Deficits in Emotion Perception and Cognition in Patients with Parkinson’s Disease: A Systematic Review

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Abstract

Non-motor symptoms (NMS) are common among Parkinson’s disease (PD) patients and have a significant impact on quality of life. NMS such as deficits in emotion perception are gaining due focus in the recent times. As emotion perception and cognitive functions share certain common neural substrates, it becomes pertinent to evaluate existing emotion perception deficits in view of underlying cognitive deficits. The current systematic review aimed at examining studies on emotion perception PD in the last decade. We carried out a systematic review of 44 studies from the PubMed database. We reviewed studies examining emotion perception and associated cognitive deficits, especially executive function and visuospatial function in PD. This review also examines how early and advanced PD differ in emotion perception deficits and how the presence of common neuropsychiatric conditions such as anxiety, apathy, and depression as well as neurosurgical procedure such as deep brain stimulation affect emotion perception. The need for future research employing a comprehensive evaluation of neurocognitive functions and emotion perception is underscored as it has a significant bearing on planning holistic intervention strategies.

Keywords: Cognitive deficits, emotion perception, non-motor symptoms, Parkinson’s disease

INTRODUCTION

The cardinal motor symptoms of PD appear due to progressive degeneration of dopaminergic neurons in substantia nigra pars compacta¹⁻⁴ and subsequently extend beyond mesencephalic region to neocortex.⁵ Along with motor symptoms, the NMS such as neuropsychiatric symptoms and cognitive deficits among many emerge and evolve as disease progress.⁶⁻⁷ One of these NMS, emotion perception deficit is gaining its due importance in the recent past.

Emotion and cognition are distinctive yet interdependent mental aspects.⁸ Emotion perception deficits in PD patients may occur secondary to the denervation of dopaminergic pathways of the ventral striatum, subthalamic nucleus, and other basal ganglia regions.⁹ These regions have connections with regions involved in emotional processing, including both subcortical areas like the amygdala, the nucleus accumbens, the hypothalamus, and other cortical regions.¹⁰ Many of these regions, especially territories of pre frontal cortex engage in various cognitive functions, especially executive functions.¹¹ Executive dysfunction in PD patients is related to the dysfunction of the frontostriatal pathways.¹² Other cognitive functions such as attention and working memory¹³ and visuospatial abilities¹⁴ are also affected in PD patients which play a crucial role in emotion perception.¹⁵ Emotion perception deficits might exist in cross-modality that is perceiving emotions through stimuli such as facial, prosody and musical. As many of neural structures involved in emotion perception overlap with each other,¹⁶,¹⁷ These subcortical regions are extensively connected and disruption of these networks might affect emotion perception in both prosodic and musical modalities.¹⁸,¹⁹

OVERVIEW

The present systematic review aimed to examine research carried out on understanding nature of emotion perception deficits in PD. We further examined how emotion perception deficits are related to cognitive deficits in PD as well contribution of disease parameters like duration and severity of illness, mediating role of neuropsychiatric conditions such as depression, anxiety and apathy, role of dopamine replacement therapy (DRT) and common neurosurgical procedure such as subthalamic nucleus deep-brain stimulation (STN-DBS) in advanced PD.

LITERATURE REVIEW: SEARCH STRATEGY AND SELECTION CRITERIA

We carried out a detailed search of literature on PubMed and other sources [refer to Table 1 and Figure 1]. The articles were restricted to English language and published between January 2010 and

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December 2019. The key terms were Parkinson’s disease, emotion, facial expression, emotional prosody and music emotion perception. A total of 44 articles reporting emotion perception and cognitive assessment in PD were selected. Articles related to DBS were also reviewed as they highlight role of this neurosurgical process on emotion perception among PD patients. We collected the following data from the selected articles: Clinical parameters and control group, nature of cognitive assessments carried out, specific/general nature of deficits. [Table 2]

**Facial Emotion Recognition (FER) in PD**

The facial emotion recognition is an essential ability to engage with our complex interpersonal world. The interpretation of emotional experiences from facial expression aids in understanding the intentions and goals of others. This ability to successfully interpret emotions through facial expressions require a complex interplay among brain regions such as amygdala, hypothalamus, mesolimbic, dopaminergic signalling pathways, as well as cortical regions such as prefrontal cortex, and areas of temporal and parietal cortex. The pathophysiological changes in PD such as loss of grey matter in amygdala, orbitofrontal cortex, affected corticostratial connections contribute to impaired emotion perception and might add to difficulty in pragmatic communication refer to Figure 2.

