

Emotion processing in Parkinson's disease: Dissociation between early neuronal processing and explicit ratings

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Abstract

Objective: Patients suffering from Parkinson's disease (PD) have a diminished ability to discriminate facial expressions of emotion. We investigated early emotion discrimination deficits in PD by means of event-related potentials (ERPs).

Methods: Emotional pictures were presented to 14 PD patients and 14 healthy controls in a rapid serial visual presentation paradigm (three frames per second) while EEG was recorded. In addition, valence and arousal ratings were obtained for a representative subsample of 54 pictures.

Results: PD patients rated pictures of highly arousing content as less exciting than did healthy controls. Pictures of high compared to low emotional arousal were associated with a pronounced relative negative shift in the ERP waveform over parietal and occipital sites developing about 220 ms after picture onset. This early posterior negativity (EPN) did not differ between PD and control group.

Conclusions: This dissociation of affective ratings and early ERP components supports the view that PD is associated with blunted emotional responses, but there is no evidence for a deteriorated early visual processing of emotional stimuli.

Significance: Frequently reported deficits in emotion discrimination are likely not due to deficits in early emotion processing.

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Keywords: Parkinson's disease; Emotion processing; Early affective discrimination; ERPs

1. Introduction

Parkinson's disease (PD) is caused by an irreversible degeneration of dopaminergic neurons in the substantia nigra pars compacta, which leads to dysfunction of the striatal structures innervated by those neurons (e.g., Parent, 1990). Research on PD mostly focused on the characteristic motor symptoms (Hoehn and Yahr, 1967) and cognitive impairments such as disturbed executive functioning (e.g., Pillon et al., 1996). In recent years, the observation that emotional processing can be affected in PD has received growing attention. Both spontaneous and posed facial

expressions have been shown to be disturbed and reduced in PD patients (Jacobs et al., 1995; Madeley et al., 1995; Smith et al., 1996; Simons et al., 2003). PD patients showed fewer and less expressive spontaneous facial expressions in response to emotional video clips (Smith et al., 1996) as well as in response to unpleasant odors (Simons et al., 2003). PD is also associated with a reduced ability to pose facial expressions voluntarily (Jacobs et al., 1995; Madeley et al., 1995). While these findings suggest an association of PD with reduced emotional behavioral outputs, few studies focused on emotion perception. Guided by clinical observations PD-related deficits were examined with respect to affective prosody (Pell, 1996; Benke et al., 1998; Breitenstein et al., 2001) and facial expression (Scott et al., 1984; Dewick et al., 1991; Jacobs et al., 1995) which are the most relevant cues on emotional communication.

In Pell's study (1996), PD patients completed a battery of emotional prosody tasks which included sentences with both

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semantically congruent and nonsense content. PD patients' performance in the identification tasks was significantly less accurate than that of control participants. Breitenstein et al. (2001) also found a considerably diminished ability to recognize affective prosody in PD patients. Similar findings are reported by Benke et al. (1998) who examined affective prosody, emotional speech detection, and humor recognition. PD patients without cognitive impairments showed deficits only in their performance of producing affective prosody, whereas patients with mild cognitive impairments showed significantly inferior performances in all three tasks compared to a healthy control group.

In a facial affect recognition task Blonder et al. (1989) demonstrated that PD patients were impaired in processing emotional features of facial expressions compared to healthy controls. Other studies revealed that PD patients have difficulties discriminating emotional facial expression and imagining emotional facial expressions compared to controls, although their performance in object imagery was not affected (Scott et al., 1984; Dewick et al., 1991; Jacobs et al., 1995). Recently, Sprengelmeyer et al. (2003) reported that the poor performance in identifying emotion in facial expressions can be improved by adequate medication. In sum, these findings suggest an impairment of processing emotional stimuli in PD, but impairments in emotion recognition were not always found (Adolphs et al., 1998).

The underlying neurological cause of these problems in processing of emotional information in PD may be the degeneration of the basal ganglia. Cancelliere and Kertesz (1990) reported that patients with cortical lesions who had additional damage to the basal ganglia showed the most pronounced deficits in emotional judgements. Moreover, Tessitore et al. (2002) showed in a fMRI-study that the amygdala is also affected in PD, and it is well documented that the amygdala is involved in processing of emotional, especially fearful stimuli like negative facial expressions (e.g., Davidson and Irwin, 1999; Davis and Whalen, 2001). Tessitore et al. (2002) investigated the activation of the amygdala in PD patients during an emotion task (matching emotional facial expressions), while they were in a hypodopaminergic state (i.e., more than 12 h after the last medication) and while they were in a dopaminergic state. In both states PD patients exhibited weaker amygdala activation in response to facial stimuli than healthy controls. In addition, the activation of the amygdala was stronger in the dopaminergic state than in the hypodopaminergic state. This influence of hypodopaminergic state on the amygdala might provide an explanation for the observed deficits in the recognition of emotional facial expressions and in emotion processing in PD.

