



Heriot-Watt University  
Research Gateway

## Identification and intensity of disgust: distinguishing visual, linguistic and facial expressions processing in Parkinson disease

### Citation for published version:

Sedda, A, Petito, S, Guarino, M & Stracciari, A 2017, 'Identification and intensity of disgust: distinguishing visual, linguistic and facial expressions processing in Parkinson disease', *Behavioural Brain Research*, vol. 330, pp. 30–36. <https://doi.org/10.1016/j.bbr.2017.05.003>

### Digital Object Identifier (DOI):

[10.1016/j.bbr.2017.05.003](https://doi.org/10.1016/j.bbr.2017.05.003)

### Link:

[Link to publication record in Heriot-Watt Research Portal](#)

### Document Version:

Peer reviewed version

### Published In:

Behavioural Brain Research

### Publisher Rights Statement:

© 2017 Elsevier B.V.

### General rights

Copyright for the publications made accessible via Heriot-Watt Research Portal is retained by the author(s) and / or other copyright owners and it is a condition of accessing these publications that users recognise and abide by the legal requirements associated with these rights.

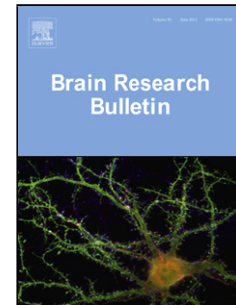
### Take down policy

Heriot-Watt University has made every reasonable effort to ensure that the content in Heriot-Watt Research Portal complies with UK legislation. If you believe that the public display of this file breaches copyright please contact [open.access@hw.ac.uk](mailto:open.access@hw.ac.uk) providing details, and we will remove access to the work immediately and investigate your claim.

## Accepted Manuscript

Title: Identification and intensity of disgust: distinguishing visual, linguistic and facial expressions processing in Parkinson disease

Authors: Anna Sedda, Sara Petito, Maria Guarino, Andrea Stracciari



PII: S0166-4328(17)30333-9  
DOI: <http://dx.doi.org/doi:10.1016/j.bbr.2017.05.003>  
Reference: BBR 10852

To appear in: *Behavioural Brain Research*

Received date: 27-2-2017  
Revised date: 27-4-2017  
Accepted date: 2-5-2017

Please cite this article as: Sedda Anna, Petito Sara, Guarino Maria, Stracciari Andrea. Identification and intensity of disgust: distinguishing visual, linguistic and facial expressions processing in Parkinson disease. *Behavioural Brain Research* <http://dx.doi.org/10.1016/j.bbr.2017.05.003>

This is a PDF file of an unedited manuscript that has been accepted for publication. As a service to our customers we are providing this early version of the manuscript. The manuscript will undergo copyediting, typesetting, and review of the resulting proof before it is published in its final form. Please note that during the production process errors may be discovered which could affect the content, and all legal disclaimers that apply to the journal pertain.

Sedda et al. - Parkinson disease and Disgust Processing

**Title: Identification and intensity of disgust: distinguishing visual, linguistic and facial expressions processing in Parkinson disease**

Heading: Parkinson disease and Disgust Processing

### **Authors**

**Anna Sedda<sup>1</sup>, Sara Petito<sup>2</sup>, Maria Guarino<sup>3</sup>, Andrea Stracciari<sup>2,3</sup>**

1 Psychology, School of Social Sciences – Heriot Watt University - Edinburgh Campus – UK

2 School of Psychology and Education Sciences, Bologna University, Cesena Campus, Italy

3 Neurology Unit, S. Orsola - Malpighi University Hospital, Bologna, Italy

*Corresponding author:*

Anna Sedda, PhD

Psychology - School of Social Sciences – Heriot Watt University

Edinburgh UK

Email to: a.sedda@hw.ac.uk.

**Highlights**

- First study of disgust processing in PD using facial expressions, visual images and sentences.
- Facial expressions of disgust impaired, but not visual images and sentences.
- A specific impairment of facial recognition but spared cognitive components of disgust.

**Abstract**

**OBJECTIVES & METHODS.** Most of the studies since now show an impairment for facial displays of disgust recognition in Parkinson disease. A general impairment in disgust processing in patients with Parkinson disease might adversely affect their social interactions, given the relevance of this emotion for human relations. However, despite the importance of faces, disgust is also expressed through other format of visual stimuli such as sentences and visual images. The aim of our study was to explore disgust processing in a sample of patients affected by Parkinson disease, by means of various tests tackling not only facial recognition but also other format of visual stimuli through which disgust can be recognized. **RESULTS.** Our results confirm that patients are impaired in recognizing facial displays of disgust. Further analyses show that patients are also impaired and slower for other facial expressions, with the only exception of happiness. Notably however, patients with Parkinson disease processed visual images and sentences as controls. **CONCLUSIONS.** Our findings show a dissociation within different formats of visual stimuli of disgust, suggesting that Parkinson disease is not characterized by a general compromising of disgust processing, as often suggested. The involvement of the basal ganglia-frontal cortex system might spare some cognitive components of emotional processing, related to memory and culture, at least for disgust.

