (SD: 11.8)
Agreeableness	Mean value: 2.3 (SD: 0.2)	Mean value: 2.9 (SD: 0.1)
	7 women, 7 men	7 women, 8 men
	Average age: 29.1 (SD: 10.3)	Average age: 28.2 (SD: 9.7)
Conscientiousness	Mean value: 2.5 (SD: 0.4)	Mean value: 3.4 (SD: 0.3)
	7 women, 7 men	7 women, 8 men
	Average age: 27.1 (SD: 6.7)	Average age: 30.1 (SD: 12.1)

Paradigm

The paradigm involved three runs of different auditory reaction paradigms. Auditory stimuli were presented by using the BrainStim software package, Brain Products, Munich. Each of the runs took exactly 10 min. The subjects had to press one of two buttons with the left or right hand assigned in advance to the different presented stimuli. The subjects were asked to press the buttons as fast as possible. Before the beginning of measurements, short test runs were carried out.

Conventional choice reaction paradigm (control task): tones task

First, 120 tones (duration: 250 ms) of different pitches (50% 800 Hz and 50% 1,300 Hz) were presented via earphones at 85 dB SPL with pseudo-randomized sequences and interstimulus intervals of 2.5–7.5 s. After hearing the low tone, the subjects were expected to react by pressing the left button with the left hand, while the reaction to the high tone was to be followed by pressing the right button with the right hand. This paradigm has been used earlier in order to evoke event-related potentials [31, 32].

Emotional choice reaction paradigm I: syllable task

The second task consisted of 120 trials of 5 different syllables (ba, be, bi, bo, bu), each of which was presented in two different emotional intonations (positive/happy and negative/sad) and with individually adjusted volume in a range between 65 and 85 dB SPL [31]. The syllables were presented with a duration of 250 ms and in a pseudo-randomized manner with respect to sequence and interstimulus intervals (2,500–7,500 ms). Subjects were asked to react to the syllables by pressing the right button when hearing syllables with positive intonation and by pressing the left button when hearing syllables with negative intonation.

Emotional choice reaction paradigm II: word task

The third task consisted of ten words with positive (happy, cheerful, friendly, calm, wonderful) and negative (sad, irritating, terrible, disgusting, unhappy) meaning, spoken by a monotonous female voice. Again, 120 stimuli were provided in a pseudo-randomized manner with respect to sequence and interstimulus intervals (2,500–7,500 ms), with a presentation duration of 500 ms (volume: 70–85 dB SPL). Subjects were asked to react to the words by pressing the button with their right hand when hearing words of positive content and the button with their left hand when hearing words of negative content.

Development and validation of the syllable task

We used the software 'Praat' (Program for Speech Analysis and Synthesis, version 4.1.15, by Paul Boersma and David Weenink, Institute of Phonetics Sciences, University of Amsterdam). Each of the syllables (ba, be, bi, bo, bu) was recorded once with a positive/happy intonation and once with a negative/sad intonation. Twenty healthy subjects (12 women, 8 men, mean age 30.1) were recruited from an academic environment for the validation step. They were given a table listing all syllables in the order of appearance in the audio presentation, while no information on the quality of their intonation (positive or negative) was offered. The subjects were asked to evaluate each syllable regarding positive/happy or negative/sad intonation. The probability of correctly recognizing a syllable with positive intonation was 99.7%, the probability of correctly recognizing a negative syllable was 99.6%.

EEG recording and evoked potentials

EEG recording

Recording took place in a sound-attenuated and electrically shielded room. Subjects were seated with open eyes in a slightly reclined chair with a head rest and were asked to look at the wall 2 m in front of them. The EEG was recorded with 27 electrodes referred to Cz (recording apparatus: Neuroscan Synamps) using an electrode cap ("electro-cap electrode system" by *Electro-Cap International, Inc. (ECI)*, Eaton, Ohio).. Electrodes were positioned according to the International 10/20 system with the additional electrodes FC1, FC2, FC5, FC6, CP5, CP6, PO9, PO10. FPz served as ground. Data were collected with a sampling rate of 1,000 Hz and an analogous bandpass filter (0.16–200 Hz). Contact between the scalp and the Sn/SnCl electrodes was established by electrode gel ("Electro-Gel™" by *Electro-Cap International, Inc. (ECI)*, Eaton, Ohio). Impedances were kept below 5 kΩ. Horizontal eye movements were recorded by means of the EOG electrode located 1 cm lateral to the left eye.

