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Subjective emotional experience at different stages of Parkinson's disease

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ABSTRACT

Subjective emotional experience is thought to rely on a large cortical–subcortical network including orbitofrontal and cingulate frontostriatal circuits together with the mesolimbic dopaminergic system that modulates their activity. Parkinson's disease (PD) provides a model for exploring this issue. By using an original emotion induction procedure, the present study examined to what extent subjective experience of emotion of PD patients at different stages of the disease was modulated by emotion in the same way as healthy individuals. A battery of film excerpts was used to elicit different emotional feelings (happiness, anger, fear, sadness, disgust, and neutral) in 15 newly diagnosed PD patients, 18 patients with advanced PD and 15 matched controls. The newly diagnosed patients were examined in two conditions: "on" and "off" dopaminergic medication. Participants reported the intensity of their emotional feelings on a scale consisting of 10 emotional categories. Results indicated that PD patients at different stages of the disease did not significantly differ from the controls in the self-reported emotional experience to the presented film excerpts. Moreover, analyses conducted within the newly diagnosed PD group (on-dopa vs. off-dopa conditions) indicated that the patients' emotional reactivity to the presented film excerpts was not significantly modulated by dopaminergic medication. These results thus question the possible role of dopaminergic pathways in subjective emotional experience, at least in this sample and in the context of emotion induction.

1. Introduction

Subjective emotional experience, also referred as feeling, is one of the various components of the complex theoretical construct of emotion, with the verbally reported feelings capturing only partially what is effectively consciously experienced [1].

To date, the neural processes underlying the feeling component of emotion are not fully understood. Findings from animal, human lesion and neuroimaging studies suggest that cortical and subcortical regions receiving extensive dopaminergic innervation and known to be involved in the processing of emotions from faces and voices (e.g. orbitofrontal and anterior cingulate cortex, amygdala, ventral striatum), are also involved in the subjective experience of emotion [2,3]. Imaging studies that have examined neural systems engaged during emotion induction in a variety of procedures (e.g. affective pictures, film clips, music) have confirmed the involvement of a large cortical–subcortical network including the basal ganglia (BG), particularly the ventral striatum, in response to affective stimuli [4–7]. For example, Menon and Levitin [5] showed that listening to music modulates activity within a network of mesolimbic structures such as the ventral tegmental area and the nucleus accumbens, and found significant dynamic interactions between (these) mesolimbic structures and distant cortical regions associated with emotion processing such as the orbitofrontal cortex and inferior frontal cortex. Consistent with neuroimaging findings, modification of emotional experience has been described in patients with circumscribed lesions in the orbitofrontal cortex and/or anterior cingulate cortex [8], in the BG and insular cortex [9], as well as in pathologies involving orbitofrontal and cingulate frontostriatal circuits, together with the mesolimbic dopaminergic system which modulates the activity of these circuits: schizophrenia [6,7], Huntington's disease [10], and Parkinson's disease [11,12].

Because Parkinson's disease (PD) is a neurodegenerative disorder affecting the nigrostriatal and mesocorticolimbic dopaminergic systems, it offers the opportunity to explore the influence of BG and dopaminergic pathways on emotional processes. Most studies have focused on the recognition of emotion from faces and from voices and have yielded relatively uniform evidence of deficiencies associated to PD [13–15]. The mechanisms that underlie these emotional changes in PD patients are yet not fully understood but the most widely held hypothesis is that dopamine depletion of the mesolimbic pathway leads to the disruption of the striatofrontal circuits [16–18]. The involvement of dopamine as a key neurotransmitter in emotional processes is largely documented [19].

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As pointed out above, most of the structures targeted by the projection of dopaminergic neurons and in particular those of the mesolimbic and mesocortical pathways are involved in emotional processing. A number of studies conducted in healthy volunteers found that activity of these structures in response to emotional stimuli was modulated by dopaminergic manipulations. For example, a fMRI study reported that during the presentation of unpleasant pictures, the activity of several limbic structures such as the amygdala was reduced in healthy individuals who had received a dopamine antagonist [20]. Another fMRI study reported increased amygdala activity during the perception of facial expressions of fear and danger after participants had received an agonist that increased the release of dopamine and inhibited its recapture [21]. These data, together with those stemming from studies of patients with neurological pathologies resulting in disturbed dopaminergic systems such as PD patients, highlight the role of dopamine neurotransmission in emotional processes.