**Keywords:** emotion recognition; Parkinson disease; disgust; facial expressions; insula.

## 1. Introduction

Disgust is a powerful emotion emerged at the beginning of human evolution to avoid potentially contaminating stimuli [1]. Visceral feelings, nausea, throat clenching, and the process of potentially harmful food expulsion characterize this emotion [1, 2]. As society developed, disgust assumed further moral connotations, related to poor hygiene, sexual inappropriate acts, death and violation of the ideal body “envelope” or exterior form [1]. As such, disgust acquired a pivotal role in human social interactions regulation. Neural correlates of disgust processing includes the insula and the basal ganglia [3-6]. Not by chance, abnormal perception of disgust is reported in various psychiatric disorders [7, 8] but also following neurological diseases that affect (either directly or indirectly) these anatomical areas [9, 10].

The study of Parkinson Disease (PD) has been pivotal in understanding processing of disgust [11]. Once mainly considered a motor disorder, PD is characterized by widespread cognitive impairments [12, 13], including facial emotion recognition deficits [11]. Several studies have shown a worse performance in PD patients, especially for facial displays of disgust, compared to healthy individuals [14-16]. Importantly, these impairments persist even when high intensities displays of emotions are adopted [16] and are more prominent in unmedicated patients [15].

Nevertheless, impairments in recognition of facial displays of disgust should not be taken as a final proof of a general impairment of this emotion in PD. As mentioned above, disgust is a complex emotion, which can be elicited also through visual images [17]. In fact, dissociations between formats of stimuli in emotional recognition have been already investigated in PD patients, such as in the study of Saenz et al. showing a deficit in facial emotion recognition accompanied by a spared recognition of the same emotions, fear and sadness, through music [18]. Given the relevance of emotional processing in everyday life,

assuming an impairment in disgust recognition in patients with PD would adversely affect how psychological management of psychiatric comorbidity is carried on.

Thus, the aim of this study was to explore if, in patients affected by PD, disgust processing impairments are selective for faces or also involve visual and semantic stimuli. More in detail, if impairments in the processing of disgust are general, patients should show a difference compared to healthy controls in any task tackling disgust processing. On the other hand, if impairments are selective for faces, patients should be impaired only in specific tasks exploring recognition of facial expressions of disgust.

## **2. Methods**

### **2.1 Participants**

Ethical approval for the study has been obtained from the Ethical Committee of the Sant'Orsola-Malpighi University hospital in Bologna (Italy) and the study has been conducted in accordance with the Declaration of Helsinki. All participants (patients and healthy controls) signed an informed consent form prior the experiment and agreed to take part in the study.

#### *2.1.1 Patients*

Nineteen patients with mild-moderate idiopathic PD have been enrolled at the Movement Disorder Centre of Neurology Unit of the Sant'Orsola-Malpighi University hospital in Bologna (Italy). The diagnosis of PD was defined according to the United Kingdom Parkinson's disease Society Brain Bank criteria[19].

Inclusion criteria for patients were: i) Hoehn and Yahr scale  $\leq 4$ [20] ( ii) a score of at least 24 at the Mini Mental State Examination (MMSE); ii) absence of neurological (out of PD) and psychiatric comorbidities as assessed by a clinical interview; iii) absence of drugs

and alcohol abuse. All patients underwent a CT scan, which excluded the presence of brain lesions.

### 2.1.2 Control participants

A control group of 20 right-handed healthy participants has been recruited for comparison. Inclusion criteria for controls were: i) a score of at least 24 at the Mini Mental State Examination (MMSE); ii) absence of neurological or psychiatric diseases comorbidities by clinical interview iii) absence of sensory or motor impairments and finally iv) absence of treatment with psychotropic drugs. Demographic and clinical features are reported in table 1.

[Table 1]

## 2.2 Tasks & Procedure

### 2.2.1 Screening

All participants have been assessed with the MMSE [21] to exclude cognitive impairments and with the Yesavage Geriatric Depression Scale (GDS – Short Form) [22, 23] to control for mood disturbances that could affect performance at the emotional tasks.

### 2.2.2 Emotional Tasks

*Disgust Rating task [17]*. This task is composed by 12 pictures depicting fear, sadness, happiness and anger scenes as control images, and by 29 pictures displaying disgusting scenes or items (spoilt food, body products, animal related disgust, contamination, death related disgust, poor hygiene and envelope violations). The total trial number is 41. Participants are presented with these images on the centre of a computer screen. Stimuli stay on the screen until the participant's response, interleaved with a fixation cross (1000 ms).

Participants are asked to rate the valence of the picture ranging from 1 (not at all disgusting) to 7 (completely disgusting) by pressing, as rapidly as possible, one of the response keys on the keyboard, always using their dominant hand.

*Disgust Scale (DS)* [24]. The DS is a self-report scale measuring individual differences in sensitivity to disgust. The total score is obtained from part A, in which the participant is asked to answer “true” or “false” to 16 sentences describing possibly disgusting situations, and from a part B, in which a 3-point rating scale is used by the participant to rate several disgust related sentences. The scale can be downloaded from <http://people.stern.nyu.edu/jhaidt/disgustscale.html> (Italian version by Francesco Mancini).

*Facial emotion recognition task (FER task)* [25]. Stimuli consist of faces expressing one of the following emotions: fear, sadness, disgust, happiness and anger. The images are taken from the Ekman and Friesen (1976)’s series [26]. Full displays were used, as previous studies demonstrated no advantage of high intensity in PD patients [16]. This task includes 12 displays for each of the 5 emotions, portrayed by 4 individuals (2 males and 2 females). Thus, in total, participants are presented with 60 trials. Participants see images on the centre of a computer screen and they are asked to press the key label corresponding to the emotion depicted in the image. Stimuli stay on the screen until the participant's response, interleaved with a fixation cross (1000 ms). Participants respond as rapidly as possible using their dominant hand.