EEG recording and preprocessing

EEG preprocessing was done using the the BrainVision Analyzer software Vers.1.05 (Brain Products, Munich, Germany). For all sweeps, 200-ms pre-stimulus and 1,000-ms post-stimulus periods were evaluated. After re-referencing to common average reference and filtering with a 70 Hz low-pass and a 1 Hz high-pass filter (time constant = 0.16 s), an amplitude criterium (+70 μV) in combination with a visual inspection of the waveforms was used for artifact rejection, involving all channels at any time point during the averaging period. Only stimuli subjects that had responded correctly were taken into account. After a baseline correction (baseline = 200 ms pre-stimulus), the grand averages of the event-related potentials were calculated for all subjects from at least 30 artifact-free EEG segments of each task. The number of EEG segments used for averaging was 112.6 (SD: 7.2) for the tones task, 91.1 (SD: 18.9) for the syllables task and 104.0 (SD: 14.0) for the words task. For none of the personality traits, a significant difference was detected between the subgroups with respect to the number of averaged EEG segments.

Parametrization

Latencies and amplitudes of the EPN potential were analyzed at Pz, P3 and P4. For the computer-aided detection, the EPN amplitude peaks were defined as the highest negative value in the time frame between 150 and 190 ms post-stimulus. According to the grand average, the P300 potential was parametrized as area under the curve in the time frame between 250 and 400 ms post-stimulus, the LPP as area under the curve (AUC) in the time frame between 400- and 700-ms post-stimulus.

Personality test (NEO Five-Factor Inventory)

The NEO Five-Factor Inventory (NEO-FFI) according to Costa and McCrae (German version in 1993) evaluates five independent personality traits: neuroticism, extraversion, openness to experience, agreeableness and conscientiousness. The test consists of 60 items that subjects have to respond to in a five-point answering scale ranging from "strongly disagree" to "strongly agree". Subjects were asked to answer all questions on the questionnaire prior to the EEG examination.

Biometry and statistics

Statistical evaluation was done using the SPSS-software package (13.0). In order to test for significant main effects of the factor task, as well as task × electrode site interactions, MANOVA with repeated measurements was used. No correction was necessary as there was no significant Mauchly test in any case. Subgroup differences were tested by adding a between-subject-factor to the MANOVA. Post hoc tests were carried out using t-tests as all variables were normally distributed. Based on three different task conditions, we performed three different tests. Therefore, using Bonferroni-correction, all tests were performed with a 2-sided $P < 0.017$. Correlations were tested using the Spearman correlation coefficient.

Results

Reaction time

Mean reaction times for the tones task were 427 ms (SD: 86.0), for the syllables task 630 ms (SD: 82.3) and for the words task 648 ms (SD: 85.1). The ANOVA yielded a significant main effect of the factor task [$F(2,56) = 236.5$, $P < 0.001$]. Post hoc tests revealed significantly lower reaction times for the tones task compared to the syllables task [$T(28) = 15.1$, $P < 0.001$] and to the words task [$T(28) = 20.9$; $P < 0.001$]. Reaction times did not differ significantly between syllables and words. On average, the subjects reacted faster to positive syllables (612 ms, SD: 82.5) than to negative syllables [648 ms, SD: 90.1; $T(28) = 3.7$, $P < 0.001$] and they reacted faster to positive words (635 ms, SD: 83.2) than to negative words [661 ms, SD: 90.5; $T(28) = 3.9$, $P < 0.001$]. Reaction times for low (422 ms, SD: 82.7) and high tones (432 ms, SD: 92.3) did not differ significantly from each other. For none of the personality traits, there was any significant difference between the reaction times of the two subgroups (according to the principle of the median split for each personality trait).

