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ORIGINAL COMMUNICATION

Cognitive status of patients with Parkinson's disease and pathological gambling

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Abstract The cognitive status of patients with Parkinson's disease (PD) who developed pathological gambling (PG) during dopamine replacement therapy has been poorly explored. We compared clinical and cognitive features of 21 consecutive PD patients with active PG (PD–PG) versus 42 PD controls of similar disease duration without any impulse control disorder. All patients underwent full neuropsychological testing to evaluate executive and other frontal lobe-related functions, attention, learning and memory, language, visuospatial abilities and neuropsychiatric status [using Geriatric Depression Scale (GDS) and Neuropsychiatric Inventory (NPI)] as well as the South Oaks Gambling Screen Scale (SOGS). PD–PG were younger (60.4 vs. 64.9, $p = 0.01$) and more frequently of male gender (85 vs. 57%, $p = 0.02$). The two groups did not differ in medication dosages and kind of dopamine agonist. PD–PG had higher MMSE (29.1 vs. 27.4, $p = 0.02$) and performed better at Rey Auditory Verbal learning Test (45.9 vs. 40.4, $p = 0.04$), verbal phonemic fluencies (38.7 vs. 31.8, $p = 0.02$), verbal semantic fluencies (44.9 vs. 37.4, $p = 0.01$) and attentive matrices (47.6 vs. 43.5, $p = 0.05$) while the remaining cognitive performances were comparable to controls. Moreover, based on the NPI, PD–PG had higher aggressiveness, irritability, disinhibition and eating disorders than controls. In conclusion the occurrence of PG in our cohort of patients with PD was associated with preserved executive functions.

Keywords Parkinson's disease · Pathological gambling · Cognitive functions · Impulse control disorders

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Introduction

Impulse control disorders (ICDs) and particularly pathological gambling (PG) have recently surged to clinical relevance as a complication of dopamine replacement therapy (DRT) in Parkinson's disease (PD) [1]. PG has 4–7% prevalence in PD and may cause large financial losses and severe distress for patients and their family [2–4]. PG is defined in the Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition, Text Revision (DSM-IV-TR) [5] as failure to resist the urge to gamble, with persistent and maladaptive behavior despite disruptive consequences on familial, occupational and social functions.

Specific risk factors for the development of PG are male gender, young age at onset, high impulsivity and novelty seeking personality traits, previous personal or family history of gambling problems, alcohol and/or substance abuse [1, 2, 6–10] but only a recent study [11] extensively investigated cognition in patients with PD who developed PG while on DRT. In this latter study, Santangelo and colleagues compared a cohort of 15 non-demented PD patients with PG with 15 matched PD patients without PG and found a significant association between frontal lobe dysfunctions and PG. We recently described resting state brain perfusion imaging in 11 patients with PD and active PG and additionally reported preserved global and frontal lobe cognitive features, though a

comprehensively description of their cognitive profile was beyond the aims of that paper [12]. The aim of the present study is to investigate demographic, clinical characteristics and cognitive functions in a large sample of PD patients with active PG and to use a full neuropsychological battery to extensively characterize their cognitive profile in comparison to matched PD controls.

Methods

We included consecutive outpatients with diagnosis of Parkinson's disease (according to the UK Brain Bank clinical diagnostic criteria [13, 14]) who attended the outpatient clinica at Parkinson Institute, Istituti Clinici di Perfezionamento, Milan, Italy during the years 2007–2008. Patients and their caregivers were interviewed about gambling and other ICDs during routine neurological examination and, in case of gambling were further assessed by an experienced neuropsychologist (C.S. or D.D.G.) who performed clinical interview and cognitive testing. Diagnosis of PG and other ICDs was established according to Diagnostic and Statistical Manual of Mental Disorders criteria (Fourth Edition, Text Revision, [5]) and those reported by Voon and Fox for ICDs not included in DSM IV [6]. We only considered in this study patients who had scores >5 at the South Oaks Gambling Screen (SOGS) [15, 16].

Twenty-one consecutive PD outpatients with active PG (PD–PG group) were identified and all agreed to clinical and cognitive testing. Five patients were included in our previous study on neuroimaging and PG [12]. The control group consisted of 42 PD patients (PD–CNTR group) selected to match for disease duration and without any history of current or previous ICD [5, 6]. None of the PD–PG and PD–CNTR patients had deep brain stimulation surgery.