To our knowledge, no study has specifically explored subjective emotional experience in PD patients. Two studies aimed at exploring emotional facial expressivity in PD patients in tasks such as viewing emotional film excerpts, found that the patients assessed the emotional intensity of the excerpts as the same way as healthy controls in spite of reduced expressiveness, thus suggesting unaltered subjective emotional experience [22,23]. However, blunted emotional reactivity in PD has been suggested on the basis of reduced physiological arousal and/or reduced arousal ratings of aversive or highly arousing pictures as compared to healthy controls [11,12,24]. Wieser et al. [12] observed reduced arousal ratings for highly arousing pictures in PD patients, in spite of normal early visual processing of emotional stimuli (i.e. normal event-related potential - ERP - waveforms). Bowers et al. [11] observed reduced startle reactivity in the context of reduced arousal ratings of aversive pictures in PD patients. In Miller et al. 's study [24] however, the reduced startle eyeblink magnitude in the PD group was observed in the context of normal subjective ratings. Bowers, Miller and colleagues [11,24] hypothesized a deficit in translating a motivational state into a physiological response to account for the reduced physiological reactivity observed in PD. According to the authors, this deficit may be related to faulty communication between the amygdala and prefrontal cortex due to low levels of dopamine. This interpretation is in line with the finding that levels of dopamine modulated the response of PD patients' amygdala during an emotional face matching task [25]. This latter fMRI study provided the first evidence of abnormal amygdala responses in PD patients [see also 26] and demonstrated the key role of dopamine neurotransmission in the modulation of emotional responses.

As a whole, emotional disturbance in PD – either in the domain of emotion recognition or physiological arousal and to some extent subjective experience – are thought to be closely linked to perturbation of dopamine availability, amygdala and striatofrontal circuits.

By using an original emotion elicitation procedure [27], the purpose of the present study was to examine to what extent subjective experience of emotion of PD patients is modulated by emotion in the same way as healthy individuals. Answering this question may provide preliminary indication as to the involvement of BG and dopaminergic pathways in the subjective experience of emotion. This was done by studying PD patients at different stages of the disease: newly diagnosed patients both in on-dopa and off-dopa conditions, and patients with advanced pathology, comparing them with healthy controls.

2. Methods

2.1. Participants

Two groups of patients with idiopathic PD at different stages of the disease (Early PD vs. Advanced PD), and a group of healthy controls (HC) participated in the study. Participants' demographic and clinical characteristics are summarized in Table 1.

Disease severity was assessed using Hoehn and Yahr staging classification [28] and the Schwab and England scale [29]. All PD patients were tested "on" their normal dosage of dopaminergic medication (levodopa preparations and/or dopamine receptor agonists). Intake was defined as the levodopa equivalent dose, calculated on the basis of the correspondences adapted from Lozano and colleagues [30]. Patients from the Early PD group were also tested in the practically defined worst "off" motor state, that is "off-dopa" (after a minimum of 12 h of therapeutic withdrawal), and after checking the motor symptoms had returned. On-dopa and off-dopa conditions were counterbalanced between session 1 and session 2. Informed consent was obtained according to the Declaration of Helsinki.

The HC had no history of neurological or psychiatric illness, and none of them presented signs of cognitive deterioration as documented by the Mattis Dementia Rating Scale [31] (see Table 2). As shown in Table 1, the three groups did not statistically differ in terms of age and education. Note that a significant difference was observed between the Early PD and Advanced PD groups on the Hoehn and Yahr scale (see Table 1). None of the PD patients showed signs of cognitive deterioration, executive dysfunction, depressive disorder or anxiety disorder on the basis of formal neuropsychological testing and psychiatric assessment (see Table 2). Note that a significant difference between the three groups was found for the Stroop interference score [36] and the MADRS depression score (see Table 2). However, for the three groups, mean scores were above the criterion for pathological interference score for the Stroop task on the one hand [37], and within the non-depressed range for the depression score on the other hand [38].