Evoked potentials

EPN

Increased negativity was identified for the emotional paradigms (syllables and words) compared to the non-emotional paradigms (tones) in parietal electrodes (for scalp distributions, see Fig. 1). This increased negativity reached its maximum at 170 ms in form of a distinct peak, which we refer to as ‘EPN 170’ (see Fig. 2). There was a significant main effect of the factor task on the amplitudes of the EPN 170 at Pz [$F(2,56) = 60.5$, $P < 0.001$]. Post hoc tests revealed significantly higher EPN 170 amplitudes at Pz for emotional paradigms than for neutral paradigms (tones) used for comparison purposes: EPN 170 amplitudes evoked by syllables [−2.32 μV, SD: 1.67; $T(28) = 8.8$, $P < 0.001$] and words [−2.41 μV, SD: 1.35; $T(28) = 8.6$, $P < 0.001$] were significantly higher than those evoked by tones (−0.01 μV, SD: 1.99). The amplitudes of high (−0.19 μV, SD: 2.21) and low tones (−0.03 μV, SD: 1.92) did not differ significantly from each other. Likewise, the amplitudes of negative (−2.54 μV, SD: 1.84) and positive syllables (−2.40 μV, SD: 1.73) did not differ significantly nor did the amplitudes of negative (−2.54 μV, SD: 1.59) and positive words (−2.59 μV, SD: 1.44). The average EPN 170 latency was 172 ms (SD: 16.1) for tones, 166 ms (SD: 12.1) for syllables and 170 ms (SD: 15.1) for words. The latencies of the three conditions did not reveal any significant differences.

Additionally, we found a significant main effect of the factor electrode site [$F(2,54) = 8.1$, $P = 0.001$] and a significant task × site effect [$F(4,108) = 9.9$, $P < 0.001$] on the amplitudes of the EPN 170. Post hoc tests showed significant higher EPN 170 amplitudes evoked by syllables in the electrode P3 (−3.16 μV, SD: 1.83) than in the electrode P4 [−2.34 μV, SD: 1.52; $T(28) = 2.98$, $P = 0.006$]. There were no significant differences between these electrodes regarding EPN 170 amplitudes evoked by words (P3: −2.74 μV, SD: 1.50; P4: −2.26 μV, SD: 1.27) or tones (P3: −1.06 μV, SD: 1.48; P4: −0.86 μV, SD: 1.76).

P300 component and LPP

The ANOVA yielded a significant main effect of the factor task [$F(2,56) = 76.0$, $P < 0.001$] on the P300 at Pz (see Fig. 2). AUC values of the P300 evoked by tones (752 μV*ms, SD: 335) were significantly higher than those evoked by words [306 μV*ms, SD: 168; $T(28) = 9.9$, $P < 0.001$] and syllables [408 μV*ms, SD: 201; $T(28) = 8.6$, $P < 0.001$]. The P300 evoked by words differed significantly from that evoked by syllables [$T(28) = 3.9$, $P = 0.001$].

Regarding the LPP, there again was a significant main effect of the factor task [$F(2,56) = 23.6$, $P < 0.001$] at Pz (see Fig. 2). In contrast to the findings regarding the P300, the LPP was significantly enhanced in the words task (1,031 μV*ms, SD: 299) compared to the syllables task [882 μV*ms, SD: 270; $T(28) = 4.0$, $P < 0.001$] and to the tones task [708 μV*ms, SD: 219; $T(28) = 6.0$, $P < 0.001$]. The LPP evoked by syllables differed significantly from that evoked by tones [$T(28) = 3.6$, $P = 0.001$].