Clinical evaluation included the Hoehn and Yahr (HY) stage and Unified Parkinson's Disease Rating Scale motor score (UPDRS III) assessed in the morning on-medication. All patients were on stable doses of DRT during the previous 6 months. Individual daily medication was recorded and total dose (total LEDD) was calculated as the sum of the levodopa and dopamine agonists converted into levodopa-equivalent daily dose (LEDD) as reported elsewhere [12].

Information on clinical variables (age at onset, disease duration, side of symptoms' onset) and on PG related features (previous or familial history of PG, monthly mean loss, PG duration, type of gambling) were collected.

All PD patients were always tested in the morning during their "medication-on" condition. Neuropsychological assessment was performed as follows. General cognitive abilities were evaluated by the mini-mental state examination (MMSE, [17]); the assessment of executive functions was performed with verbal fluencies, using both phonemic (letters F, P, and L) and category cues (animal, fruits, and cars) [18, 19], Raven's Coloured Progressive Matrices Sets (CPM_Raven [20]) and the Frontal Assessment Battery (FAB, [22, 23]); evaluation of visuospatial and verbal short term memory was conducted using Corsi Block Tapping Test [21] and Digit Span Test [24] respectively; verbal learning and long term memory were assessed using Rey Auditory Verbal Learning test (RAV-LT, [25]) and attention with attentive matrices [26]; 30-points Geriatric depression scale (GDS, [27]) was used to rate depressive symptoms.

Finally, we used the Neuropsychiatric Inventory (NPI) to assess behavioural disturbances: this is a questionnaire that is commonly used in patients with dementia [28] where information is obtained from a caregiver familiar with the patient's behaviour.

Testing scores were adjusted by age and education according to normative data. Total testing scores corrected, and dichotomous (normal-pathological, according to established cut-off values) variables were calculated.

Informed consent was obtained from each participant according to the Declaration of Helsinki. The study was approved by our institution Ethic committee.

Statistical analysis

Comparisons between continuous variables in the PD–PG ad PD–CNTR, were performed using the unpaired t test ($p < 0.05$), while the χ^2 test was used for categorical variables ($p < 0.05$). Statistical analysis was performed using the software program SPSS (Windows Release 10.0; SPSS Inc, Chicago, IL, USA).

Results

Demographic and clinical features of PD–PG patients and PD–CNTR are detailed in Table 1. PD–PG patients were younger than PD–CNTR (60.4 vs. 64.9 years, $p < 0.05$) and prominent males (86 vs. 57%, $p < 0.05$). We did not find any other difference between groups in clinical variables, including total LEDD and frequency of dopamine agonist used (Table 1). The SOGS in PD–PG ranged 6–15 (mean 8.25 ± 2.81). 13/21 PG patients (61.9%) presented other ICDs, including hypersexuality ($n = 6$), internet addiction ($n = 1$), compulsive eating ($n = 4$), compulsive shopping ($n = 5$) (Table 1).

Nine PD–PG patients had occasional non-problematic gambling behavior before PD onset (card playing, occasional Casino, Lotto or scratch cards playing); two patients had familial history of PG. After PG onset the mean loss per month in this cohort was about 2,500 Euros (range 500–8000) and frequency of gambling behavior was about

Table 1 Comparison of clinical characteristics

	Mean (SD)		p^*
	PD–PG	PD–CNTR	
N	21	42	
Sex (M/F)	18/3	24/18	**0.02**
Age (years)	60.38 (7.6)	64.97 (5.9)	**0.01**
Age at PD onset (years)	52.9 (8.6)	56.9(7.3)	0.06
Side of onset %dx	62%	68%	0.82
Disease duration (years)	8.4 (4.5)	8.7 (3.9)	0.79
Education (years)	8.9 (4.1)	8.8 (4.6)	0.92
H&Y	2.06 (0.7)	2.32 (0.39)	0.16
UPDRS III ("on" state)	16.58 (7.7)	20.18 (12.5)	0.26
LEDD (mg/day)	267.8 (113.5)	239.4 (130.5)	0.45
Range	150–600	50–600	
Ldopa (mg/day)	503.9 (211.7)	598.5 (295.3)	0.23
Range	200–870	100–1,500	
Total LEDD (mg/day)	731.0 (283.9)	786.67 (283.9)	0.57
Range	160–1,250	300–1,750	

*p value reported are from t test for continuous variables, and from non parametric tests for frequencies or ordinal variables

Significant values are highlighted in bold

LEDD levodopa equivalents, *Ldopa* levodopa, *Total LEDD* LEDDLEDD + Ldopa

once a day for every patient. Three patients used to gamble in Casinos while the others preferred scratch cards, Lotto game and slot machines. The mean latency between PD onset and PG onset was 6.9 ± 3.9 years and the mean PG duration was 25.8 ± 16.1 months.