2.2. Materials and procedure

For a full description of the emotion elicitation procedure used in the present study, we invite the reader to refer to Vicente et al. [27]. The procedure uses two series (A and B) of six film excerpts each, to elicit different emotional feelings: happiness, anger, fear, sadness, disgust and neutral. For each participant, the order of presentation of the six excerpts within a series was determined randomly. In order to avoid a possible test–retest effect between the on and off-dopa conditions in the Early PD patient group, half of the participants in the on-dopa condition were presented with series A and the other half with series B, while in the off-dopa condition the former were presented with series B and the latter with series A. Presentation of series A and B was also counterbalanced across participants of the Advanced PD group and of the HC group. Before each excerpt presentation participants went through a relaxation session for about 3 min. After each relaxation period and each film excerpt presentation (i.e. before and after each film excerpt), participants reported the intensity of their emotional feelings on the Differential Emotions Scale (DES, French translation by Philippot [39]) consisting of 10 emotional categories (i.e. emotional feelings) to be rated on an visual analog scale ranging from "not at all" to "very much". Scores on the scale could vary between 0 (lower limit = no emotional feeling at all) and 7.5 (upper limit = very intense emotional feeling) which correspond to the physical distance in centimeters between the lower and upper limits of the scale. Ratings (position of one's response on the scale) were measured in centimeters from the lower limit. The entire study was completed in a single 90' session (including the neuropsychological and psychiatric assessment). The Early PD patients underwent a second 45' session in the "off" (or "on") dopa condition.

3. Results

A first $6 \times 3 \times 2 \times 10$ exploratory ANOVA was conducted with the Type of emotion induced (happiness, anger, sadness, fear, disgust and

Table 1
Demographic and clinical characteristics of the participating groups.

Variable	Early PD (n = 15)			Advanced PD (n = 18)			Healthy controls (n = 15)			Stat. value	*p* value[b]
	Mean	*SD*	Range	Mean	*SD*	Range	Mean	*SD*	Range		
Gender (F/M)	10F/5M			10F/8M			8F/7M				
Age (years)	62.33	8.51	39–74	60.28	7.46	48–74	57.27	9.33	34–70	1.38[†]	ns
Education (years)	14.47	4.42	8–22	13.67	3.27	8–19	15.00	4.24	9–23	0.47[†]	ns
Disease duration (years)	2.48	1.41	0.17–5	11.55	3.36	7–17	–	–	–	−9.73[#]	<0.001
LED (mg/day)	409.33	243.06	0–850	997.50	515.70	150–2345	–	–	–	−3.78[#]	<0.001
Hoehn and Yahr[a]	0.77	0.73	0–2	1.39	0.65	0–2	–	–	–	−2.58[#]	<0.05
Schwab and England[a]	93.33	6.17	80–100	88.33	7.86	80–100	–	–	–	2[#]	ns

Note. PD = Parkinson's disease; LED = levodopa equivalent dose; Stat. value = Statistical value; ns = non significant.
[a] Scores obtained from PD patients in the on-dopa state.
[b] The analyses used an alpha level of 0.05.
[†] Single-factor ANOVA comparing the three groups.
[#] *t*-test for independent samples (Early PD and Advanced PD groups).

neutral that is, no emotion induced), the Group (Early PD on-dopa, Advanced PD and HC), the Moment (before vs. after the presentation of the film excerpt) and the 10 items of the Differential Emotions Scale (interested, happy, sad, angry, fearful, anxious, disgusted, disdainful, surprised, and warmhearted) as factors, and with the ratings on the emotional scales as the dependent variable. Because the interaction among the four factors was statistically significant ($F(90, 225) = 1.35$, $p < 0.05$), we decided to investigate more specifically – for each type of emotion induced – the effects of Group, Moment and Type of film excerpt (emotional excerpt vs. neutral excerpt). For this reason the subsequent ANOVAs were conducted for each type of emotion induced separately and targeted the DES emotional category that corresponded to the subjective feeling the more likely to be reported for a given excerpt (e.g. the feeling of happiness for the excerpt intended to induce happiness). The next series of ANOVAs thus examined whether the three groups (Early PD on-dopa, Advanced PD and HC) differed in the intensity with which the target emotional feeling was reported after vs. before the corresponding film excerpt, as compared with the intensity with which the same feeling was reported after vs. before the neutral excerpt which served as a baseline (i.e. no emotion induction). Mean ratings and *SD*s for the target emotional categories included in the ANOVAs are reported in Table 3.