*Procedure* Experimental tasks (DRT, FER) were administered through the software Opensesame [27] that allowed collecting *Reaction time* (RTS ) (calculated only for correct responses, in milliseconds, as the time latency between the stimulus appearance and the participant response) and *Rating* or *Accuracy* (calculated as the percentage of correct responses). All stimuli were presented on a 13-inch PC. All subjects were positioned at an equal distance from the PC monitor (50 cm from the eye to the screen centre) and were



resting with their dominant hand on a fixed starting position, kept in between all the trials, to avoid biased lags between reactions times. Order of stimuli was randomized across participants and within the same subject. We did not provide any feedback on performance accuracy during the experiment. All the other tests were paper and pencil versions.

### 2.2.3 Data Analysis

Data have been analysed through Statistical Package for Social Sciences (SPSS) version 22.0.0.1 for Windows (IBM©).

The DS scores have been compared between the 2 groups by means of an independent t test. For the DRT, we run a mixed ANOVA, with Group as between (Patients, Controls) and Category (control images, food, body products, animal related disgust, contamination, death related disgust, and envelope violations) as within subject factors. Both rating and RTS have been analysed. FER data have been analysed through a mixed ANOVA procedure with Group as between (Patients, Controls) and Emotion (Anger, Fear, Sadness, Happiness and Disgust) as within subject factors. This procedure has been applied to both accuracy (percentage of correct answers) and RTS (for correct answers only). Post hoc comparisons have been carried out by means of estimated marginal means comparisons (Bonferroni corrected for multiple comparisons). In all cases, alpha level was set at .05. Effect sizes are reported as partial  $\eta^2$  ( $\eta^2_p$ ).

Clinical variables<sup>1</sup> association with disgust processing has been explored by means of Pearson correlation procedures when continuous (such as disease duration) and by means of Chi Square tests when nominal or categorical (such as presence or absence of drug treatment with L – Dopa).

---

<sup>1</sup> It was not possible to analyse some variables (depression, visual hallucinations) due to the small numerosness of individuals presenting the feature.

### 3. Results

#### 3.1 DS analysis

Average score (SD) for patients was 16.6 (6.5), while for controls it was 18.3 (3.9).

No significant differences were highlighted for this instrument when comparing the 2 groups ( $p > .05$ ).

#### 3.2 DRT analyses

##### 3.2.1 Rating

The mixed ANOVA (Green-House Geissser correction applied) showed a main effect of Category ( $F_{(3.952; 146.226)} = 35.489$ ;  $p < .001$  ;  $\eta^2_p = .49$ ) but not of Group ( $p > .05$ ) and no interaction between factors ( $p > .05$ ) (Fig. 1).

The Category effect was driven by an expected significantly lower rating for control images ( $M (SD)=2.6 (0.2)$ ) compared to all the other categories {food  $M (SD) =5.4(0.22)$ , body products  $M (SD) =5.3(0.24)$ , animal related disgust  $M (SD) =5.2(0.22)$ , contamination  $M (SD) =5.1(0.3)$ , death related disgust  $M (SD) =6.1 (0.2)$ , poor hygiene  $M (SD) =5.1(0.1)$  and envelope violations  $M (SD) =5.9(0.22)$ }.

[FIGURE 1]

##### Reaction Times

Similarly to ratings, the mixed ANOVA (Green-House Geissser correction applied) on RTS showed a main effect of Category ( $F_{(4.510; 166.872)} = 5.123$ ;  $p < .001$  ;  $\eta^2_p = .12$ ) and no

interaction between factors ( $p > .05$ ). Importantly, the Group effect was not significant either ( $p > .05$ ).

The Category effect was driven by faster RTS in rating images of death related disgust compared to body products (mean difference  $-912.82$ ,  $p = .007$ ), and of poor hygiene (mean difference  $-956.46$ ,  $p = .001$ ) and of animal related disgust (mean difference  $-608.62$ ,  $p = .024$ ) compared to control images. No other differences were found.

## **FER analyses**

### *Accuracy*

The mixed ANOVA (Green-House Geissser correction applied) showed a main effect of Emotion ( $F_{(2.743; 101.495)} = 23.361$ ;  $p < .001$  ;  $\eta^2_p = .38$ ) and of Group ( $F_{(1,37)} = 39.341$ ;  $p < .001$ ;  $\eta^2_p = .51$ ) and a significant interaction between the factors ( $F_{(2.743; 101.495)} = 3.813$ ;  $p = .015$ ;  $\eta^2_p = .09$ ).

On average, controls recognized emotions with greater accuracy than patients did (M (SD) controls=83 (2.08); M (SD) patients=64.2 (2.12)), driving the Group effect. As expected, the main effect of Emotion was due to a greater accuracy in recognizing happiness compared to all the other emotions (M (SD) happiness=95.4 (2.3); M (SD) anger=67.1 (3.1); M fear=69.1 (2.7); M (SD) sadness=68.8 (3.4); M (SD) disgust=67.6 (2.3)), independently from being a patient or a control.

When exploring the interaction between Group and Emotion (Fig. 2), controls outperformed patients in anger (mean difference=  $15.78$ ,  $p = .016$ ), fear (mean difference=  $24.23$ ,  $p < .001$ ), sadness (mean difference=  $28.94$ ,  $p < .001$ ), and disgust recognition (mean difference=  $21.31$ ,  $p < .001$ ), but not happiness ( $p > .05$ ).