Table 2 shows neuropsychological testing scores. Statistical analysis showed that PD–PG had significant higher scores for MMSE, long-term verbal learning task (RAVLT-learning), verbal fluencies (PF and SF) and attentive matrices. Mean scores of both groups were in the normal range for all tests. Frequencies of patients with pathological scores were similar in PD–PG versus PD–CNTR (see Table 2).

As shown in Table 3 the PD–PG group had significantly higher scores in NPI sub-items of anger/aggressiveness, disinhibition, irritability and eating disorders, whereas PD–CNTR had higher scores in anxiety and apathy.

In addition, we directly compared two subgroups of PD-patients with PG, those who never gambled before the onset of PD ($n = 12$) versus those who occasionally gambled ($n = 9$) and found no significant differences.

Discussion

We found that PG in PD is associated with preserved executive functions and cognitive performance in the high range of control PD. We considered two cohorts with similar disease duration to minimize the variability linked to disease progression. To our knowledge, this is the largest cohort of consecutive PD patients with active PG undergoing comprehensive neuropsychology assessment.

We found that PD patients with PG were younger and predominantly of male gender [2, 6, 10, 29]. This is consistent with general epidemiology of gambling [30] and it may be associated with the relatively enhanced responsiveness

Table 2 Comparison of neuropsychological characteristics

	Corrected scores [Mean (SD)]			Dichotomous values (% pathological)		
	PD–PG	PD–CNTR	p^*	PD–PG	PD–CNTR	p^*
N	21	42		21	42	
MMSE cor	29.1 (1.1)	27.4 (3.1)	**0.02**	0%	4%	0.44
FAB cor	15.2 (2.2)	13.7 (3.6)	0.06	18%	40%	0.10
CPM_Raven cor	27.5 (5.4)	27.2 (7.2)	0.80	5%	5%	0.07
PF cor	38.7 (13.2)	31.1 (9.9)	**0.02**	0%	4%	0.48
SF cor	44.9 (11.2)	37.4 (9.6)	**0.01**	5%	7%	0.65
RAVLT						
Learning cor	45.5 (9.1)	40.4 (8.1)	**0.04**	0%	9%	0.26
Recall cor	9.8 (3.5)	8.3 (2.7)	0.11	5%	9%	0.56
Denomination	17.5 (1.5)	17.4 (2.3)	0.93	0%	0%	1.00
Digit Span cor	5.6 (1.3)	5.7 (0.8)	0.91	0%	0%	1.00
Corsi Block Tapping cor	4.8 (0.9)	4.5 (1.1)	0.46	11%	16%	0.51
Attentive matrices cor	47.6 (5.9)	43.5 (8.9)	**0.05**	0%	9%	0.25

*p value reported are from t test for continuous variables, and from non parametric tests for frequencies or ordinal variables

Significant values are highlighted in bold

cor score are corrected by age and education, *MMSE* mini-mental state examination, *FAB* Frontal Assessment Battery, *CPM_Raven* Raven's Coloured Progressive Matrices, *PF* Phonemic fluencies, *SF* Semantic Fluencies, *RAVLT* Rey Auditory Verbal Learning Test

to rewards of the mesocorticolimbic system in males compared to females [31, 32].