For each type of emotion induced, the $2 \times 2 \times 3$ ANOVA computed with Film (emotional vs. neutral), Moment (before vs. after) and Group (Early PD on-dopa vs. Advanced PD vs. HC) as factors, revealed a main effect of Film, a main effect of Moment, and a significant Film × Moment interaction (see Table 4). This demonstrated that overall, ratings on the target feeling were significantly higher after than before the film excerpt intended to induce this specific feeling, as compared to the neutral excerpt. Of more interest for our question, the ANOVAs computed for the "Happiness", "Sadness", "Anger" and "Disgust" excerpts revealed no significant main effect of Group and no significant interactions involving the Group factor (see Table 4), indicating that emotional reactivity to these emotional excerpts was not significantly different across the three groups. Note that a main effect of Group was obtained for the "Fear" excerpt, however none of the interactions involving the Group factor reached significance (see Table 4). This Group effect was due to significant differences in self-ratings of fear between the controls on the one hand, and the two PD

Table 2
Performances of the three groups on the neuropsychological tests and psychiatric scales.

Variable	Early PD				Advanced PD		Healthy controls		Stat. value[†]	*p* value[b]
	On-dopa		Off-dopa		Mean	*SD*	Mean	*SD*		
	Mean	*SD*	Mean	*SD*						
MDRS[a]	140.13	3.91	140.69	4.01	141.28	2.16	140.53	1.77	0.70	ns
Stroop Interference	−1.66	12.07	–	–	3.25	6.15	9.13	9.75	4.84	<0.05[c]
TMT B-A	57.73	29.23	–	–	53.33	25.67	50.13	32.74	0.26	ns
MCST cat.	5.87	0.52	–	–	5.82	0.39	6	0	0.94	ns
MCST pers.	0.80	1.08	–	–	0.71	1.45	0.53	0.84	0.20	ns
Category Fluency	28.87	10.97	–	–	34.33	8.45	36.13	8.61	1.88	ns
Letter Fluency	20.33	7.72	–	–	25.11	7.25	21.67	7.06	2.48	ns
STAI-Trait	38.33	10.64	–	–	36.78	10.10	33.87	8.76	0.79	ns
STAI-State[a]	40.27	7.77	34.00	9.66	34.89	11.92	33.60	7.89	2.06	ns
MADRS	5.60	4.98	–	–	4.39	4.17	1.87	2.07	3.49	<0.05[d]

Note. PD = Parkinson's disease; MDRS = Mattis Dementia Rating Scale [31]; TMT B-A = time difference between completion of parts B and A on the Trail-Making test [32]; MCST cat. = number of categories achieved on the Modified Card Sorting Test [33]; MCST pers. = number of perseverative errors on the Modified Card Sorting Test; STAI-Trait = score on the Trait subscale of the State-Trait Anxiety Inventory [34]; STAI-State = score on the State subscale of the State-Trait Anxiety Inventory; MADRS = Montgomery and Asberg Depression Rating Scale [35]; Stat. value = Statistical value; ns = non significant.
[a] The MDRS and the STAI-State subscale were also administered to the Early PD group in the off-dopa condition. However data were missing for two patients on the MDRS and for four patients on the STAI-State scale. No significant differences were observed on the MDRS and on the anxiety score (STAI-State) between the on and off-dopa conditions ($t(12) = -0.05$, $p > 0.10$ and $t(10) = 2.11$, $p > 0.05$ respectively).
[b] The analyses used an alpha level of 0.05.
[c] The difference was due to a significantly greater interference score in the Early PD group than in the HC group ($F(1, 44) = 9.65$, $p < 0.01$), while the difference between the Advanced PD Group and the HC group did not reach significance ($F(1, 44) = 3.04$, $p > 0.05$), and the two groups of PD patients did not significantly differ from one another on this measure ($F(1, 44) = 2{,}12$, $p > 0.10$).
[d] The difference was due to the Early PD group who scored significantly higher on the scale than the HC group ($F(1, 45) = 6.68$, $p < 0.05$), while the Early PD and Advanced PD groups did not significantly differ from one another ($F(1, 45) = 0.76$, $p > 0.10$), nor the Advanced PD and HC groups ($F(1, 45) = 3.32$, $p > 0.05$).
[†] Single-factor ANOVA comparing the Early PD on-dopa, the Advanced PD and the Healthy Controls.

Table 3
Mean ratings on the DES target emotional category reported before and after the corresponding film excerpt and the neutral excerpt in each group.