[FIGURE 2]

*Reaction Times*

A main effect of Emotion ( $F_{(2,655; 98,244)} = 8.095$ ;  $p < .001$  ;  $\eta^2_p = .18$ ) and Group ( $F_{(1,37)} = 17.700$ ;  $p < .001$ ;  $\eta^2_p = .32.4$ ) and a significant interaction between these two factors ( $F_{((2,655; 98,244))} = 3.813$ ;  $p = .021$ ;  $\eta^2_p = .08$ ) emerged from the mixed ANOVA (Green-House Geisser correction applied) analysis.

The Group effect was driven by controls being faster in answering than patients (M (SD) controls=2684 (372); M (SD) patients=4929 (382)). As for accuracy, the main effect of Emotion was driven by faster RTS in recognizing happiness compared to all the other emotions (M (SD) happiness=2906 (256); M (SD) anger=3870 (261); M (SD) fear=4178 (266); M (SD) sadness=4028 (279); M (SD) disgust=4049 (450)), independently from the group.

The significant interaction between Group and Emotion (Fig. 3) was explained by a significant difference for patients in recognizing happiness versus anger (mean difference= -1131.7,  $p=.003$ ), fear (mean difference= -1498.1,  $p<.001$ ), sadness (mean difference= -1488,  $p<.001$ ), and disgust (mean difference= -2040.7,  $p=.001$ ). Importantly, no other significant differences between emotions (i.e. disgust compared to fear, anger and sadness) were highlighted in patients ( $p > .05$ ). Differently, controls were faster only in recognizing happiness versus fear (mean difference= -10.465,  $p<.001$ ). When comparing patients and controls for each single emotion, patients resulted slower in recognizing anger (mean difference= -1916.5,  $p=.001$ ), fear (mean difference= -2033.8,  $p=.001$ ), sadness (mean difference= -2313.8,  $p < .001$ ), happiness (mean difference= -1582.2,  $p=.004$ ) and disgust (mean difference= -3376.5,  $p=.001$ ).

[FIGURE 3]

### *Errors pattern*

To understand further the recognition impairments highlighted in PD, we analysed the error pattern (i.e. incorrect responses) of patients at this task (Table 2). The total number of errors in each emotional category identified as impaired from the previous analyses suggest that the amount of errors is not different between categories in patients with PD. As can be seen from Table 2 the percentage of errors is homogeneously distributed in the four emotional categories (happiness is not considered as it was not impaired in patients compared to controls). Patients show an average of 25% errors across all trials (range: 24 to 26).

When looking at the substitution pattern (i.e. type of incorrect identification), our findings show that happiness is rarely chosen incorrectly as target emotion (with a maximum of 7% for anger recognition). On the other hand, disgust and fear are most frequently incorrectly identified as anger (respectively 63% and 43% of the times). Sadness is mostly identified as disgust (41%) and anger as fear (43%). Overall, independently from the target emotion, anger is the most common substitution error, followed by fear and disgust (Table 3).

A repeated measure ANOVA for each correct emotion (with the exclusion of happiness, which was not compromised in patients) with each substitution category (fear, anger, disgust, sadness or happiness, depending on the target emotion) as factor revealed an interesting pattern. Patients substitute disgust with a different frequency ( $F_{(2; 54)} = 31.263$ ;  $p < .001$ ;  $\eta^2_p = .63$ ). Substitution with anger is significantly more frequent than with fear (mean difference = 2.52;  $p < .001$ ), happiness (mean difference = 3;  $p < .001$ ) or sadness (mean difference = 1.94;  $p = .002$ ). Happiness is less frequently substituted than sadness (mean difference = -1.05;  $p = .006$ ). No differences are highlighted between fear and happiness, and fear and sadness (all  $p > .05$ ). Similarly, patients wrongly identify anger with a different frequency of

substitution errors ( $F_{(2; 54)} = 6.768$ ;  $p < .001$ ;  $\eta^2_p = .27$ ). In this case, substitution with fear is significantly more frequent than with happiness (mean difference = 1.68;  $p = .003$ ) and sadness (mean difference = .89;  $p = .019$ ). The same different frequency of substitution errors appeared for sadness ( $F_{(2; 54)} = 6.382$ ;  $p < .001$ ;  $\eta^2_p = .26$ ). For this emotion, though, substitutions with happiness are less frequent than fear (mean difference = 1.52;  $p = .002$ ) and disgust (mean difference = .51;  $p = .013$ ), but no other differences between fear, disgust and anger emerge (all  $p > .05$ ). Finally, when the correct emotion is fear, frequency is significantly distributed ( $F_{(2; 54)} = 7.991$ ;  $p < .001$ ;  $\eta^2_p = .30$ ) with happiness less frequently chosen than anger (mean difference = 1.89;  $p = .001$ ), disgust (mean difference = 2.5;  $p = .002$ ), and sadness (mean difference = 3.1;  $p = .003$ ). Sadness, disgust and anger on the other hand are similarly substituted (all  $p > .05$ ).

[TABLE 2]

[TABLE 3]

### **Association with Clinical Variables - Disgust**

An average rating of all the seven disgust related categories has been calculated for the DRT. The final score is a general disgust rating score not divided by category. The same procedure has been applied to RTS for this task. For the FER task, only disgust recognition (accuracy and RTS) has been taken into account at this stage, given the purpose of this analysis.