It can be concluded that PD patients have impairment in correctly identifying emotions as represented by facial stimuli. Some of the reviewed studies provide evidence in support of specific emotion perception deficits such as decoding negative emotions. The accuracy to perform on emotion perception tasks is moderated by nature of emotion perception tasks (for example, performance varies on identification task compared to intensity rating task).

The performance on emotion perception was independent of clinical factors such as motor disability or mood disorder.

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**Figure 1:** Flow diagram describing the steps for shortlisting the articles for review

**Table 1: Results of PubMed and other additional research with various combinations**

| Key Words (Filter: Publication in past 10 years) | Articles found (reviewed) |
|-------------------------------------------------|--------------------------|
| Emotion Perception AND Parkinson’s disease       | 174 (44) Reviewed        |
| Facial Emotion/Perception AND Parkinson’s disease| 32                       |
| Prosody Emotion Recognition/Perception AND Parkinson’s disease | 12               |
| Music Emotion Recognition/Perception AND Parkinson’s Disease | 3                |
such as depression. The cognitive performance on executive function and visuospatial tasks do tend to correlate with emotion perception performance.

One of the characteristic motor-symptoms of PD is hypomimia. This reduced emotional expressivity is linked to hypodopaminergic state results to hypokinesia and bradykinesia of facial muscles.[22] As a result PD patients perceived to be “cold” or “unhappy”.[23] It has been found that this reduced facial expression is related to impaired facial emotion perception in PD patients.[24] It is proven in healthy controls where observing and imitating facial emotion expression lead to activation in premotor areas, as well as superior temporal cortex, insula and amygdala.[25] Since facial mimicry aids in recognition of emotions.[26] The embodied simulation theory brings these components together and argue that impairment in facial emotion perception could be related to deficits in emotion expressivity and hypomimia.[27]

The other factor is status of DRT (ON vs OFF state) while performing the emotion perception task. For example, in early course of illness, dopaminergic treatment improves motor symptoms though at same time hyperdopaminergic state of mesolimbic regions can impair effective emotion recognition however this effect becomes beneficial in later course of illness.[28] Though only a few studies have conducted with cross-over design to assess PD patients under ON and OFF medication state[29] accuracy improves after administration of DRT as it activates default mode network.[30] Role of STN-DBS is not widely studied where few studies report STN-DBS does not affect emotion recognition performance[31-33] while other reports a contrary finding.[34]

In conclusion, facial emotion recognition studies found that mild to moderate PD individuals appear to have deficits in perception of negative emotions while advanced PD patients report of broad emotion perception deficits. These deficits were related to cognitive performance while mostly independent of disease severity.

**Emotion Recognition through Prosody (PER) in PD**

The effective processing of emotional prosody allows people to convey and understand varied range of emotions. However, question about how pwPD process emotional signals through

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**Figure 2:** Neural systems associated with emotion perception and role of Parkinson’s disease pathophysiology. The above figure mention processes and neural systems involved in emotional processing (in grey boxes) and pathophysiological changes (in blue boxes) associated with PD which affect process of emotion perception. Abbreviations: ACC-Anterior cingulate cortex; BG- Basal ganglia; FFA- Fusiform Face Area; GM- Grey matter; IOG- Inferior Occipital Gyrus; OFC-orbitofrontal cortex; PFC- Pre frontal cortex; PT-Pulvinar thalamus; STG- Superior Temporal gyrus.
### Table 2: Master Chart- overview of findings reported in scientific literature about Emotional processing in Parkinson’s disease