All the studies on emotion recognition mentioned above except for the latter one dealt with behavioral responses (e.g., recognition tasks) to emotional stimuli. Because behavioral output tasks require participants to fully process and evaluate the stimuli, these studies did not differentiate between stages of processing. It is well documented

however, that emotional processing involves a multitude of processes in several brain circuits. One example is the somatic marker hypothesis by Damasio, which states that emotions result from an interpretation of somatic states (e.g., Bechara et al., 2000). To our knowledge, affective responses at the early (sensory) rather than the later (postperceptual and decision) stages of stimulus processing have not been examined separately. This is necessary to identify the pathological underpinnings of the observed deficits. Besides, motor responses as required in the emotion recognition studies may be affected in PD per se and should therefore be regarded very carefully.

Event-related brain potentials (ERP) in response to affective visual stimuli are regarded as an appropriate research tool for investigating the attentional processes at early stages of stimulus encoding. Recent ERP studies have clearly demonstrated that affective cues automatically capture attention (Junghoefer et al., 2001; Schupp et al., 2003). Even when the pictures were presented rapidly, i.e., in a rapid serial visual presentation paradigm (RSVP), the brain discriminates affective from neutral stimuli (Junghoefer et al., 2001). At fast presentation rates (3 or 5 Hz), early emotion discrimination is reflected in an early posterior negativity (EPN) developing about 200 ms after picture onset. Pictures of high compared to low emotional arousal caused a pronounced relative negative shift in the ERP waveform on temporo-occipital sites compared to low arousing pictures. The main neural sources of this early emotion discrimination seem to be located in primary and secondary visual processing areas of the brain. The automatic processing of emotionally arousing pictures is observable even when attention is explicitly directed to other features of the stimuli. Schupp et al. (2003) investigated this by instructing healthy participants to detect specific checkerboard images (targets) which were presented at random positions in the stream of emotional and neutral pictures. Most participants succeeded in the non-emotional detection task (as reflected by behavioral data and in the P3 amplitude), but pictures of high emotional arousal still elicited an augmented EPN, regardless of whether participants viewed the picture under free viewing conditions or under the non-emotional attention task. In sum, the EPN associated with highly emotional pictures provides an early cortical index of selective emotional processing in the human brain. Because the RSVP paradigm allows for short durations of experiments it seems to be particularly well suited for studies with neurological patients. One further advantage of that paradigm is the large number of presented trials and therefore an improved signal-to-noise ratio.

The main purpose of the present study was to replicate reports of diminished emotional responses of PD patients as reflected in diminished arousal ratings for pictures, which are normally rated as highly arousing and emotionally salient. Most important we also wanted to examine whether the reported deficits in emotion discrimination in PD

patients arise at early stages of stimulus processing as indexed by the EPN or whether this deficit appears only at later stages of information processing as indexed by ratings. We expected that the early emotion discrimination as reflected by the EPN would be diminished in PD patients.

2. Method

2.1. Participants

Fifteen PD patients (10 men and 5 women) and 15 healthy controls matched for age and sex participated in the study. The PD patients were recruited from a local PD support group. All of them had been diagnosed with idiopathic PD by a neurologist. The control participants were recruited through advertisements in local newspapers offering a reimbursement of Euro 8 per hour. Exclusion criteria for controls included any current psychiatric or neurological disorder. Exclusion criteria for both groups were dementia as indicated by a score of 21 or below on the German version of the Mini Mental State Examination (MMSE, Folstein et al., 1975). One PD patient and consequently the matched control participant had to be excluded because of excessive sleepiness during the video presentation (as observed through video monitoring), resulting in a total sample of 14 participants in each group (nine men and five women). All participants reported normal or corrected-to-normal vision.

2.2. Participants characteristics

Demographic data and questionnaire scores for each group are reported in Table 1.

Patients and controls were matched for age (± 1 year) and sex. Furthermore, the groups were comparable in all sociodemographic variables such as their family status (i.e., married, widowed, divorced, and living alone), $\chi^2(3, N=28)=0.4, P=.94$, housing situation (i.e., living alone, with

family, with partner, with others), $\chi^2(3, N=28)=7.3, P=.07$, educational level (i.e., years of basic schooling: 9 or 10 years: qualification for apprenticeship or trade-school; 13 years: qualification for University studies), $\chi^2(3, N=28)=4.4, P=.22$, and employment status (i.e., employed, housewife/house husband, retired, unemployed), $\chi^2(3, N=28)=1.0, P=.60$. Most were on disability or retired but in each group one person was employed.