L – Dopa drug treatment (criterion: presence/absence of treatment) did not reveal any association with DRT ratings or RTS ( $p > .05$ ). We found a significant positive correlation between *disease duration* and RTS when recognizing facial expressions of disgust ( $r = .701$ ,  $p = .001$ ). No other correlations were found for the facial emotions.

**Association with Disease Duration – Other impaired emotional categories (FER task)**

To explore further the association between disease duration and emotion recognition, we also calculated correlations between this variable, and accuracy and RTS for the other impaired emotional categories (sadness, fear and anger). We found a significant positive correlation between RTS for fear recognition and duration of the disease ( $r = .486$ ,  $p = .035$ ), suggesting longer times to recognize this emotion in patients with a longer disease duration. No other significant correlations have been found ( $p > .05$  all correlations with accuracy and for RTS in both sadness and anger).

**Summary**

In summary, our results show a clear-cut difference in patients with PD when it comes to disgust processing. Visual images and sentences processing of disgust appear intact in these patients, both in terms of ratings and of velocity of processing. On the other hand, patients with PD are impaired in recognizing facial expressions of disgust. Importantly, this impairment in facial expression recognition is not selective for disgust but clearly widespread across all categories, with the exception of happiness. Secondly, the association with clinical features shows that the disease duration is related to the velocity of processing of facial expression of disgust (the longer the time affected by the disease, the longer the time required to recognize faces expressing disgust) and fear, but not of other forms of processing.

**Discussion**

The study of patients affected by Parkinson Disease (PD) is an invaluable source of information to understand disgust processing and its neural basis. Several studies have shown a more or less selective impairment in disgust recognition in PD patients compared to healthy

individuals [11, 14-16]. These results contributed to putting forward the notion that the basal ganglia among others are fundamental for disgust processing [3-6]. Furthermore, the reverse is also true: understanding if disgust processing is impaired in PD might provide valuable cues on how much emotions are affected in this condition and consequently how much attention should be devoted to this during treatments. An impairment in disgust recognition also affects the ability to interact socially and to follow moral and “basic” hygiene rules. For instance, a person might not feel disgusted by spoiled apples or might not take a shower when needed; this information is important in planning caregiving assistance, and to inform the patients themselves.

Studies on PD patients emotional processing have shown impairments of recognition of emotions from prosody, not selective for disgust [28, 29]. Recent work by Wagenbreth et al. adopted a paradigm using the eye region of the face to investigate implicit and explicit processing of emotions, trying to shed light on Theory of Mind impairments in PD [30]. This work has shown that a generally preserved implicit processing, with the specific exception of disgust and happiness, and a clearly impaired processing of explicit information, again specific for disgust portrayed by the eyes, characterize PD. As well as previous studies, the involvement of a disturbed facial processing in PD appears to be the ground for higher emotional deficits that are not apparent when different stimuli are used. These findings, showing a dissociation within formats of stimuli for disgust processing, suggest that PD is not characterized by a general compromising of disgust processing. These dissociations have already been shown for other emotions, such as fear and sadness, between facial displays and music processing [18].

However, most of the studies relied on the use of facial displays of disgust. Despite the importance of faces to communicate our internal feeling of disgust, this emotion is much more complex and is associated to higher cognitive expressions involving domains such



sexual inappropriate acts, death and violation of the ideal body “envelope” or exterior form [1]. As such, disgust can also be explored using linguistic items, such as sentences, and through the presentation of visual images depicting relevant items.

The peculiarity of our study was to explore disgust processing in a sample of patients affected by PD, by means of various tests tackling not only facial recognition but also other formats of stimuli through which disgust can be processed. If PD is characterized by a selective impairment in disgust as previously suggested [11, 14-16], one could expect to find differences between patients and controls on all the tests. On the contrary, our results show that patients with PD process visual images and “linguistic” displays of disgust as controls, both in terms of intensity of rating, velocity of processing and semantic meaning. Despite the integrity of these processes, patients with PD in our study are impaired in recognizing facial displays of disgust and show the most important slowing down for this emotion. Notably however, they are also slower (all emotions) and impaired (with the exception of happiness), compared to controls, in recognizing other categories of facial expressions. Interestingly, the detailed analyses of errors (i.e. the emotion incorrectly chosen instead of the one displayed) committed by patients in the facial emotion recognition task further stress this concept, as the number of errors committed by patients is similar for all target emotions. In other words, the number of errors patients commit when they have to identify disgust is not different from the one when the target emotion is fear, sadness or anger. Furthermore, patients seem to recognize anger more often in facial displays than other emotions. This detailed analysis of errors also highlighted that for disgust the most common incorrect response is anger, and for anger the most common is fear.

Importantly, clinical variables did not appear to be strictly associated with disgust processing, with the only relevant exception of disease duration being associated to faces (disgust and fear only) processing velocity.

One might question if our results from the DS are due to psychometric limits of the scale itself. It has been pointed out that DS subscales (i.e. scores for specific food or animal related disgust) have low reliability [24, 30]. However, this issue does not affect the total score of the DS, which has good reliability and validity [30], with an alpha coefficient of 0.84 [24, 30]. Given the above issues with subscales, we did not interpret scores separately; neither did we have a rationale to expect one or the other domain of disgust sensitivity to be particularly impaired. Considering the points above, and that we were exploring general differences between controls and patients, rather than the subscales to characterize patients only, it is quite unlikely that results are due to psychometric limitations of the DS.