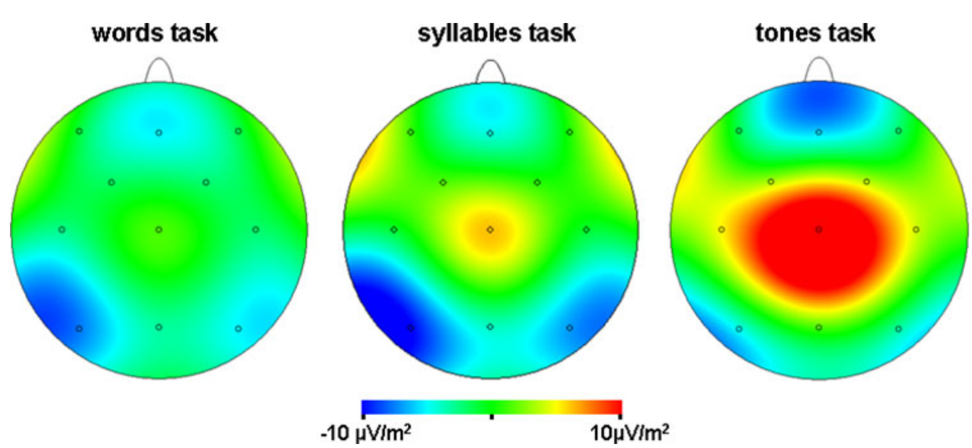

Fig. 1 Grand average current source density *maps* showing the scalp distribution of the EPN 170 in the time frame 160–180 ms post-stimulus (calculated using interpolation by spherical splines)

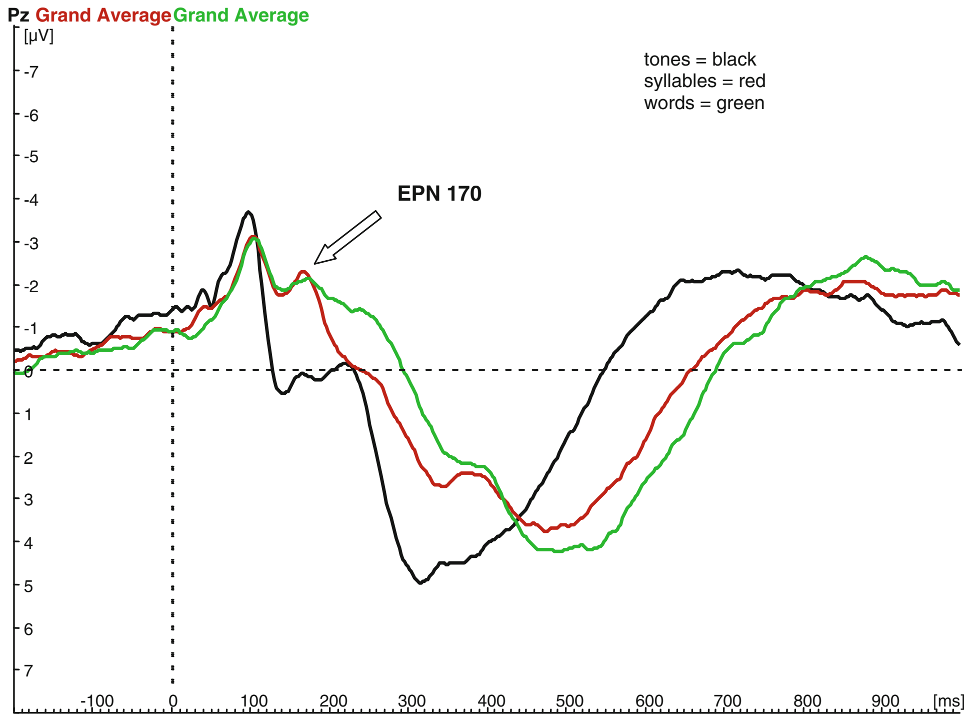

Fig. 2 Grand averages at Pz: *black line* tones; *red line* syllables; *green line* words. For syllables and words, there is a peak "EPN 170" at 170-ms post-stimulus