| Authors | Disease duration (Mean ± SD) years | DRT when assessed (ON/OFF) | Emotion Perception Task | Cognitive Assessment (+/-) | Mood Assessment (+/-) | Findings Deficit emotion (+) |
|---------|-----------------------------------|-----------------------------|-------------------------|---------------------------|-----------------------|-------------------------------|
| Assogna et al., (2010)[43] | 4.9±4.2 | ON | ID | + | + | Disgust (+) |
| Cohen et al., (2010)[44] | 4.79 (2.85) | ON | ID | + | - | Nil |
| Martinez-Corrales et al., (2010)[45] | DOI=4.83±2.95 PD -non apathy DOI=7.26±4.26 | ON | ID | + | + | Fear (+) |
| van Tricht et al., (2010)[46] | 11.9±4.6 | ON | ID | + | + | Fear (+) |
| Delaveau et al., (2010)[50] | 11.4±4.4 | ON and OFF | Matching | + | + | Anger (+) No impairment |
| Péron et al., (2010)[37] | 11±3.6 | ON | ID | + | + | STN-DBS modifies |
| Vicente et al., (2011)[47] | Early PD | ON and OFF | ID | + | + | Emotion perception No impairment |
| Herrera et al., (2011)[48] | 2.48±1.41 Advanced PD | 11.55±3.36 | ON | ID | + | + | General deficits |
| Narme et al., (2011)[49] | 9.8±3.7 | ON | ID | + | + | Anger (+) |
| Brück et al., (2011)[50] | 15±6 | STN-DBS -ON and OFF | ID | - | + | No effect of DBS ON/OFF |
| García-Rodríguez et al., (2012)[53] | H&Y stage range I-II | LD naive | ID | - | + | General deficits |
| Garrido-Vásquez et al., (2013)[52] | LPD H&Y stage=2.1(51) RPD H&Y stage=2.33(77) | ON | ID | + | + | No impairment |
| Ventura et al., (2012)[53] | H&Y stage-II | ON | ID | + | - | Sadness (+) |
| Baggio et al., (2012)[54] | 5.67±3.8 | ON | ID | + | + | Fear (+) |
| Dietz et al., (2013)[55] | 6.6±4.3 | ON | ID | - | + | unpleasant processing (+) |
| Lima et al., (2013)[56] | 8.3±4.9, | ON | ID | + | + | Happiness (+) |
| Saenz et al., (2013)[57] | 8.58±5.27 | ON | ID | + | + | Fear (+) |
| Buxton et al., (2013)[58] | 6.68±5.46 | ON | ID | + | - | Sadness (+) Disgust (+) |
| Mermillod et al., (2014)[51] | 12.36±0.71 | STN-DBS ON and OFF DRT ON and OFF | ID | + | + | DRT and STN-DBS has no impact. |
| Alonso-Recio et al., (2014)[59] | 6.57±4.01 | ON | ID and Discri. | + | + | Overall Negative |

*Contd...*
### Table 2: Contd...