Scores on the Hoehn and Yahr scale (Hoehn and Yahr, 1967) were obtained from the participants themselves using a questionnaire in which the five stages of PD were presented as personal statements (Stage I=unilateral disease and mild symptoms to stage V=severe disability, either confined to bed or wheelchair). Self-report of the level of disability has been shown to be highly consistent with clinical ratings (Brown et al., 1989). Both the patient and control group classified primary symptoms using 4-point Likert scales (1=no disability to 4=severe disability).

In addition, participants in both groups completed the following set of questionnaires: a brief demographic questionnaire; the German version of the Self-rating Depression Scale (SDS, Zung, 1965); the German version of the Questionnaire for Experiences of Attention Deficit (FEDA, Zimmermann et al., 1991; Suslow et al., 1998) and the German version of the Positive and Negative Affect Schedule (PANAS, Krohne et al., 1996).

Self-reported disease duration of the PD patients ranged from 1 to 14 years ($M=6.9, SD=4.3$). Six patients met Hoehn and Yahr stage I criteria (unilateral disease with mild symptoms), one met stage II criteria (bilateral involvement) and seven patients met stage III criteria (bilateral symptoms with postural and gait disturbances). Rigidity was the primary symptom for six patients and tremor for four patients. Both tremor and rigidity were dominant in four patients. All patients were investigated while being administered anti-Parkinsonian medication, distributed as follows: carbidopa/L-dopa ($n=11$); d2-agonist ($n=8$); MAO-B inhibitor ($n=2$); COMT inhibitor ($n=1$); amantadine ($n=5$); anticholinergics ($n=1$).

Table 1
Description of 14 PD patients and 14 healthy control participants

	PD patients		Control participants		<i>t</i>	<i>P</i>
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>		
Age	66.4	5.2	66.0	6.4	0.2	.87
MMSE	28.2	2.6	29.2	0.9	1.4	.18
SDS sum score	41.0 ^a	7.4	29.9	3.7	4.9	.00
SDS psy	18.5 ^a	5.2	13.4	1.9	3.4	.00
SDS som	22.5 ^a	3.5	16.5	2.7	4.9	.00
PAS sum score	26.7	6.5	33.6 ^b	6.4	2.8	.01
NAS sum score	15.0	4.8	15.3 ^b	6.5	0.1	.89
FEDA	46.5	13.4	54.6 ^a	4.7	1.9	.06

Note: MMSE, Mini Mental State Examination; SDS, Self-Rating Depression Scale; SDS psy, Psychological items of SDS; SDS som, somatic items of SDS; PAS, Positive affect subscale of Positive And Negative Affects Scale; NAS, Negative affect subscale of Positive And Negative Affects Scale; FEDA, Fragebogen erlebter Defizite der Aufmerksamkeit (Questionnaire on Experienced Deficits of Attention).

^a $n=12$.

^b $n=13$.

As shown in Table 1, the mean SDS sum score as well as the SDS subscales (psychological symptoms and somatic symptoms) were significantly higher for the PD group than for the control group. PD patients had significantly lower scores in the positive affective state subscale (PAS) of PANAS than controls, whereas no significant difference was found in the negative affective state subscale (NAS). The groups did not differ significantly in the mean FEDA sum scores and in dementia scores either.

2.3. Stimulus material

As in previous emotional RSVP studies (Junghoefer et al., 2001; Schupp et al., 2003), all 702 pictures from the International Affective Picture System (Center for the Study of Emotion and Attention, 1999) were used. Based on standardized ratings of arousal (Lang et al., 1999) the picture categories were defined as high and low in emotional arousal by median split. The pictures were presented for 333 ms each in a continuous stream (a presentation rate at 3 Hz) without interstimulus intervals and alternating pictures of high and low arousal. The total presentation time was 4 min and 19 s.

2.4. Procedure

After arriving at the laboratory, participants read and signed an informed consent form. In order to avoid effects due to stimulus novelty, participants were familiarized with examples of the stimulus set. Afterwards, the electrode cap was attached and participants were informed that a video would be presented in which pictures were shown as a rapid continuous stream of images. Participants were instructed to simply view the pictures and maintain their gaze on the center of the screen. After the presentation of the video, participants were asked to rate on a 5-point Likert scale how tired they got while watching the video and how attentive they were now. Then, participants rated on a 9-point Likert scale the valence (ranging from negative to positive) and the arousal (ranging from low arousing to high arousing) of a representative subset of 54 pictures using the Self-Assessment Manikin (Bradley and Lang, 1994). Each picture was presented for 1 s. Subsequently the valence and then the arousal rating scales were presented, and participants had to give their response by pressing the corresponding keyboard button. Overall, the experimental session lasted about 1.5 h.