Taken together the results of our own study and of previous research, it appears unlikely that PD compromises disgust processing *per se*. It appears more plausible that, impacting a connection hub to and from the frontal cortex such as the basal ganglia-frontal cortex system [31], PD affects emotional processing at different levels but not necessarily entire emotional categories. One could speculate that different emotional formats of stimuli might be impacted depending on the damage to the network, not necessarily guaranteeing the same impairments in all patients or in all emotional categories. This idea has been put forward for right temporal lobe epilepsy, for instance, showing that disease duration is related to accuracy in recognizing facial displays of emotions [25]. Such an account would explain the discrepant results from the literature [32, 33]. However, even within facial recognition, differences can be found in PD. We have shown that disease duration is related to processing velocity for disgust and fear depicted by faces. On the other hand, the duration of the disease does not relate to accuracy when recognizing facial displays. As such, the hypothesis of a different damage in relation to format of stimuli as the disease progress seems unlikely.

Finally, the involvement of the basal ganglia-frontal cortex system might spare higher cognitive components of emotional processing, related to memory and culture, at least for

disgust when presented with stimuli not linked to processing of faces. Another interesting account that might explain our findings is the difference between identification of emotions and assessment of their intensity. In PD, our and previous findings clearly indicate an issue with identification. From our study, one would be tempted to conclude that intensity is not impaired while identification is in PD. However, previous studies have shown that intensity for facial expressions is also impaired in PD: these patients rate target emotions lower than the healthy controls during facial emotion recognition tasks, for instance [16]. As such, findings from our study rather than suggesting a dichotomy between intensity and identification, points towards a difference in identification and intensity processing of emotions in terms of format of presentation.

Understanding if and how the mechanisms of disgust processing in PD are compromised can inform us about real life related social skills that are fundamental for effective interactions and consequently for a good quality of life. Neurological conditions exist that compromise the understanding of disgust, as it happens in Huntington's disease. These patients rate unpleasant odours as significantly less disgusting than controls [34], leading to real life consequences such as poor hygiene and impaired social interactions. The differences we highlighted between facial, visual and semantic displays of disgust tell us that in PD the situation might be different, and that the impairment in disgust processing might not affect conventional domains. In conclusion, we have shown that disgust is not entirely compromised in PD. In detail, facial displays impairments are not necessarily accompanied by visual stimuli decoding or linguistic processing deficits. Likely, these findings suggest that interpreting the basal ganglia hub as a core area for disgust processing might be too tentative.

**Authors' contribution**

Study conception and design: ASe, SP, & ASt

Study recruitment and testing: SP, MG & ASt

Data analysis and interpretation of the data: ASe & ASt

Manuscript preparation: ASe & ASt

Final draft review and critique: ASe, SP, MG & ASt

**Disclosure**

ASe, SP, MG & ASt confirm that there are no financial or conflicts of interests involved in this study.