| Authors                  | Disease duration (Mean±SD) years | DRT when assessed (ON/OFF) | Emotion Perception Task | Cognitive Assessment (+/-) | Mood Assessment (+/-) | Findings | Deficit emotion (+) |
|--------------------------|----------------------------------|----------------------------|-------------------------|---------------------------|-----------------------|----------|---------------------|
| Aiello et al., (2014)[34] | 10.9 (4.0)                       | DRT (On/Off) STN DBS stimulation (On/Off) | ID and Discri. | + | + | Emotions | DBS reduces |
| Albuquerque et al., (2014)[32] | 15.85±7.02 | ON | ID | + | - | Discrimination. Performance | No significant |
| Péron et al., (2014)[38] | Early PD-2.8±1.2 | ON and OFF | ID | + | - | Decline after STN-DBS. | General deficits |
| Robert et al., (2014)[60]  | 11.6±4.03; Advanced PD-11.1±3.4 | ON | ID | + | + | General deficits |
| Wabnegger et al., (2015)[61] | 6.28±3.64 | OFF | Intensity | - | + | No impairment |
| Schienle et al., (2015)[62] | 6.28±3.64 | OFF | ID | - | + | No impairment |
| Ille et al., (2015)[63]   | 6±3 | OFF | ID | + | + | No impairment |
| McIntosh et al., (2015)[64] | H&Y stage till 2.0 | ON and OFF | ID | - | - | No differential effects of DRT or STN-DBS on emotion recognition |
| Lin et al., (2016)[65]     | H&Y stage- 2.84 | OFF | Discr. | _ | + | General deficits |
| Albuquerque et al., (2016)[66] | 14.6±6.0 | ON | Discr. | + | | No impairment |
| Pietschnig et al., (2016)[67] | range 0.25-19.00 | ON | ID | + | + | General deficits |
| Bologna et al., (2016)[68] | 5.9 (2.3) | ON | ID | - | - | Disgust (+) | |
| Jin et al., (2017)[69]     | 7.93±2.3 | ON | ID | + | + | General deficits |
| Kalampokini et al., (2017)[70] | 9 | ON | ID | + | + | Surprise (+) |
| de Risi et al., (2017)[71] | 6.7±2.6 | ON | ID | + | + | Sadness (+) |
| Sedda et al., (2017)[72]   | 9±6.7 | ON | ID | - | + | Anger (+) |
| Ricciardi et al., (2017)[24] | 7.3±4.1 | ON | ID | - | + | General deficits |
| Enrici et al., (2017)[73]  | 12.56±3.03 | ON | ID | + | + | No impairment |
| Moonen et al., (2017)[73]  | 5.3±3.9 | ON | ID | + | + | No impairment |
| Pohl et al., (2017)[74]    | 5.94±4.39 | ON | ID | + | - | General deficits |
| Bell et al., (2017)[75]    | 7.3±2.2 | ON | fMRI task | + | + | No Impairment |
| Stirnimann et al., (2018)[76] | Left-side PD | ON | Discr. | _ | | General deficits |
|                         | 12.85±6.13 | | | | | |

*Contd...*
prosody has not been investigated in much detail. The evidence gathered from event-related potential (ERP) and neuroimaging studies suggest that not just cortical brain areas, but subcortical areas such as basal ganglia which engage in sequencing auditory affective information are crucial in emotion recognition through prosody \(^{[45]}\) and impairments of these areas provide a model to understand emotion recognition through prosody.

General (non-specific) recognition of prosody deficits has been reported in both mild to moderately PD and advanced PD others reported specific prosody deficits in fear, anger, disgust. In pwPD, deficits in recognizing emotions through prosody are related to executive function.

Effect of DRT is not studied extensively, report suggested that DRT tends to improve performance on prosody emotion perception in advanced PD.\(^{[28]}\) However, in early PD the administration of DRT negatively influence prosody emotion perception in comparison to OFF state\(^{[28]}\) possibly due to dopamine overdose in mesocorticolimbic pathway\(^{[36]}\) which is still intact in early PD.

Only a handful of studies have evaluated the effect of DBS on PER. Some reported alteration in PER for pwPD who underwent STN-DBS,\(^{[37]}\) while other studies found no alteration in identifying emotions.\(^{[35]}\) To summarise, most of reviewed studies report intact positive emotion perception thorough prosody while more studies reported deficits in negative emotion recognition through prosody.

**Emotion Recognition through Music (MER) in PD**

Musical emotion perception among PD patients is a relatively a new area of research. Music is capable of inducing strong emotions with both positive and negative emotional valence. Music activates brain region such as which overlap with processing linguistic stimuli.\(^{[38]}\) Music can induce wide range of emotions which mediated by brain structures such amygdala and insula that is implicated in encoding many other kinds of emotional stimuli.\(^{[39]}\) Some common neural regions between music processing and the affected regions in PD, such as orbitofrontal cortex\(^{[40]}\) as well mesolimbic reward circuitry\(^{[41]}\) are worth studying.

To summarise, the findings remain inconclusive in terms of presence or absence of emotion perception deficits through musical stimuli and require further evaluation to conclude.

**Discussion**

Emotion perception deficits as a crucial NMS has gained significant research interest. Emotion perception deficits have debilitating effect on overall functioning in PD patients. In this systematic review, we found three main approaches taken to study emotion perception in PD namely facial, prosody and musical emotions. These three modalities are mediated by overlapping and distinct neural pathways.\(^{[15,41]}\) The existing studies have predominantly assessed facial emotion and findings are suggestive of impaired facial emotion recognition in PD. This trend is not so strong in emotion recognition through prosody and inconclusive for emotion perception through musical stimuli. For facial emotion recognition, the overall identification of negative emotions is affected in PD which is partially related to cognitive functions such as executive functions though this trend is not significant in other studies. Neuroimaging studies do corroborate the claim of impairment in identifying negative emotion is probably due to dysfunction in frontostriatal pathways and mesolimbic regions as well as dysfunction of striatum, amygdala, basal ganglia and related dopaminergic pathways.