Our findings are not consistent with the hypothesis that PG in PD is related to executive dysfunction and in particular with defects at the FAB [11]. Since we applied correction for age and education to the raw scores, we can exclude that minor age differences between PG–PD and PD–CNTR accounted for our results. In a very recent study, Santangelo and colleagues found an association between frontal lobe dysfunction at FAB test and PG [11]. In striking contrast, we did not find any sign of cognitive dysfunction in PD patients with PG, in consistence with the lack of any difference in FAB scores also reported by Voon and colleagues [33]. There are some methodological differences to highlight. First of all we did not limit the study groups excluding patients with dementia, but we chose to match the PD control subjects only by disease duration in order to highlight differences between gamblers and 'standard' PD. The clinical characteristics of the PG sample resulted to be in agreement with those available in current literature as discussed above. It may be worth underlining that we found high rate of pathological scores in the PD–CNTR (also including the FAB) and that two control patients had clinical dementia. This is likely due to the unbiased selection of consecutive patients fulfilling criteria for PD without any exclusion criteria, in adherence to clinical practice. Accordingly, our findings in PD–CNTR are consistent with the frequency of frontal lobe deficit reported in PD [34] and with the observation that only about 62% of PD patients have normal scores in cognitive assessment [35]. In second instance, our study and the abovementioned one by Voon and colleagues [33] investigated a larger sample size of both PD gamblers and PD controls. This is likely to have enhanced the power of the statistical analysis. Furthermore, in PD decision-making and global cognitive performance may be inversely related, namely patients with worst outcome at the Iowa Gambling Task performed best at memory and frontal lobe testing [34, 36]. We hypothesize that preserved executive abilities may help PD–PG patients develop strategies such as lying on their gambling behavior to caregivers and treating neurologists for a long time.

While a strength of our study is the investigation of a large cohort of continuous patients with active PG, some minor limitations may derive from the lack of specific tests on decision-making, likely to be differentially involved in PG [37]. Another potential limitation may derive from the presence of some PD–PG patients either with history of personal gambling behavior prior to PD onset, even if the lack of differential cognitive features compared to those PD–PG without any personal history of PG make this difference unlikely to bias our results.

Caregivers reported the presence of more neuropsychiatric symptoms in PD–PG than in PD–CNTR. These symptoms included enhanced irritability and aggressiveness, disinhibition and eating disorder, in consistence with increased impulsivity in patients with ICDs [8]. On the other hand, PD controls were found to be more anxious and apathetic. These findings may reflect the behavioral spectrum observed in PD. The majority of patients are commonly risk adverse [34, 38, 39] while in the small group developing PG enhanced novelty-seeking personality traits are observed [6, 40]. Consistently more than half of PG patients may present other concomitant compulsive behaviors [8].

Though early findings suggested a correlation between gambling and non-ergot D3-preferring dopamine agonists [41], more recent cohort studies have shown no relationship [4, 10]. We did not find differences in medication dosage or type (levodopa and/or class of dopamine agonist) between PD–PG and PD–CNTR.

We did not find any difference in side of onset in agreement with a recent study [11]. A previous study had suggested that left hemisphere is more frequently involved in PG–PD [33].

In conclusion, occurrence of PG in PD patients is not associated with the significant impairment of cognitive performance, including executive functions. Conversely, PD gamblers showed better skills in some cognitive abilities compared to their PD counterparts. Moreover, we further confirm that this behavioral disturbance occurs in patients with younger age, male gender, even when

Table 3 Comparison of neuropsychiatric characteristics

	Mean (SD)		*p*
	PD–PG	PD–CNTR	
N	21	42	
NPI total score	34.4 (20.5)	26.1 (13.2)	0.14
NPI item 1. Delusions	0.71 (2.9)	0.4 (1.4)	0.56
NPI item 2. Hallucinations	0.47 (1.1)	1.2 (2.5)	0.23
NPI item 3. Agitation/aggression	5.1 (4.4)	1.6 (3.2)	0.02
NPI item 4. Depression	4.47 (3.6)	4.9 (3.1)	0.64
NPI item 5. Anxiety	3.1 (3.0)	5.6 (3.9)	**0.02**
NPI item 6. Euphoria	2.1 (3.8)	0.9 (1.9)	0.23
NPI item 7. Apathy	0.8 (2.0)	2.4 (2.8)	**0.02**
NPI item 8. Disinhibition	3.6 (3.0)	0.6 (1.6)	**0.00**
NPI item 9. Irritability/lability	5.3 (4.1)	3.3 (3.1)	**0.04**
NPI item 10. Aberrant motor behavior	0.0 (0.0)	0.6 (1.8)	**0.02**
NPI item 11. Sleep disorders	5.2 (4.5)	3.7 (3.9)	0.2
NPI item 12. Eating disorders	3.4 (4.7)	0.9 (2.1)	**0.05**
GDS	10.7 (5.3)	11.0 (6.7)	0.89

NPI Neuropsychiatric Inventory, *GDS* 30 points Geriatric Depression Scale

Significant values are highlighted in bold

dopaminergic medications are prescribed in normal dose range. All these observations, together with the association between PG and other ICDs with a personal or family history of addictive disorders, highlight the need for further studies investigating individual predisposing factors, such as biological and/or personality traits.