2.5. Apparatus and data analysis

Electrophysiological data were recorded using 21 AgAgCl-electrodes located according to the 10–20 system

with a 32-channel recordings system (Synamps) and acquisition software (Neuroscan 4.0): Fp1, Fpz, Fp2, F7, F3, Fz, F4, F8, T7, C3, Cz, C4, T8, P7, P3, Pz, P4, P8, O1, Oz, and O2. Scalp impedance for each sensor was kept below 5 k Ω . The EEG was recorded continuously with a sampling rate of 1000 Hz. Cz was used as the reference and data were bandpass filtered from 0.01 to 100 Hz on-line. Both the vertical and the horizontal electrooculogram were recorded from pairs of electrodes placed above and below the right eye and at the outer canthus of each eye, respectively. A 10 Hz low-pass filter was applied off-line to the continuous EEG data, then stimulus-synchronized epochs lasting from 100 ms before picture onset until 800 ms after picture onset were extracted. The raw EEG epochs were corrected for eye movements (Gratton et al., 1983), and trials on which a transition threshold of 100 μ V (sample to sample) was exceeded, were excluded from the analyses. Finally, data were transformed to an average reference (Brain-Vision-Analyzer version 1.04, Brain Products GmbH, Germany).

Averages of EEG waveforms for pictures low and high in emotional arousal were calculated for each sensor and participant separately. Following the procedures of previous studies (Junghoefer et al., 2001; Schupp et al., 2003), the early posterior negativity (EPN) amplitude was scored as the mean activity in two time intervals, from 168 to 232 ms (EPN1) and 232 to 296 ms (EPN2), over electrodes P3, P4, O1 and O2 allowing for a more detailed temporal resolution. The ERP measures were tested in a repeated measures analyses of variance (ANOVA) including the within-subject variable emotional arousal (low vs. high), time (EPN1 vs. EPN2), position (parietal vs. occipital), and laterality (left vs. right), and the between-subject variable group (PD patients vs. healthy controls). Significant effects were followed up by separate ANOVAs.

Affective ratings of the presented subset of 54 pictures are available from 10 PD patients only and their matched controls, as four participants got tired and asked to leave the laboratory after the EEG recording.

According to Bradley et al. (2001) the subset of 54 pictures can be categorized in 24 positive (nature, families, food, sports, adventure, attractive people, erotic couples), six neutral (household objects, mushrooms) and 24 negative pictures (pollution, illness, loss, accidents, contamination, attacking animals, attacking humans, mutilated bodies) or alternatively in high and low arousing pictures. The arousal and valence rating averaged for picture category were analyzed by separate analyses of variance (ANOVAs), with valence category (positive vs. neutral vs. negative) or arousal category (high arousal vs. low arousal) as within-subject variable, and group (PD patients vs. healthy controls) as between-subject variable. Significant effects were followed up by separate *t*-tests for independent samples.

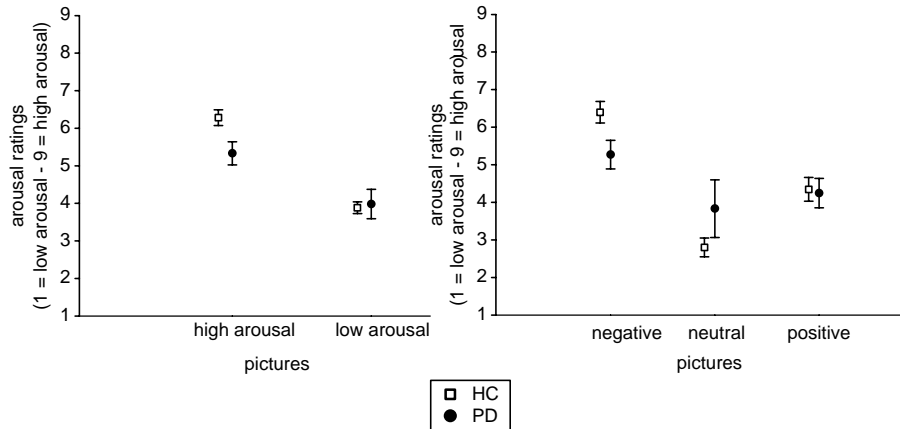


Fig. 1. Affective arousal ratings for pictures high and low in emotional arousal (left panel) and pictures with negative, neutral and positive content (right panel). Ten Parkinson's disease patients (PD) and 10 age and sex matched healthy control participants (HC) were examined. (mean \pm SEM).