Correlation of EPN 170 and personality traits

The personality trait extraversion correlated with the amplitude of the EPN 170 in emotional paradigms: for syllables in the Pz ($r_s = -0.41$, $P = 0.03$) and the P3 channel ($r_s = -0.47$, $P = 0.01$) and for words in the P3 channel ($r_s = -0.40$, $P = 0.03$). Regarding the subgroups created based on median split for the extraversion dimension, there was no significant task × group, site × group or task × site × group effect. However, compared to subjects of the introverted subgroup, extroverted persons exhibited significantly higher EPN 170 amplitudes in the P3 channel for emotional paradigms (syllables and words, see Figs. 3, 4) but not in the tones task (see Fig. 5). The amplitude of the EPN 170 in P3 for syllables was higher for the group of extroverts (−4.07 µV, SD: 1.47) compared to introverts [−2.18 µV, SD: 1.70; $T(27) = 3.2$, $P = 0.004$]. The EPN 170 amplitude evoked by words was higher in extroverted persons (−3.60 µV, SD: 1.22) than in introverted persons [−1.84 µV, SD: 1.24; $T(27) = 3.8$, $P = 0.001$].

Discussion

This study was intended to investigate neurophysiological correlates of attention to emotion using an auditory choice reaction paradigm. Moreover, the relationship between the extraversion–introversion personality trait and this neurophysiological marker was examined. The major result of this study was the finding of an EPN component also in the auditory modality. It was characterized by a distinct peak at 170 ms in parietal electrodes (EPN 170). The EPN 170 amplitude was correlated to the dimension "extraversion–introversion" and was shown to be significantly higher in subjects with high extraversion scores. Additionally, we were able to replicate recent findings showing a late positive component of the event-related potential (ERP) to be enhanced for emotional pictures within the auditory modality. This late positive potential (LPP) is known to be enhanced after the presentation of pleasant and unpleasant pictures compared to neutral pictures [33, 34].

The major finding of this study was a parietal EPN in the context of an auditory choice reaction paradigm. This EPN might represent the perception and processing of emotional stimuli in the auditory modality. While Schupp et al. [12] examined the processing of emotional pictures and observed selective processing of positive and negative pictures in the form of temporo-occipital negativity ("early posterior negativity"/EPN), which means that emotional pictures caused a significantly higher negativity than the neutral pictures, the present study is the first to provoke an EPN by means of acoustic presentation of emotional stimuli. The characteristic negativity manifested itself at the parietal electrodes on both sides, being stronger on the left side. A study investigating the saliency of unpleasant sounds presented among neutral sounds with an oddball event-related potential paradigm found no differences of neural activity before 290 ms after stimulus presentation [35], which might be due to the use of unpleasant but not