Target emotional category and film excerpt	Early PD				Advanced PD		Healthy controls	
	On-dopa		Off-dopa		Mean	*SD*	Mean	*SD*
	Mean	*SD*	Mean	*SD*				
DES Item (2) joyful, happy, amused								
Before 'happiness' excerpt	1.50	1.50	1.78	1.89	1.54	1.34	1.80	2.19
After 'happiness' excerpt	5.33	1.51	5.22	1.89	4.32	2.35	5.06	1.38
Before 'neutral' excerpt	2.68	2.20	2.49	2.01	1.70	1.52	1.91	2.05
After 'neutral' excerpt	2.21	2.18	1.02	1.17	1.87	1.65	2.77	2.43
DES Item (4) angry, irritated, mad								
Before 'anger' excerpt	1.19	2.05	1.18	2.03	0.62	0.51	0.20	0.15
After 'anger' excerpt	5.36	2.50	4.27	2.46	5.63	1.75	4.59	2.04
Before 'neutral' excerpt	0.52	0.61	1.03	1.92	0.69	1.11	0.41	0.54
After 'neutral' excerpt	0.59	0.66	0.35	0.41	0.48	0.36	0.21	0.14
DES Item (3) sad, downhearted, blue								
Before 'sadness' excerpt	0.73	1.08	0.89	1.90	0.62	0.69	0.46	0.72
After 'sadness' excerpt	3.62	2.25	2.96	2.08	2.64	2.31	3.08	2.13
Before 'neutral' excerpt	0.43	0.40	0.98	1.90	0.95	1.46	0.44	0.56
After 'neutral' excerpt	0.60	0.95	0.41	0.46	0.93	1.39	0.55	0.91
DES item (5) fearful, scared, afraid								
Before 'fear' excerpt	0.94	1.81	0.41	0.54	0.75	0.96	0.22	0.23
After 'fear' excerpt	4.63	1.92	4.00	2.49	4.10	2.19	2.87	2.28
Before 'neutral' excerpt	0.73	0.88	0.95	1.86	1.05	1.69	0.24	0.21
After 'neutral' excerpt	0.32	0.33	0.33	0.42	0.52	0.45	0.21	0.14
DES Item (7) disgusted, turned off, repulsed								
Before 'disgust' excerpt	0.95	1.90	0.48	0.94	0.46	0.29	0.24	0.20
After 'disgust' excerpt	4.39	3.05	4.62	2.53	4.46	2.29	3.40	2.20
Before 'neutral' excerpt	1.08	1.70	0.96	1.90	0.93	1.48	0.69	1.08
After 'neutral' excerpt	0.38	0.40	0.42	0.60	0.43	0.26	0.41	0.77

Note. PD = Parkinson's disease.

patient groups considered together on the other hand (F (1, 45) = 8.60, $p<0.01$), while ratings of fear were not significantly different between the two PD patient groups ($F<1$). Thus, PD patients reported a more intense feeling of fear than healthy controls, and this effect was global, that is, independent of the film excerpt (fear or neutral) and of the moment (before or after).

Another series of ANOVAs was conducted within the Early PD group in order to examine the influence of dopaminergic medication on emotional reactivity. Thus, for each type of emotion induced, a $2\times2\times2$ ANOVA was conducted with Dopaminergic medication (on-dopa vs. off-dopa), Film excerpt (emotional vs. neutral), and Moment (before vs. after) as factors (see Table 5). These analyses revealed no significant Dopaminergic medication × Film × Moment interactions. More specifically, any of the interactions involving the Dopaminergic medication factor were significant, and there were no significant main effect of Dopaminergic medication. Note however that for the film excerpt supposedly inducing fear, the analysis yielded a statistical trend for a main effect of dopaminergic medication, in the sense of a more intense self-reported feeling of fear when on-dopa, and this effect is global that is, independent of the other factors under study. Thus, these ANOVAs (i) confirmed that ratings on the target feeling were more intense after than before the film excerpt intended to induce this feeling as compared to the neutral excerpt, and (ii) demonstrated that these effects were not significantly modulated by dopaminergic medication. Note however that in the case of the target feeling of fear, the patients' ratings tended to be globally higher when on-dopa.