**References**

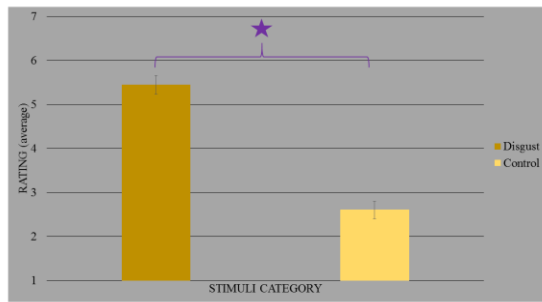
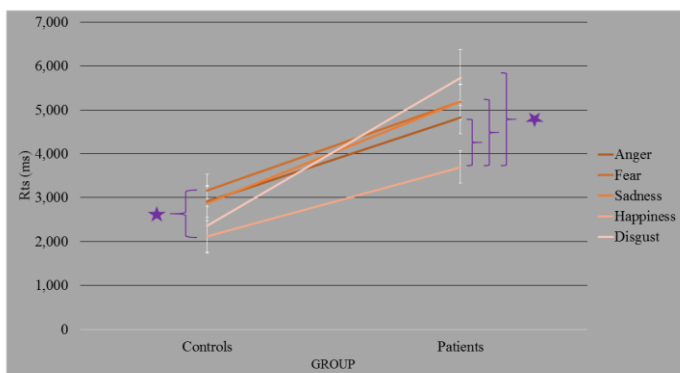
- [1] P. Rozin, J. Haidt, K. Fincher, *Psychology*. From oral to moral, *Science* 323(5918) (2009) 1179-80.
- [2] P. Rozin, A.E. Fallon, A perspective on disgust, *Psychological review* 94(1) (1987) 23-41.
- [3] R. Adolphs, Neural systems for recognizing emotion, *Current opinion in neurobiology* 12(2) (2002) 169-77.
- [4] B. Wicker, C. Keysers, J. Plailly, J.P. Royet, V. Gallese, G. Rizzolatti, Both of us disgusted in My insula: the common neural basis of seeing and feeling disgust, *Neuron* 40(3) (2003) 655-64.
- [5] M. Jabbi, J. Bastiaansen, C. Keysers, A common anterior insula representation of disgust observation, experience and imagination shows divergent functional connectivity pathways, *PloS one* 3(8) (2008) e2939.
- [6] T. Klucken, J. Schweckendiek, G. Koppe, C.J. Merz, S. Kagerer, B. Walter, G. Sammer, D. Vaitl, R. Stark, Neural correlates of disgust- and fear-conditioned responses, *Neuroscience* 201 (2012) 209-18.
- [7] U. Buhlmann, R.J. McNally, N.L. Etcoff, B. Tuschen-Caffier, S. Wilhelm, Emotion recognition deficits in body dysmorphic disorder, *Journal of psychiatric research* 38(2) (2004) 201-6.
- [8] D. McKay, Treating disgust reactions in contamination-based obsessive-compulsive disorder, *Journal of behavior therapy and experimental psychiatry* 37(1) (2006) 53-9.
- [9] A. Sedda, Disorders of emotional processing in amyotrophic lateral sclerosis, *Current opinion in neurology* 27(6) (2014) 659-65.
- [10] R. Sprengelmeyer, M. Rausch, U.T. Eysel, H. Przuntek, Neural structures associated with recognition of facial expressions of basic emotions, *Proceedings. Biological sciences / The Royal Society* 265(1409) (1998) 1927-31.
- [11] F. Assogna, F.E. Pontieri, C. Caltagirone, G. Spalletta, The recognition of facial emotion expressions in Parkinson's disease, *European neuropsychopharmacology : the journal of the European College of Neuropsychopharmacology* 18(11) (2008) 835-48.
- [12] B. Dubois, B. Pillon, Cognitive deficits in Parkinson's disease, *Journal of neurology* 244(1) (1997) 2-8.
- [13] A.M. Owen, Cognitive dysfunction in Parkinson's disease: the role of frontostriatal circuitry, *The Neuroscientist : a review journal bringing neurobiology, neurology and psychiatry* 10(6) (2004) 525-37.
- [14] Y. Kan, M. Kawamura, Y. Hasegawa, S. Mochizuki, K. Nakamura, Recognition of emotion from facial, prosodic and written verbal stimuli in Parkinson's disease, *Cortex; a journal devoted to the study of the nervous system and behavior* 38(4) (2002) 623-30.
- [15] R. Sprengelmeyer, A.W. Young, K. Mahn, U. Schroeder, D. Woitalla, T. Buttner, W. Kuhn, H. Przuntek, Facial expression recognition in people with medicated and unmedicated Parkinson's disease, *Neuropsychologia* 41(8) (2003) 1047-57.
- [16] K. Dujardin, S. Blairy, L. Defebvre, S. Duhem, Y. Noel, U. Hess, A. Destee, Deficits in decoding emotional facial expressions in Parkinson's disease, *Neuropsychologia* 42(2) (2004) 239-50.
- [17] G. Bottini, P. Brugger, A. Sedda, Is the desire for amputation related to disturbed emotion processing? A multiple case study analysis in BIID, *Neurocase* 21(3) (2015) 394-402.
- [18] A. Saenz, A. Doe de Maindreville, A. Henry, S. de Labbey, S. Bakchine, N. Ehrle, Recognition of facial and musical emotions in Parkinson's disease, *European journal of neurology* 20(3) (2013) 571-7.

- [19] A.J. Hughes, S.E. Daniel, L. Kilford, A.J. Lees, Accuracy of clinical diagnosis of idiopathic Parkinson's disease: a clinico-pathological study of 100 cases, *Journal of neurology, neurosurgery, and psychiatry* 55(3) (1992) 181-4.
- [20] M.M. Hoehn, M.D. Yahr, Parkinsonism: onset, progression and mortality, *Neurology* 17(5) (1967) 427-42.
- [21] M.F. Folstein, S.E. Folstein, P.R. McHugh, "Mini-mental state". A practical method for grading the cognitive state of patients for the clinician, *Journal of psychiatric research* 12(3) (1975) 189-98.
- [22] J.A. Yesavage, T. Brink, T.L. Rose, O. Lum, V. Huang, M. Adey, V.O. Leirer, Development and validation of a geriatric depression screening scale: a preliminary report, *Journal of psychiatric research* 17(1) (1983) 37-49.
- [23] J.A. Yesavage, J.I. Sheikh, 9/Geriatric Depression Scale (GDS) recent evidence and development of a shorter violence, *Clinical gerontologist* 5(1-2) (1986) 165-173.
- [24] J. Haidt, C. McCauley, P. Rozin, Individual differences in sensitivity to disgust: A scale sampling seven domains of disgust elicitors. , *Personality and Individual Differences* 16 (1994) 701-713.
- [25] A. Sedda, D. Rivolta, P. Scarpa, M.D. Burt, E. Frigerio, G. Zanardi, A. Piazzini, K. Turner, M.P. Canevini, S. Francione, G. Lorusso, G. Bottini, Ambiguous emotions recognition in temporal lobe epilepsy: the role of expression intensity., *Cognitive, Behavioral and Affective Neuroscience* (2013).
- [26] P. Ekman, W.V. Friesen, *Pictures of Facial Affect*, Consulting Psychologist Press, Palo Alto, 1976.
- [27] S. Mathot, D. Schreij, J. Theeuwes, OpenSesame: an open-source, graphical experiment builder for the social sciences, *Behavior research methods* 44(2) (2012) 314-24.
- [28] S.L. Buxton, L. MacDonald, L.J. Tippett, Impaired recognition of prosody and subtle emotional facial expressions in Parkinson's disease, *Behavioral neuroscience* 127(2) (2013) 193-203.
- [29] L. Albuquerque, M. Martins, M. Coelho, L. Guedes, J.J. Ferreira, M. Rosa, I.P. Martins, Advanced Parkinson disease patients have impairment in prosody processing, *Journal of clinical and experimental neuropsychology* 38(2) (2016) 208-16.
- [30] B.O. Olatunji, D. McKay, *Disgust and its disorders: Theory, assessment, and treatment implications*, American Psychological Association, Washington, DC, 2009.
- [31] R. Levy, B. Dubois, Apathy and the functional anatomy of the prefrontal cortex-basal ganglia circuits, *Cerebral cortex* 16(7) (2006) 916-28.
- [32] M.D. Pell, H.S. Cheang, C.L. Leonard, The impact of Parkinson's disease on vocal-prosodic communication from the perspective of listeners, *Brain and language* 97(2) (2006) 123-34.
- [33] I. Biseul, P. Sauleau, C. Haegelen, P. Trebon, D. Drapier, S. Raoul, S. Drapier, F. Lallement, I. Rivier, Y. Lajat, M. Verin, Fear recognition is impaired by subthalamic nucleus stimulation in Parkinson's disease, *Neuropsychologia* 43(7) (2005) 1054-9.
- [34] I.J. Mitchell, H. Heims, E.A. Neville, H. Rickards, Huntington's disease patients show impaired perception of disgust in the gustatory and olfactory modalities, *The Journal of neuropsychiatry and clinical neurosciences* 17(1) (2005) 119-21.