References

1. Weintraub D (2009) Dopamine and impulse control disorders in Parkinson's disease. Ann Neurol 64(S2):S93–S100
2. Weintraub D, Koester J, Potenza M, Siderowf A, Stacy M, Whetteckey J, Wunderlich GR, Lang AE, FRCPC, for the DOMINION Study Group (2008) Dopaminergic therapy and impulse control disorders in Parkinson's disease: top line results of a Cross-Sectional Study of over 3,000 patients. Mov Disord Suppl. LB4
3. Lu C, Bharmal A, Suchowersky O (2006) Gambling and Parkinson's disease. Arch Neurol 63:298
4. Grosset KA, Macphee G, Pal G, Stewart D, Watt A, Davie J, Grosset DG (2006) Problematic gambling on dopamine agonists: not such a rarity. Mov Disord 21:2206–2208
5. American Psychiatric Association (2000) Diagnostic and statistical manual of mental disorders fourth edition: DSM-IV-TR. American Psychiatric Association, Washington, DC
6. Voon V, Fox SH (2007) Medication-related impulse control and repetitive behaviors in Parkinson disease. Arch Neurol 64(8): 1089–1096
7. Potenza MN, Voon V, Weintraub D (2007) Drug insight: impulse control disorders and dopamine therapies in Parkinson's disease. Nat Clin Pract Neurol 3(12):664–672
8. Isaias IU, Siri C, Cilia R, De Gaspari D, Pezzoli G, Antonini A (2008) The relationship between impulsivity and impulse control disorders in Parkinson's disease. Mov Disord 23(3):411–415
9. Voon V, Hassan K, Zurowski M, de Souza M, Thomsen T, Fox S, Lang AE, Miyasaki J (2006) Prevalence of repetitive and reward-seeking behaviors in Parkinson disease. Neurology 67(7):1254–1257
10. Gallagher DA, O'Sullivan SS, Evans AH, Lees AJ, Schrag A (2007) Pathological gambling in Parkinson's disease: risk factors and differences from dopamine dysregulation. An analysis of published case series. Mov Disord 22(12):1757–1763
11. Santangelo G, Vitale C, Trojano L, Verde F, Grossi D, Barone P (2009) Cognitive dysfunctions and pathological gambling in patients with Parkinson's disease. Mov Disord 9 (Epub ahead of print)
12. Cilia R, Siri C, Marotta G, Isaias IU, De Gaspari D, Canesi M, Pezzoli G, Antonini A (2008) Functional abnormalities underlying pathological gambling in Parkinson disease. Arch Neurol 65(12):1604–1611
13. Hughes AJ, Daniel SE, Kilford L, Lees AJ (1992) Accuracy of clinical diagnosis of idiopathic Parkinson's disease: a clinico-pathologic study of 100 cases. J Neurol Neurosurg Psychiatry 55:181–184
14. Gelb DJ, Oliver E, Gilman S (1999) Diagnostic criteria for Parkinson's disease. Arch Neurol 56:33–39
15. Lesieur HR, Blume SB (1987) The South Oaks Gambling Screen (SOGS): a new instrument for the identification of pathological gamblers. Am J Psychiatry 144(9):1184–1188
16. Battersby MW, Thomas LJ, Tolchard B, Esterman A (2002) The South Oaks Gambling Screen: a review with reference to Australian use. J Gambl Stud 18(3):257–271
17. Folstein MF, Folstein SE, McHugh PR (1975) 'Mini-mental state'. A practical method for grading the cognitive state of patients for the clinician. J Psychiatr Res 12:189–198
18. Heaton RK, Pendleton MG (1981) Use of neuropsychological tests to predict adult patients' everyday functioning. J Consult Clin Psychol 49:807–821
19. Novelli P, Capitani L, Vallar G, Cappa S (1986) Test di fluenza verbale. Archivio di Psicologia, Neurologia e Psichiatria 47(4)
20. Basso A, Capitani E, Laiacona M (1987) Raven's coloured progressive matrices: normative values on 305 adult normal controls. Funct Neurol 2(2):189–194
21. De Renzi E, Nichelli P (1975) Verbal and non verbal short term memory impairment following hemispheric damage. Cortex 11:33–41