4. Discussion

The main finding of the present study was that PD patients at different stages of the disease (Early PD on-dopa and Advanced PD) did not significantly differ from HC in their emotional reactivity – in terms of self-reported emotional experience – to the presentation of film excerpts intended to induce specific emotions. This is consistent with results of prior studies that were not focused on the investigation of emotional experience in PD but still demonstrated that PD patients report subjective feelings that are comparable to those reported by healthy controls in the context of emotional film excerpts viewing [22,23]. However, our finding contrasts with reports of blunted emotional reactivity in PD patients on the basis of reduced physiological arousal and/or reduced arousal ratings of affective stimuli [11,12,24]. This discrepancy is likely to be based on differences in the objective and design of the emotion elicitation procedure used. The authors of the above mentioned studies were primarily interested in the exploration of physiological reactivity of PD patients to affective stimuli. In this context, sets of aversive, pleasant and neutral pictures were briefly presented, associated with either measures of startle eyeblink responses [11,24] or ERPs recordings [12], and with subsequent valence and arousal self-reports. Here subjective emotional experience was collected both before and after the presentation of short films excerpts, which is considered an effective method for eliciting intense and specific target emotions [39]. Moreover, subjective experience was collected on a questionnaire that captures nuances and distinctions in the description of the participants' emotional feelings that extends beyond that of valence and arousal bipolar scales. However, it is noteworthy that in Miller et al.'s study [24] normal subjective ratings were reported by the PD patients on the valence and arousal scales in spite of reduced startle eyeblink magnitude.

More generally, our findings are also in contrast to the numerous studies conducted in the domain of emotion recognition that demonstrated emotional processing deficiencies in PD [13–18]. This point suggests that although emotion recognition and subjective emotional experience rely – at least in part – on common cerebral networks (see Introduction section), suggesting some degree of

Table 4
Results of the ANOVAs conducted for each film excerpt comparing ratings on the target emotional category before and after the corresponding film excerpt and the neutral excerpt, between the Early PD on-dopa, the Advanced PD and the HC groups.

Source of variance	df	*F*	*p* value[a]	η^2	Power (1-β)
'Happiness' excerpt					
Film (happiness vs. neutral)	1, 45	19.08	<0.0001	0.30	0.99
Moment (before vs. after)	1, 45	103.28	<0.0001	0.70	1
Group (Early PD vs. Advanced PD vs. HC)	2, 45	0.84	0.44	0.03	0.19
Film × Moment	1, 45	58.63	<0.0001	0.56	1
Moment × Group	2, 45	1.02	0.37	0.04	0.23
Film × Group	2, 45	0.04	0.96	0.001	0.06
Film × Moment × Group	2, 45	2.10	0.13	0.08	0.43
'Anger' excerpt					
Film (anger vs. neutral)	1, 45	152.10	<0.0001	0.77	1
Moment (before vs. after)	1, 45	172.54	<0.0001	0.79	1
Group (Early PD vs. Advanced PD vs. HC)	2, 45	2.71	0.08	0.11	0.54
Film × Moment	1, 45	199.22	<0.0001	0.81	1
Moment × Group	2, 45	0.36	0.70	0.02	0.11
Film × Group	2, 45	0.88	0.42	0.04	0.21
Film × Moment × Group	2, 45	1.02	0.37	0.04	0.23
'Sadness' excerpt					
Film (sadness vs. neutral)	1, 45	42.87	<0.0001	0.49	0.99
Moment (before vs. after)	1, 45	49.87	<0.0001	0.52	0.99
Group (Early PD vs. Advanced PD vs. HC)	2, 45	0.21	0.81	0.01	0.08
Film × Moment	1, 45	54.28	<0.0001	0.55	1
Moment × Group	2, 45	0.76	0.47	0.03	0.18
Film × Group	2, 45	2.44	0.10	0.10	0.49
Film × Moment × Group	2, 45	0.39	0.68	0.02	0.11
'Disgust' excerpt					
Film (disgust vs. neutral)	1, 45	56.89	<0.0001	0.56	1
Moment (before vs. after)	1, 45	53.72	<0.0001	0.54	1
Group (Early PD vs. Advanced PD vs. HC)	2, 45	1.29	0.28	0.05	0.28
Film × Moment	1, 45	87.69	<0.0001	0.66	1
Moment × Group	2, 45	0.34	0.71	0.01	0.10
Film × Group	2, 45	0.81	0.45	0.03	0.19
Film × Moment × Group	2, 45	0.53	0.59	0.02	0.14
'Fear' excerpt					
Film (fear vs. neutral)	1, 45	73.35	<0.0001	0.62	1
Moment (before vs. after)	1, 45	80.13	<0.0001	0.64	1
Group (Early PD vs. Advanced PD vs. HC)	2, 45	4.30	<0.05	0.16	0.75
Film × Moment	1, 45	99.40	<0.0001	0.69	1
Moment × Group	2, 45	0.35	0.70	0.01	0.11
Film × Group	2, 45	1.75	0.18	0.07	0.37
Film × Moment × Group	2, 45	1.49	0.24	0.06	0.32

Note. Based on Shapiro–Wilk normality tests, the normal distribution hypothesis was rejected for a number of rating score distributions. The ANOVAs were thus repeated with log-transformed data. As these analyses yielded comparable results to those obtained with raw data, only those latter are reported here.