Findings in emotion recognition through prosody report general rather specific emotion perception deficits. However, the relation between emotion recognition and cognitive functions are not very clear.

Findings in emotion recognition thorough musical stimuli is a recent trend in PD research. There are only handful of studies that report contradictory results on emotion recognition. The
relation of emotion recognition through music and cognitive functions is also not clear.

Several confounding variables can explain the mixed results more so in prosody and music emotion recognition. For example, task used for the assessment, emotions displayed. The other factors such as clinical parameters, cognitive deficits, medication status, presence of co-morbid mood conditions such as depression, apathy, anxiety may influence the findings. For example, only few studies have controlled for cognitive deficits or mood disturbances.

Future studies can probe further into emotion perception through multi-modal emotion stimuli, which provide crucial outlook on how subcortical and in advanced stage, neocortex has been affected in PD. Future work may examine the effect of DRT on emotion perception. Role of DBS which improves complications of motor symptoms also require extensive examination. Thus, a well-controlled study is desirable to study emotion perception in PD patients.

PD patients often report social interaction problem and being misunderstood by others as one of the important factors adversely affecting their quality of life. The relevance to understand psychological aspects of PD, providing indications on how to provide support to PD patients who have emotion perception deficits.

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References
1. Ouchi Y, Yoshikawa E, Okada H, Futatsubashi M, Sekine Y, Iyo M, et al. Alterations in binding site density of dopamine transporter in the striatum, orbitofrontal cortex, and amygdala in early Parkinson’s disease: Compartment analysis for beta-CFT binding with positron emission tomography. Ann Neurol 1999;45:601-10.
2. Yoshimura N, Kawamura M, Masaoka Y, Homma I. The amygdala of patients with Parkinson’s disease is silent in response to fearful facial expressions. Neuroscience 2005;131:523-34.
3. Ichihara-Tibbals N, Junque C, Tolosa E, Marti MJ, Valdecoria F, Bargallo N, et al. Neuroanatomical correlates of impaired decision-making and facial emotion recognition in early Parkinson’s disease. Eur J Neurosci 2009;30:1162-71.
4. Hughes AJ, Daniel SE, Ben-Shlomo Y, Lees AJ. The accuracy of parkinsonian syndromes in a specialist movement disorder service. Brain 2002;125:861-70.
5. Braak H, Ghebremedhin E, Rüb U, Bratza H, Del Tredici K. Stages in the development of Parkinson’s disease-related pathology. Cell Tissue Res 2004;318:121-34.
6. Burke RE, Dauer WT, Vonsattel JP. A critical evaluation of the Braak staging scheme for Parkinson’s disease. Ann Neurol 2008;64:485-91.
7. Raj NK, Goyal V, Kumar N, Shukla G, Srivastava AK, Singh S, et al. Neuropsychiatric co-morbidities in non-demented Parkinson’s disease. Ann Indian Acad Neurol 2015;18:33-8.
8. Ekman PE, Davidson RJ. The Nature of Emotion: Fundamental Questions. Oxford University Press; 1994.
9. Moore RY. Organization of midbrain dopamine systems and the pathophysiology of Parkinson’s disease. Parkinsonism Relat Disord 2003;9(Suppl 2):S65-71.
10. Pessoa L. On the relationship between emotion and cognition. Nat Rev Neurosci 2008;9:148-58.
11. Smith EE, Jonides J. Storage and executive processes in the frontal lobes. Science 1999;283:1657-61.
12. Owen AM. Cognitive dysfunction in Parkinson’s disease: The role of frontostriatal circuitry. Neuroscientist 2004;10:525-37.