3. Results

3.1. Picture ratings

Regarding valence ratings (not depicted), a main effect of valence category, $F(2,36)=144.66$, $P<.001$, $\eta_p^2=.89^1$, indicated that participants rated emotional pictures as expected such that negative pictures were considered to be more negative than neutral pictures, $t(19)=10.86$, $P<.01$, and more negative than positive pictures, $t(19)=22.60$, $P<.01$. In addition, positive pictures were rated as more positive than neutral ones, $t(19)=3.14$, $P=.01$. A main effect of arousal category, $F(1,18)=161.39$, $P<.001$, $\eta_p^2=.90$, indicated that participants rated high arousing pictures as more negative than low arousing pictures. No group differences were found for valence ratings of pictures.

Concerning arousal ratings (see Fig. 1), a main effect of arousal, $F(1,18)=35.77$, $P<.001$, $\eta_p^2=.67$, revealed that high arousing pictures were rated as more arousing than low arousing pictures. Regarding the valence categories, a main effect of valence, $F(2,36)=16.16$, $P<.001$, $\eta_p^2=.47$, indicated that participants rated emotional pictures as more arousing than neutral ones. Furthermore, in accordance with our a-priori hypothesis that PD patients show reduced arousal ratings for normally high arousing pictures we found a group main effect, $F(1,18)=3.03$, $P<.05$ (one-tailed), $\eta_p^2=.14$. This indicated differences in arousal ratings between PD patients and healthy controls. This effect was modulated by a significant group \times arousal category interaction, $F(2,36)=2.97$, $P<.05$ (one-tailed), $\eta_p^2=.14$, which was expected and therefore was further examined. Post-hoc comparisons revealed that PD patients only rated pictures with highly arousing content as less arousing than did healthy controls, $t(18)=2.57$, $P<.02$, whereas no

differences were found for pictures with low arousing content between groups, $t(18)=0.23$, $P=.82$, (see Fig. 1). Additionally, t -tests on the arousal ratings in the valence categories revealed that PD patients rated negative pictures as less arousing compared to healthy controls, $t(18)=2.36$, $P<.03$. No differences were found for positive and neutral pictures. Thus, subjective ratings on emotional arousal point towards a reduced intensity of emotional responses in PD patients compared to healthy controls.

3.2. Early posterior negativity (EPN)

Fig. 2 illustrates the arousal-dependent modulation of the visual ERPs at parietal and at occipital electrodes. An early posterior negativity (EPN) in association with high arousing emotional stimuli can be seen in both groups; high arousing pictures relative to low arousing pictures elicited a negative deviation of the waveform over parietal and occipital sites starting at about 220 ms and peaking at about 290 ms after picture onset. Fig. 3 depicts the spatial topography of this affective modulation pointing towards primary and secondary visual cortices as likely sources of the EPN.

The overall ANOVA confirmed that the visual ERPs differed as a function of emotional arousal, $F(1,26)=4.51$, $P=.04$, $\eta_p^2=.15$, and also revealed that ERPs varied across the two EPN time windows $F(1,26)=19.73$, $P<.001$, $\eta_p^2=.43$. In addition, significant Arousal \times Time, $F(1,26)=18.34$, $P<.001$, $\eta_p^2=.41$, Arousal \times Position, $F(1,26)=10.19$, $P<.01$, $\eta_p^2=.28$, and Arousal \times Time \times Position, $F(1,26)=4.55$, $P<.04$, $\eta_p^2=.15$, interactions were found. There was no main effect and no interaction effects involving the factor Group suggesting that the observed affective modulation of visual ERPs was not differentially expressed in PD participants compared to healthy controls, Group \times Arousal: $F=0.11$, $P=.74$, $\eta_p^2=.004$, Group \times Arousal \times Time, $F=.13$, $P=.72$, $\eta_p^2=.005$. Also, no effects concerning laterality reached significance.

In order to follow up the three way interaction, separate ANOVAs for each time window of the EPN were

¹ The partial Eta squared indicates the magnitude of the effect. The partial Eta squared is the proportion of the total variance that is attributed to an effect.