[a] The analyses used an alpha level of 0.05.

interdependence, they may constitute distinct components of emotion, in line with a multicomponential approach of emotion [1].

Taken together, we found no evidence for changes in subjective emotional experience in PD thus questioning the role of the BG and dopaminergic pathways in such emotional processes, at least in this sample and with the emotion elicitation procedure used here. One possible explanation is that the procedure used was ineffective in inducing marked emotions. This is unlikely because results showed that the intensity with which each specific target feeling was reported after vs. before the film excerpt intended to induce this feeling, was significantly higher than the intensity with which the same feeling was reported after vs. before a neutral excerpt, indicating that each emotional excerpt was highly effective in inducing the target feeling. Another possible explanation is that changes in emotional experience in PD appear at a level that is not captured by declarative self-reports and that our procedure was in fact unable to reveal. For instance, Bowers et al. [11] found that physiological responses to affective stimuli – as indexed by startle eyeblink amplitude – were altered in PD. Moreover, in Miller et al.'s study [24], reduced startle eyeblink magnitude in PD patients was observed in the context of normal subjective ratings. This question can only be solved with further studies including physiological measures in addition to self-reports of emotional experience. Finally, another possibility (which does not exclude the previous ones) for the discrepancy between the result reported here and prior reports of emotional processing deficiencies in PD, is related to sample characteristics. PD is characterized by a combination of dopaminergic and non-dopaminergic lesions which expand as the pathology progresses. These diffuse lesions account not only for motor symptoms but also cognitive, neuropsychiatric and emotional symptoms, all of which being potential confounding factors. From a methodological point of view, exploring the involvement of dopaminergic circuits in emotional processes means it is important to select homogeneous groups regarding clinical variables such as disease duration and severity, and dopamine replacement therapy, and to match patient and healthy control groups with care according to sociodemographic, cognitive, and neuropsychiatric variables. This means in turn, that significant group effects observed in the context of heterogeneous patient groups and/or in groups in which cognitive and neuropsychiatric disturbances cannot be disgarded, or even simply in patient groups that are inaccurately described, may be difficult to interpret. For example, Wieser et al. [12] suggested to interpret their findings cautiously because of heterogeneities in their sample in terms of disease duration, anti-Parkinsonian medication, disease severity. In the present study, the patient and healthy control groups were matched for age and education and the PD patients were free of cognitive deficits and mood disorders. Moreover, two groups of PD patients were constituted thus contributing to homogenize each patient group not only in terms of disease duration, but also of disease severity and of dopaminergic medication.

Regarding the influence of dopaminergic medication on subjective emotional experience, analyses conducted within the Early PD group (on-dopa vs. off-dopa conditions) indicated that emotional reactivity to the presented film excerpts was not significantly modulated by dopaminergic medication. Although the treatment did not appear to influence self-reported emotional experience in the context of emotion induction, it may not be without effect on the intensity with which specific emotional feelings are felt independently of the induction of emotion. We observed that ratings of fear in the Early PD patients tended to be globally higher when on-dopa. This trend is in line with the finding of a globally more intense feeling of fear in the two PD patient groups (Early PD on-dopa and Advanced PD) as compared to HC, independently of the induction of a specific emotion. This overall more intense feeling of fear may then be related to the dopaminergic medication more than to the disease itself. It has been proposed that administration of dopaminergic medication may replete dopamine-depleted circuits but overdose relatively intact ones [40]. Because the mesocorticolimbic pathway is known to be less affected than nigrostriatal pathway in early stages of PD [41], the former may be overstimulated by dopaminergic medication which may lead in turn to amygdala (over)stimulation [11,25] and perhaps to a globally heightened feeling of fear when under treatment. For the time being, this interpretation is only speculative and we lack an off-dopa condition in the Advanced PD group to support this view.

In conclusion, the present study showed that patients at different stages of PD did not significantly differ from the controls in the self-reported emotional experience to the presented film excerpts and that the Early PD patients' emotional reactivity to the presented film excerpts was not significantly modulated by dopaminergic medication. A major limitation to our study comes from the globally small to medium observed effect size relative to the group factor (main effect or interaction effects) — except for the significant main effect of group

Table 5
Results of the ANOVAs conducted for each film excerpt within the Early PD group comparing ratings on the target emotional category before and after the corresponding film excerpt and the neutral excerpt, in the on-dopa and the off-dopa conditions.