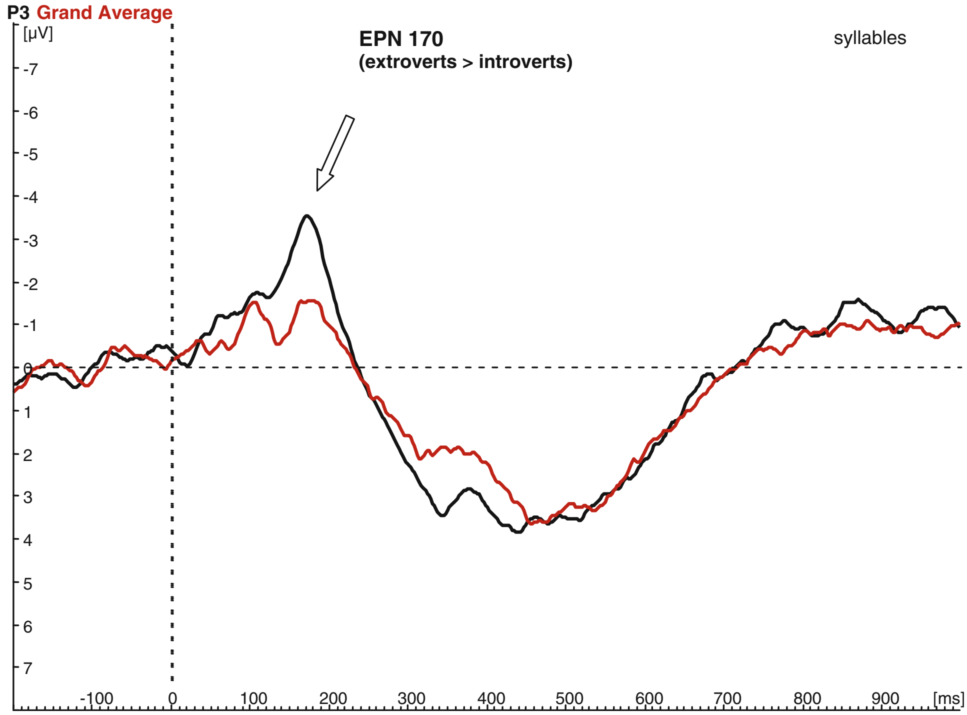

Fig. 3 Grand averages for syllables at the electrode P3: *black line* extroverted persons; *red line* introverted persons; extroverts exhibit higher EPN 170 amplitudes than introverts

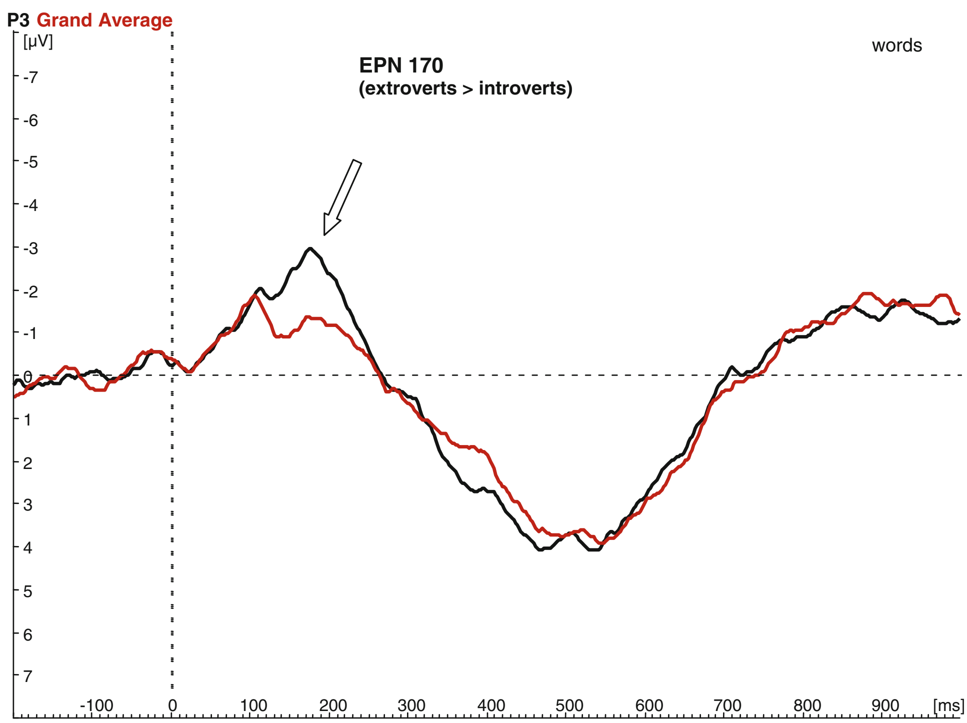

Fig. 4 Grand averages for words at the electrode P3: *black line* extroverted persons; *red line* introverted persons; extroverts exhibit higher EPN 170 amplitudes than introverts

emotional-intonated stimuli, as used in the present study. Czigler et al. [36] reported an early posterior negative component elicited by aversive compared to everyday sounds presented as task-irrelevant stimuli in an oddball paradigm. Although they found no distinct EPN peak evoked by the aversive sounds, the results might be related to the present findings due to the emotion-eliciting tendency of these stimuli.