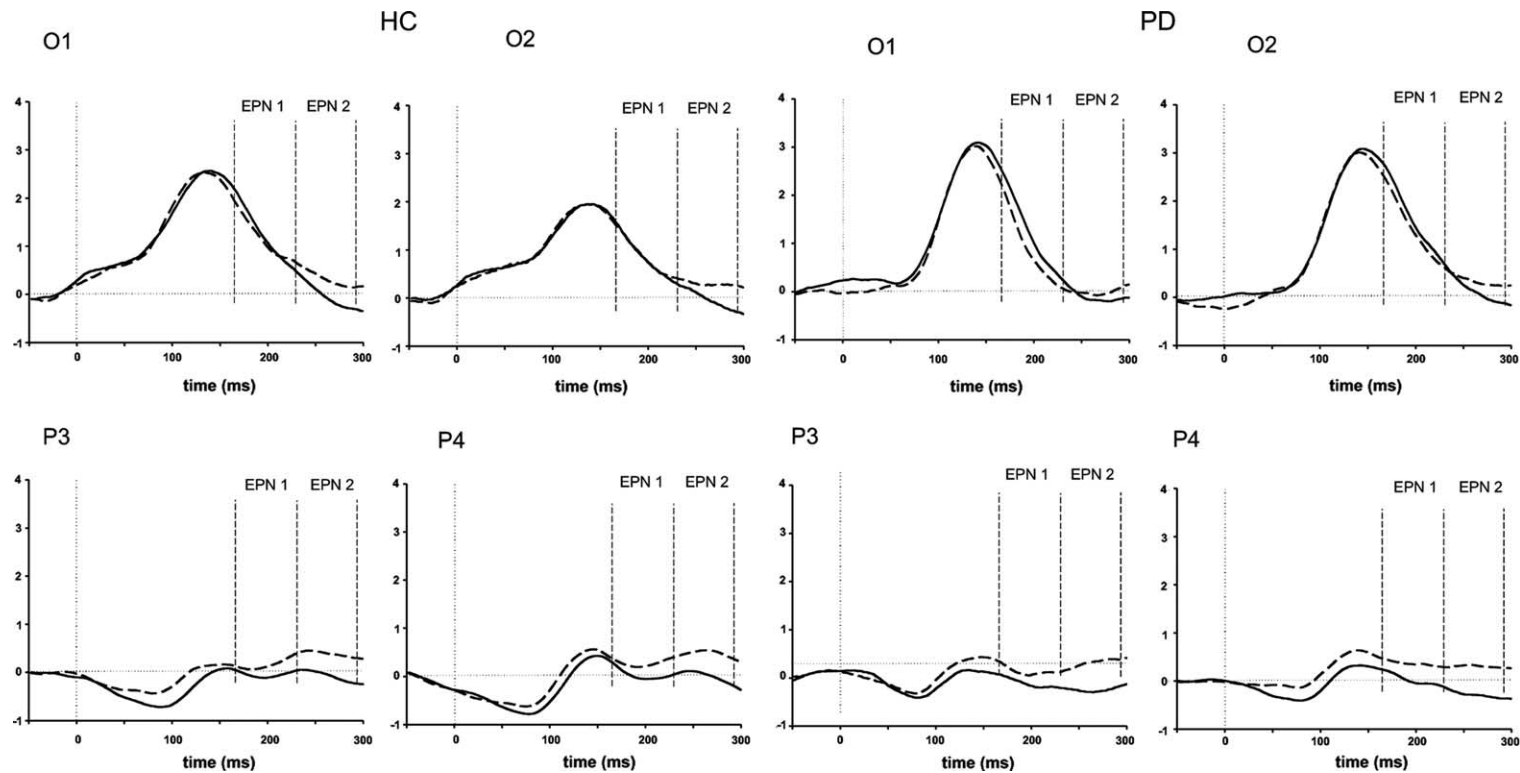


Fig. 2. Grand-average ERP waveforms triggered by high (solid line) and low (dotted line) arousing pictures. Fourteen Parkinson's disease patients (PD) and 14 age and sex matched healthy control participants (HC) were examined. The upper panel shows the early posterior negativity (EPN) at occipital electrodes (O1, O2), the lower panel at parietal electrodes (P3, P4).