Source of variance	df[a]	*F*	*p* value[b]	η^2	Power (1-β)
'Happiness' excerpt					
Film (happiness vs. neutral)	1, 13	35.63	<0.0001	0.73	1
Moment (before vs. after)	1, 13	41.04	<0.0001	0.76	1
Dopaminergic medication (on vs. off dopa)	1, 13	0.02	0.89	0.001	0.05
Film × Moment	1, 13	61.95	<0.0001	0.82	1
Moment × Dopaminergic medication	1, 13	1.49	0.24	0.10	0.38
Film × Dopaminergic medication	1, 13	2.99	0.11	0.19	0.65
Film × Moment × Dopaminergic medication	1, 13	0.34	0.57	0.02	0.12
'Anger' excerpt					
Film (anger vs. neutral)	1, 13	37.93	<0.0001	0.74	1
Moment (before vs. after)	1, 13	23.26	<0.001	0.64	0.99
Dopaminergic medication (on vs. off dopa)	1, 13	0.66	0.43	0.05	0.20
Film × Moment	1, 13	52.69	<0.0001	0.80	1
Moment × Dopaminergic medication	1, 13	2.54	0.13	0.16	0.58
Film × Dopaminergic medication	1, 13	1.33	0.27	0.09	0.35
Film × Moment × Dopaminergic medication	1, 13	0.006	0.94	0.0005	0.05
'Sadness' excerpt					
Film (sadness vs. neutral)	1, 13	33.24	<0.0001	0.72	1
Moment (before vs. after)	1, 13	16.99	<0.01	0.57	0.99
Dopaminergic medication (on vs. off dopa)	1, 13	0.17	0.69	0.01	0.09
Film × Moment	1, 13	45.98	<0.0001	0.78	1
Moment × Dopaminergic medication	1, 13	3.37	0.09	0.20	0.70
Film × Dopaminergic medication	1, 13	2.34	0.15	0.15	0.55
Film × Moment × Dopaminergic medication	1, 13	0.13	0.72	0.01	0.08
'Disgust' excerpt					
Film (disgust vs. neutral)	1, 13	37.29	<0.0001	0.74	1
Moment (before vs. after)	1, 13	21.28	<0.001	0.62	0.99
Dopaminergic medication (on vs. off dopa)	1, 13	0.00008	0.99	7.05e-06	0.05
Film × Moment	1, 13	29.92	<0.001	0.70	1
Moment × Dopaminergic medication	1, 13	1.69	0.22	0.11	0.42
Film × Dopaminergic medication	1, 13	0.02	0.90	0.001	0.05
Film × Moment × Dopaminergic medication	1, 13	0.66	0.43	0.05	0.20
'Fear' excerpt					
Film (fear vs. neutral)	1, 13	55.34	<0.0001	0.80	1
Moment (before vs. after)	1, 13	29.04	<0.001	0.69	0.99
Dopaminergic medication (on vs. off dopa)	1, 13	4.14	0.06	0.24	0.78
Film × Moment	1, 13	50.57	<0.0001	0.79	1
Moment × Dopaminergic medication	1, 13	0.0009	0.98	7.72e-05	0.05
Film × Dopaminergic medication	1, 13	1.15	0.30	0.08	0.31
Film × Moment × Dopaminergic medication	1, 13	0.14	0.72	0.01	0.08

Note. Based on Shapiro–Wilk normality tests, the normal distribution hypothesis was rejected for a number of rating score distributions. The ANOVAs were thus repeated with log-transformed data. As these analyses yielded comparable results to those obtained with raw data, only those latter are reported here.
[a] Data were missing for one patient in the off-dopa condition.
[b] The analyses used an alpha level of 0.05.

observed for the "Fear" excerpt. It is thus not possible to determine here whether effects relative to the group factor failed to reach significance due to the lack of power of our sample size or to the actual absence of group differences. Further research is thus needed with a larger sample of PD patients and/or with other statistical methods to be able to conclude to an absence of group differences.

Keeping in mind these limitations, our findings should stimulate further research to clarify the role of BG and dopaminergic pathways in the subjective experience of emotion and not only in the context of emotion induction.

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