13. Owen AM, Iddon JL, Hodges JR, Summers BA, Robbins TW. Spatial and non-spatial working memory at different stages of Parkinson’s disease. Neuropsychologia 1997;35:519-32.
14. Pereira JB, Junque C, Marti MJ, Ramirez-Ruiz B, Bargallo N, Tolosa E. Neuroanatomical substrate of visuospatial and visuoperceptual impairment in Parkinson’s disease. Mov Disord 2009;24:1193-9.
15. Phillips ML, Drevets WC, Rauch SL, Lane R. Neurobiology of emotion perception I: The neural basis of normal emotion perception. Biol Psychiatry 2003;54:504-14.
16. Blood AJ, Zatorre RJ. Intensely pleasurable responses to music correlate with activity in brain regions implicated in reward and emotion. Proc Natl Acad Sci U S A 2004;101:8418-23.
17. Koelsch S. Brain correlates of music-evoked emotions. Nat Rev Neurosci 2014;15:170-80.
18. Meyer M, Steinhauer K, Alter K, Friederici AD, von Cramon DY. Brain activity varies with modulation of dynamic pitch variance in sentence melody. Brain Lang 2004;89:277-89.
19. Paulmann S, Pell MD, Kotz SA. Functional contributions of the basal ganglia to emotional prosody: Evidence from ERPs. Brain Res 2008;1217:171-8.
20. Niedenthal PM, Brauer M. Social functionality of human emotion. Annu Rev Psychol 2012;63:259-85.
21. Hill D, Ouyang B, Lonquiat E, Newcombe J. Pragmatic communication is impaired in Parkinson disease. Int J Neurosci 2011;121:254-6.
22. Bologna M, Fabbrini G, Marsili L, Defazio G, Thompson PD, Berardelli A. Facial bradykinesia. J Neurol Neurosurg Psychiatry 2013;84:681-5.
23. Tickle-Degnen L, Lyons KD. Practitioners’ impressions of patients with Parkinson’s disease: The social ecology of the expressive mask. Soc Sci Med 2004;58:603-14.
24. Ricciardi L, Visco-Comandini F, Erro R, Morgante F, Bologn A, Faiano A, et al. Facial emotion recognition and expression in Parkinson’s disease: An emotional mirror mechanism? PLoS One 2017;12:e0169110.
25. Carr L, Iacoboni M, Dubeau M-C, Mazzotta JC, Lenzi GL. Neural mechanisms of empathy in humans: A relay from neural systems for imitation to limbic areas. Proc Natl Acad Sci U S A 2004;101:5047-502.
26. Goldman AI, Sripada CS. Simulation models of face-based emotion recognition. Cognition 2005;94:193-213.
27. Argaud S, Vérin M, Sauleau P, Grandjean D. Facial emotion recognition in Parkinson’s disease: A review and new hypotheses. Mov Disord 2018;33:554-67.
28. Péron J, Grandjean D, Draper S, Vérin M. Effect of dopamine therapy on nonverbal affect burst recognition in Parkinson’s disease. PLoS One 2014;9:e90092.
29. Sprengelmeyer R, Young A, Mahn K, Schroeder U, Woiwoda D, Bütter T, et al. Facial expression recognition in people with medicated and unmedicated Parkinson’s disease. Neuropsychologia 2003;41:1047-57.
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31. Mermillod M, Mondillon I, Rieu I, Devaux D, Chambres P, Auxette C, et al. Dopamine replacement therapy and deep brain stimulation of the subthalamic nucleus induce modulation of emotional processes at different spatial frequencies in Parkinson’s disease. J Parkinsons Dis 2014;4:97-110.

32. Albuquerque L, Coelho M, Martins M, Guedes LC, Rosa MM, Ferreira JJ, et al. STN-DBS does not change emotion recognition in advanced Parkinson’s disease. Parkinsonism Relat Disord 2014;20:166-9.

33. Enrici I, Mitkova A, Castelli L, Lanotte M, Lopiano L, Adenzato M. Deep brain stimulation of the subthalamic nucleus does not negatively affect social cognitive abilities of patients with Parkinson’s disease. Sci Rep 2017;7:9413.

34. Aiello M, Eleopra R, Lettieri C, Mondani M, D’Auria S, Belgrado E, et al. Emotion recognition in Parkinson’s disease after subthalamic deep brain stimulation: Differential effects of microlesion and STN stimulation. Cortex 2014;51:35-45.