An important aspect of the present study was that subjects were asked to actively detect the quality of the emotional stimulus. In other words, attention was directed toward emotional content. By contrast, Junghöfer et al. [11]

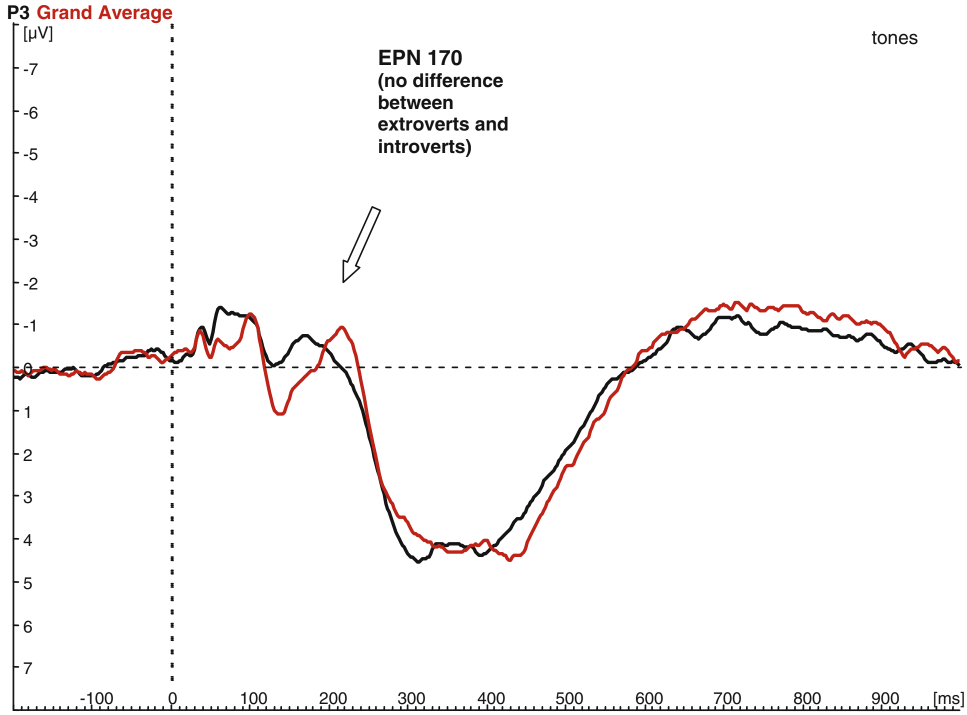

Fig. 5 Grand averages for tones at the electrode P3: *black line* extroverted persons; *red line* introverted persons; the EPN 170 amplitude does not reveal any differences between extroverted and introverted persons

did not require any response in their examination: they showed emotional pictures to their subjects but did not ask them to perform any other task. For highly emotional pictures, compared to neutral pictures, the event-related potentials revealed an increased negativity starting around 150 ms and reaching its maximum at about 260 ms. Negativity was detected on both sides but mainly in the occipital and the right parietal cortex.

Based on the study by Junghöfer et al., Schupp et al. [37] conducted a further picture-related test that also resulted in the identification of an EPN. They modified the experimental setup in a way that the subjects had to fulfill a task requiring their attention at the same time as being confronted with emotional stimuli. The cognitive task designed to divert the subjects attention consisted of selecting and counting pictures containing colored rectangles interspersed with the sequence of emotional pictures. The selective emotion processing and the cognitive task were analyzed separately. Although subjects did not concentrate on the emotional pictures and had not been asked to classify the stimuli as emotional or neutral, selective processing of positive and negative pictures was observed in terms of temporo-occipital negativity. Emotional pictures resulted in a significantly higher negativity than neutral pictures, which started around 150 ms and reached its maximum deviation from neutral pictures between 232 and 292 ms.