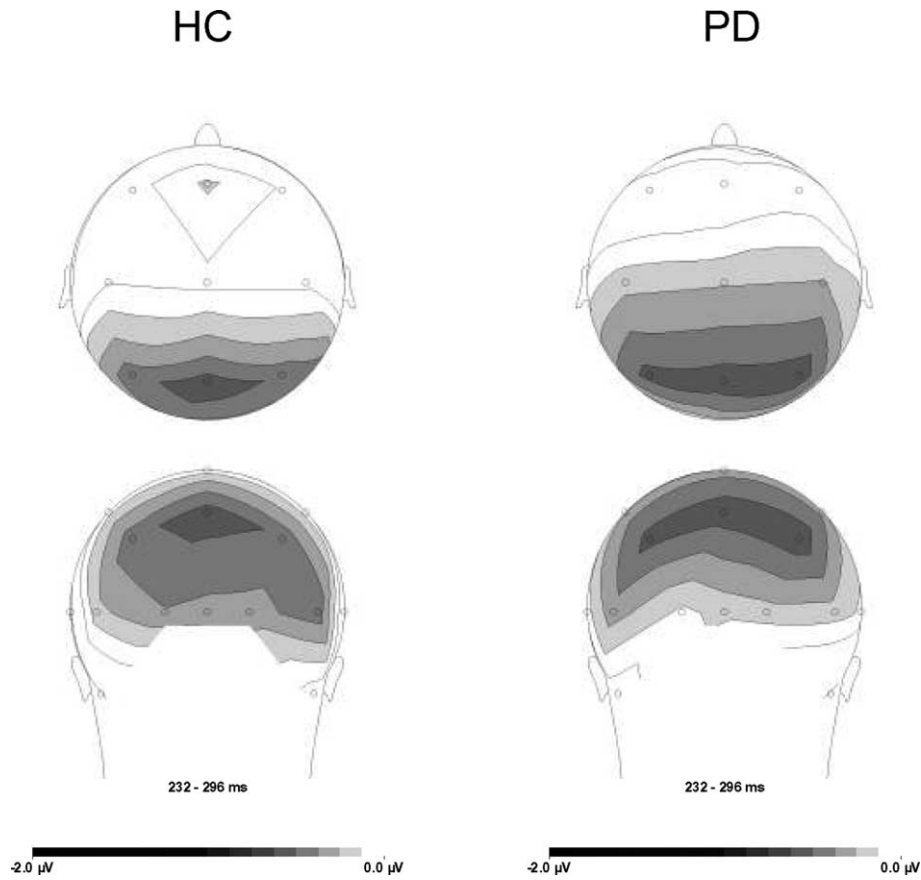


Fig. 3. Difference maps (high arousal minus low arousal) for the late period of the EPN (232–296 ms) for 14 Parkinson's disease patients (PD) and 14 age and sex matched healthy control participants (HC). Illustrated is the top and back view of the model head. Bilateral parietal-occipital negativity appeared for high arousing compared to low arousing pictures in both groups.

calculated. For EPN1 (168–232 ms), no main effect of arousal was found, but a significant Arousal \times Position interaction, $F(1,26) = 13.65$, $P = .001$, $\eta_p^2 = .34$. The EPN1 was modulated by arousal only at parietal electrodes, $F(1, 26) = 5.33$, $P < .03$, $\eta_p^2 = .17$, and not at occipital electrodes. For EPN2 (232–296 ms), however, a main arousal effect, $F(1,26) = 13.4$, $P < .01$, $\eta_p^2 = .34$, as well as an Arousal \times Position interaction, $F(1,26) = 5.78$, $P = .03$, $\eta_p^2 = .18$, were found. Although the arousal effect was more strongly expressed at parietal compared to occipital electrodes, post-hoc t -tests (one-tailed) showed significant affective modulation at both electrodes (both P 's $< .05$).

4. Discussion

In line with previous findings on reduced affect in Parkinson's disease (Jacobs et al., 1995; Madeley et al., 1995; Smith et al., 1996; Simons et al., 2003), the present study also found PD patients to report less arousal compared to healthy controls during extended viewing of the emotional pictures. The reduced emotional responses of PD patients cannot be attributed to a generally increased fatigue or an overall enhanced depression score, since we

did not find overall reduced arousal ratings but reduced arousal ratings elicited specifically by high arousing pictures. These findings most likely reflect blunted emotional responses of PD patients.

However, until now it remains an open question whether PD patients also show deficits in an early visual processing of emotional stimuli. Event-related brain potentials (ERPs) registered within the rapid serial visual presentation paradigm (RSVP) were shown to reflect the automatic capture of attention by emotionally relevant stimuli during encoding (e.g., Schupp et al., 2003), and the present study is to our knowledge the first to examine in PD patients early emotion discrimination based on this paradigm. The early posterior negativity (EPN) as an index of such a process was reliably found in patients suffering from PD, and the EPN of PD patients did not differ from the EPN of sex and age matched healthy control participants. Therefore, we conclude that PD is not associated with a diminished or deteriorated early visual processing of emotional stimuli.