35. Pell MD, Cheang HS, Leonard CL. The impact of Parkinson’s disease on vocal-prosodic communication from the perspective of listeners. Brain Lang 2006;97:123-34.

36. Swainson R, Rodgers R, Sahakian B, Summers B, Polkey C, Robbins T. Probabilistic learning and reversal deficits in patients with Parkinson’s disease or frontal or temporal lobe lesions: Possible adverse effects of dopaminergic medication. Neuropsychologia 2000;38:596-612.

37. Péron J, Grandjean D, Le Jeune F, Sauleau P, Haegele C, Drapier D, et al. Recognition of emotional prosody is altered after subthalamic nucleus deep brain stimulation in Parkinson’s disease. Neuropsychologia 2010;48:1053-62.

38. Wildgruber D, Ackermann H, Kreifelts B, Ethofer T. Cerebral processing of linguistic and emotional prosody: fMRI studies. Prog Brain Res 2006;156:249-68.

39. Adolphs R, Tranel D, Damasio H, Damasio A. Impaired recognition of emotion in facial expressions following bilateral damage to the human amygdala. Nature 1994;372:669-72.

40. Menon V, Levitin DJ. The rewards of music listening: Response and physiological connectivity of the mesolimbic system. Neuroimage 2005;28:175-84.

41. Salimpoor VN, Benovoy M, Larcher K, Dagher A, Zatorre RJ. Anatomically distinct dopamine release during anticipation and experience of peak emotion to music. Nat Neurosci 2011;14:257-67.

42. Behari M, Srivastava AK, Pandey R. Quality of life in patients with Parkinson’s disease. Parkinsonism Relat Disord 2005;11:221-6.

43. Assogna F, Pontieri FE, Cravello L, Peppe A, Pierantozzi M, et al. Selective attention and facial emotion recognition and expression in patients with Parkinson’s disease. Arch Clin Neuropsychol 2014;29:374-84.

44. Robert G, Le Jeune F, Dondaine T, Drapier S, Péron J, Lozarneau C, et al. Apathy and impaired emotional facial recognition networks overlapped in Parkinson’s disease: A PET study with conjunction analyses. J Neurol Neurosurg Psychiatry 2014;85:1153-8.

45. Wabnegger A, Ille R, Schwingensuh P, Katschnig-Winter P, Kögl-Wallner M, Wenzel K, et al. Facial emotion recognition in Parkinson’s disease: An fMRI investigation. PLoS One 2015;10:e0136110.

46. Schienle A, Ille R, Wabnegger A. Experience of negative emotions in Parkinson’s disease: An fMRI investigation. Neurosci Lett 2015;609:142-6.

47. Wabnegger A, Schwingensuh P, Katschnig-Winter P, Kögl-Wallner M, Wenzel K, et al. Intact emotion recognition and experience but dysfunctional emotion regulation in idiopathic Parkinson’s disease. J Neurol Sci 2016;361:72-8.

48. Mcintosh LG, Mannava S, Carnalier CR, Folley BS, Albritton A, Konrad PE, et al. Emotion recognition in early Parkinson’s disease patients undergoing deep brain stimulation or dopaminergic therapy: A comparison to healthy participants. Front Aging Neurosci 2015;6:549.

49. Lin C-Y, Tien Y-M, Huang J-T, Tsai C-H, Hsu L-C. Degraded impairment of emotion recognition in Parkinson’s disease extends from negative to positive emotions. 2016;2016, Article ID 9287092. https://doi.org/10.1155/2016/9287092.

50. Albuquerque L, Martins M, Coelho M, Guedes L, Ferreira JJ, Rosa M, et al. Advanced Parkinson disease patients have impairment in prosody processing. J Clin Exp Neuropsychol 2016;38:208-16.

51. Pietschnig J, Schröder L, Ratheiser I, Kryspin-Exner I, Pflüger M, Moser D, et al. Facial emotion recognition and its relationship to cognitive and depressive symptoms in patients with Parkinson’s disease. Int Psychogeriatr 2016;28:1165-79.