The present study combined the perception of emotional stimuli with a task requiring the subjects attention, even though it was not highly demanding. It remains unclear whether the emotional perception of stimuli was independent of the subject's attention on something else. Possible modifications of the EPN 170 by attention directed to the emotional stimuli will be investigated in further studies. There is also evidence that the EPN, which represents the processing of emotional information, does not depend on cognitive skills alone. Wieser et al. [38] found the EPN in patients suffering from M. Parkinson, i.e. people commonly agreed to have reduced cognitive and executive skills. Their EPN in parietal and occipital regions did not differ at all from those of healthy subjects.

In contrast to findings from studies on the recognition of emotional faces [7, 8], we did not find any difference in the EPN 170 amplitudes between emotionally positive and negative stimuli, although subjects reacted faster to positive syllables and words than to negative, while reaction times for low and high tones did not differ significantly from each other. However, this lack of effects of the different emotions on the EPN 170 may also be due to not counterbalancing for the response hand with regard to positive and negative emotions. One limitation of the present study is the principal differences between emotional stimuli and non-emotional control stimuli: in contrast to emotional stimuli, in fact, no EPN 170 was elicited by non-emotional tone stimuli. Further studies should investigate EPN 170 differences between syllables or words with or without emotional intonation.

In summary, the auditory EPN 170 detected in the present study differs from the EPN established using visual paradigms in the distinctive peak of the EPN at 170 ms.

There is no indication of the existence of such a peak for visual stimuli in any of the EPN studies mentioned previously. In addition, the EPN for the visual paradigm tends to be stronger on the right side [39], while we found the auditory-evoked EPN 170 to be characterized by a significantly stronger activation in the left hemisphere. This divergence could be due to the involvement of left hemisphere language regions in the present study, whereas the visual paradigms may have been non-verbal.

Extraversion and neuroticism have recently been rediscovered in various fields of neuroscientific research [27, 36]. Extraversion has been linked with increased emotional responding to funny [40] or sad [41] stimuli. Canli et al. were the first to examine the influence of stable personality traits on the processing of emotional stimuli in a fMRI study, where the participants were asked to look passively at emotional pictures. Their study showed that amygdala activation following positive stimuli varies as a function of extraversion. However, the nature of the given task does not permit any conclusions regarding the origin of the emotional experience, the number of mental processes involved and the activation of additional processes, such as the retrieval of autobiographic memories [28]. Canli et al. [42] conducted another study based on the emotional Stroop task, focusing on regions of interest assumed to be involved in attention processes. They found that an increase in activity in the anterior cingulate cortex following the presentation of emotional stimuli correlated with extraversion. However, the time-related dynamics of mental processes were not investigated in that study. In order to add a new perspective to personality and emotion processing research, especially with respect to time-related dynamics, we used the event-related EPN 170 to examine the individual differences in the processing of emotions. We found that the group of extroverts had significantly higher EPN 170 amplitudes for emotional paradigms (syllables and words) than the introverted subjects. The neutral paradigm—where subjects only had to distinguish between two tones—did not reveal any difference between extroverted and introverted persons. Our findings are in line with the idea that extroverts, who are defined as people who generally like stimulation and excitement, have an increased ability for cerebral information processing of both negative and positive emotional stimuli compared to introverts. Increased EPN 170 amplitudes of extroverts in comparison with introverts are a specific finding related to emotional stimuli and not due to enhanced overall attention capacities of extroverts, since extroverts did not differ from introverts in the control condition that also required attention.

Concerning the limitations of this study, it has to be mentioned that only two left-handed subjects participated in this study, which might have influence on the laterality of our findings. Further studies should address the issue of laterality of the EPN 170 in the context of hemispheric dominance. In addition, it could be interesting to learn more about the underlying genetic background [43] and to identify underlying electrical generators using EEG source analysis [44], fMRI [45] or EEG-fMRI [46].

In conclusion, this is the first report of the EPN 170 emerging in the AEP following emotional stimuli. The amplitude of the EPN 170 was correlated to the personality dimension “extraversion–introversion”.

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