The found dissociation between, on the one hand, a normal early visual processing of emotional stimuli as reflected in neurophysiological measures and, on the other hand, blunted emotional responses as reflected in subjective ratings suggest that PD leads to deteriorated late cortical

evaluative processes, while early automatic subcortical and occipital emotional processes remain intact. The observed deficits in evaluative emotional processing may in part be explained by cognitive demands underlying the emotion rating tasks. The present like all earlier studies asked participants to match, to identify or to rate emotional stimuli (e.g., Sprengelmeyer et al., 2003). Such tasks involve executive abilities, which are known to be impaired in PD (e.g., Pillon et al., 1996). Maybe this overall executive deficit causes impaired performances in evaluative emotion recognition and rating tasks. In contrast, the emotional RSVP paradigm we used to detect potential deficits in early processes did not require an explicit categorization task. This differentiation is important since different brain regions are necessary for declarative (hippocampus) and implicit (amygdala) emotional reactions (Bechara et al., 2000). Early posterior negativity in event-related brain potentials in response to arousing affective pictures is not related to cognitive processes involving executive functions but rather is associated with reflexive attention mechanisms (Schupp et al., 2003). Facilitated selective processing of highly arousing stimuli in the visual cortex may be related to subcortical activation by aversive stimuli, especially in the amygdala (Morris et al., 1997; 1998). Interestingly, this mechanism seems to be mostly intact in our patient sample although there is preliminary evidence that the amygdala is affected by the dopaminergic loss in PD (Tessitore et al., 2002).

A number of earlier studies examined the recognition of facial expressions as indices of emotional processing in PD (Jacobs et al., 1995; Breitenstein et al., 1998; Sprengelmeyer et al., 2003; Dujardin et al., 2004). Impairments were mainly found if homogeneous groups of patients were examined (see Adolphs et al., 1998). The PD patients in the present study had quite a broad range of disease duration (1–15 years), a great variety of medical treatments, and the range of Hoehn and Yahr scores was relatively wide (range from 1 to 3). Because of these heterogeneities of our sample, our findings must be interpreted cautiously. Especially, medical treatment and disease severity may have influenced the affective ratings and neurophysiologic measures. However, correlational analyses within the patient sample did not return significant correlations between disease severity (H and Y stages) or disease duration and affective ratings or ERP measures. Since all patients received anti-Parkinsonian medication, future studies should evaluate whether the observed dissociation between intact early automatic but reduced late evaluative processing of emotional arousal can be also found in un-medicated PD patients.

Because the patients in our sample had significantly higher scores in measures of depression which is quite common (Cummings, 1992), it might be speculated that our results are also attributable to depression. However, depression is typically associated with a decrease in arousal ratings especially for positive pictures (e.g., Sloan et al.,

2001; Dunn et al., 2004) a pattern opposite to the one we found. PD patients in the current study compared to healthy controls generally rated pictures of high arousal and especially negative pictures as less arousing. Furthermore, correlation analyses within our samples did not return significant correlations between depression and affective ratings or ERP measures.

In contrast to previous reports in younger samples (e.g., Junghoefer et al., 2001), the present study found no arousal-related modulation at posterior electrodes in the early time (EPN1) course of the EPN, neither in the PD patients nor in the old control participants. Since we examined considerably older participants than all previous studies, this effect is most likely due to the participants' age. Age is known to be associated with a decline in cognitive functions (see review Friedman, 2003). In a comparable way, age may be associated with a decline in emotional processing, here a delayed onset of emotion discrimination.

Several limitations of the present study should be addressed in the future. Since we only examined physiological correlates of early emotional processes, future studies should be designed to map the complete time course of visual processing (see Williams et al., 2004). This could be realized with a longer presentation time of emotional stimuli and with distinct inter-trial intervals (Schupp et al., 2004). Additionally, some of our patients did receive PD medication (dopamine substitution) which at least one study found to be associated with fewer deficits in emotion recognition using facial stimuli (Tessitore et al., 2002). Therefore, we may have underestimated the deficits in emotional processing, and future studies with unmedicated patients are needed to reveal the pure effect of PD on emotional processing. Finally, most previous studies used emotional facial stimuli to examine deficits in emotion discrimination in PD patients while we used emotional stimuli out of several categories. In order to link the present findings with these previous studies, it would be valuable to replicate our ERP findings with facial stimuli. This should be possible since Schupp et al. (2004) were able to replicate the general EPN findings observed in healthy participants by using emotional facial stimuli.

Taken together, our results revealed that PD patients exhibited no deficits in early stages of automatic emotional information processing but showed blunted emotional responses assessed with ratings. This dissociation may indicate that only response output or declarative processes are responsible for affective deficits in PD patients while automatic input processes remain intact.

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