52. Bologna M, Berardelli I, Paparella G, Marsili L, Carnalier CR, Folley BS, Albritton A, Konrad PE, et al. Emotion recognition in early Parkinson’s disease patients undergoing deep brain stimulation or dopaminergic therapy. A comparison to healthy participants. Front Aging Neurosci 2015;6:549.

53. Lin C-Y, Tien Y-M, Huang J-T, Tsai C-H, Hsu L-C. Degraded impairment of emotion recognition in Parkinson’s disease extends from negative to positive emotions. 2016;2016, Article ID 9287092. https://doi.org/10.1155/2016/9287092.

54. Albuquerque L, Martins M, Coelho M, Guedes L, Ferreira JJ, Rosa M, et al. Advanced Parkinson disease patients have impairment in prosody processing. J Clin Exp Neuropsychol 2016;38:208-16.

55. Pietschnig J, Schröder L, Ratheiser I, Kryspin-Exner I, Pflüger M, Moser D, et al. Facial emotion recognition and its relationship to cognitive and depressive symptoms in patients with Parkinson’s disease. Int Psychogeriatr 2016;28:1165-79.

56. Bologna M, Berardelli I, Paparella G, Marsili L, Ricciardi L, Fabbriini G, et al. Altered kinematics of facial emotion expression and emotion recognition deficits are unrelated in Parkinson’s disease. Front Neurol 2016;7:230.

57. Perez R, Zuo Z, Xu Z, Zhang Y, Yu X. Altered emotional recognition and expression in patients with Parkinson’s disease. Neuropsychiatrie Dis Treat 2017;13:2891-902.

58. Kalampokini S, Lyros E, Luley M, Schöpe J, Spiegel J, Bürmann J, et al. Facial emotion recognition in Parkinson’s disease: Association with age and olfaction. J Clin Exp Neuropsychol 2018;40:274-84.

59. D’Aniello A, et al. Facial emotion decoding in patients with Parkinson’s disease. J Neurol Sci 2018;128:71-8.

60. Aydogan F, Paparella G, Marsili L, Ricciardi L, Fabbriini G, et al. Altered kinematics of facial emotion expression and emotion recognition deficits in Parkinson’s disease. Neurology 2018;90:1460-9.

61. Caliskan D, Caliskan M, Yildirim A, Aydogan F, Paparella G, Marsili L, et al. Altered kinematics of facial emotion expression and emotion recognition deficits in Parkinson’s disease. Neurology 2018;90:1460-9.

62. Sedda A, Petito S, Guarino M, Stracciai A. Identification and intensity...
of disgust: Distinguishing visual, linguistic and facial expressions processing in Parkinson disease. Behav Brain Res 2017;330:30-6.
73. Moonen AJ, Wijers A, Dujardin K, Leentjens AF. Neurobiological correlates of emotional processing in Parkinson’s disease: A systematic review of experimental studies. J Psychosom Res 2017;100:65-76.
74. Pohl A, Anders S, Chen H, Patel HJ, Heller J, Reetz K, et al. Impaired emotional mirroring in Parkinson’s disease-A study on brain activation during processing of facial expressions. Front Neurol 2017;8:682.
75. Bell PT, Gilat M, Shine JM, McMahon KL, Lewis SJ, Copland DA. Neural correlates of emotional valence processing in Parkinson’s disease: Dysfunction in the subcortex. Brain Imaging Behav 2019;13:189-99.
76. Stirnimann N, N'Diaye K, Le Jeune F, Houvenaghel J-F, Robert G, Drapier S, et al. Hemispheric specialization of the basal ganglia during vocal emotion decoding: Evidence from asymmetric Parkinson’s disease and 18FDG PET. Neuropsychologia 2018;119:1-11.
77. Palmeri R, Buono VL, Bonanno L, Allone C, Drago N, Sorbera C, et al. Impaired recognition of facial emotion in patients with parkinson disease under dopamine therapy. J Geriatr Psychiatry Neurol 2020;33:265-71.
78. Saffarian A, Shavaki YA, Shahidi GA, Jafari Z. Effect of parkinson disease on emotion perception using the Persian affective voices test. J Voice 2019;33:580.e1-9.