**Figure 1.** Ratings at the DRT task, control versus disgust categories are presented, averaged for patients and controls. Bars represent standard error of the mean.

**Figure 2.** FER Accuracy in patients and controls (y axis presents percentage of accurate answers). With the exception of happiness, all comparisons are significant (stars indicate significant differences at  $p < .05$ ). Bars represent standard error of the mean.

**Figure 3.** FER RTS in patients and controls (y axis presents velocity of response in milliseconds). In patients, happiness is recognized significantly faster than all other emotions, while controls show a difference only between happiness and fear. Bars represent standard error of the mean.

**Fig.1****Fig.2****Fig.3**



**Tables & Figures legend**

**Table 1.** Demographic and clinical features of patients and controls. Values for age, education, Mini-mental State Examination (MMSE) and Geriatric Depression Scale (GDS) are mean  $\pm$  standard deviation. The other variables indicate the number of participants. Demographic variables and scores at the MMSE and GDS have been compared between patients and controls by means of independent t tests when continuous (age, education, MMSE and GDS score) and by means of Pearson's Chi Square tests when nominal or categorical (gender). None of these comparisons showed any significance, all  $p$ s  $>$  .05), confirming that the two groups are comparable for demographic and baseline variables.

**Table 2.** Overview of errors and type of substitution made by patients in the FER task. The first columns describe the total number of errors in each category. Target emotion indicates the correct answer; error indicates the number of incorrect identifications made by patients. Substitution provides an overview of the type of error made (i.e. the incorrect emotion identified). Total percentage is calculated considering the overall number of errors (i.e. independently from the emotional category). % of substitutions is computed within the emotional category.

**Table 3.** Total types of substitutions for each emotion, computed on all trials independently from the target emotion.

Table 1.

		<i>Patients</i>	<i>Controls</i>	$t/\chi^2$	$p$
Demographic Features	<b>Age</b>	71.8 ( $\pm 7.8$ )	70.1 ( $\pm 5.7$ )	.797	.431
	<b>Education</b>	9.2 ( $\pm 4.4$ )	7.3 ( $\pm 2.6$ )	1.656	.109
	<b>Gender</b>	10 males	10 males	.027	.869
Clinical features	<b>MMSE</b>	27.2 ( $\pm 2.4$ )	27 ( $\pm 1.8$ )	.388	.700
	<b>GDS</b>	5.1 ( $\pm 2.9$ )	3.9 ( $\pm 2.9$ )	1.200	.238
	<b>Depression by GDS &gt; 5</b>		3		
	<b>Disease duration</b>		9 ( $\pm 6.7$ )		
	<b>Hoehn and Yahr scale</b>	$\leq 2$	9		
		<b>3 or 4</b>	10		
	<b>Dopamine agonist treatment</b>		8		
	<b>L-Dopa Treatment</b>		15		
	<b>Mood Treatment</b>		5		
<b>Visual Hallucinations</b>		2			

**Table 2.**

<b>Target Emotion</b>	<b>Total number of Errors</b>	<b>% Errors (Total)</b>	<b>Substitution</b>	<b>Number of Substitutions</b>	<b>% of Substitutions</b>
<i>Disgust</i>	94	26	<i>Fear</i>	11	12
			<i>Happiness</i>	2	2
			<i>Anger</i>	59	63
			<i>Sadness</i>	22	23
<i>Anger</i>	88	24	<i>Fear</i>	38	43
			<i>Happiness</i>	6	7
			<i>Disgust</i>	23	26
			<i>Sadness</i>	21	24
<i>Sadness</i>	94	26	<i>Fear</i>	33	35
			<i>Happiness</i>	4	4
			<i>Disgust</i>	39	41
			<i>Anger</i>	18	19
<i>Fear</i>	87	24	<i>Happiness</i>	1	1
			<i>Anger</i>	37	43
			<i>Disgust</i>	22	25
			<i>Sadness</i>	27	31
<b>Total</b>	<b>363</b>	<b>100</b>			

**Table 3.**

Total substitutions	<b>Number of Substitutions (Total)</b>	<b>% of Substitutions (total)</b>
<i>Fear</i>	82	23
<i>Happiness</i>	13	4
<i>Anger</i>	114	31
<i>Sadness</i>	70	19
Disgust	84	23