22. Dubois B, Slaechevsky A, Litvan I, Pillon B (2000) The FAB: a frontal assessment battery at bedside. Neurology 55:1621–1626
23. Appollonio I, Leone M, Isella V, Piamarta F, Consoli T, Villa ML, Forapani E, Russo A, Nichelli P (2005) The frontal assessment battery (FAB): normative values in an Italian population sample. Neurol Sci 26:108–116
24. Wechsler D (1981) Wechsler Adult Intelligence scale. The Psychological Corporation, New York
25. Carlesimo GA, Caltagirone C, Gainotti G (1996) The Mental Deterioration Battery: normative data, diagnostic reliability and qualitative analyses of cognitive impairment. The Group for the Standardization of the Mental Deterioration Battery. Eur Neurol 36(6):378–384
26. Spinnler H, Tognoni G (1987) Standardizzazione e taratura italiana di test neuropsicologici. Italian J of Neurol Sci 6(Suppl. 8): 47–50
27. Yesavage JA, Brink TL, Rose TL, Lum O, Huang V, Adey M, Leirer VO (1983) Development and validation of a geriatric depression screening scale: a preliminary report. J Psychiatr Res 17:37–49
28. Cummings JL, Mega M, Gray K, Rosenberg-Thompson S, Carusi DA, Gornbein J (1994) The neuropsychiatric inventory: comprehensive assessment of psychopathology in dementia. Neurology 44:2308–2314
29. Singh A, Kandimala G, Dewey RB, O'Suilleabhain P (2007) Risk factors for pathologic gambling and other compulsions among Parkinson's disease patients taking dopamine agonists. J Clin Neurosci 14:1178–1181
30. Petry N, Stinson F, Grant B (2005) Comorbidity of DSM-IV pathological gambling and other psychiatric disorders: results from the national epidemiologic survey on alcohol and related conditions. J Clin Psychiatry 66:564–574
31. Hoeft F, Watson CL, Kesler SR, Bettinger KE, Reiss AL (2008) Gender differences in the mesocorticolimbic system during computer game-play. J Psychiatr Res 42(4):253–258
32. Munro CA, McCaul ME, Wong DF, Oswald LM, Zhou Y, Brasic J, Kuwabara H, Kumar A, Alexander M, Ye W, Wand GS (2006) Sex differences in striatal dopamine release in healthy adults. Biol Psychiatry 59(10):966–974
33. Voon V, Thomsen T, Miyasaki JM, de Souza M, Shafro A, Fox SH, Duff-Canning S, Lang AE, Zurowski M (2007) Factors associated with dopaminergic drug-related pathological gambling in Parkinson disease. Arch Neurol 64:212–216
34. Pagonabarraga J, Kulisevsky J, Llebaria G, García-Sánchez C, Pascual-Sedano B, Gironell A (2008) Parkinson's disease-cognitive rating scale: a new cognitive scale specific for Parkinson's disease. Mov Disord 23(7):998–1005
35. Caviness JN, Driver-Dunckley E, Connor DJ et al (2007) Defining mild cognitive impairment in Parkinson's disease. Mov Disord 22(9):1272–1277
36. Kobayakawa M, Koyama S, Mimura M, Kawamura M (2008) Decision making in Parkinson's disease: analysis of behavioral

and physiological patterns in the Iowa gambling task. Mov Disord 23(4):547–552
37. Brand M, Labudda K, Kalbe E, Hilker R, Emmans D, Fuchs G, Kessler J, Markowitsch HJ (2004) Decision-making impairments in patients with Parkinson's disease. Behav Neurol 15:77–85
38. Künig G, Leenders KL, Martin-Sölch C, Missimer J, Magyar S, Schultz W (2000) Reduced reward processing in the brains of Parkinsonian patients. Neuroreport 11(17):3681–3687
39. Fujii C, Harada S, Ohkoshi N, Hayashi A, Yoshizawa K (2000) Cross-cultural traits for personality of patients with Parkinson's disease in Japan. Am J Med Genet 96(1):1–3
40. Dagher A, Robbins TW (2009) Personality, addiction, dopamine: insights from Parkinson's disease. Neuron 61(4):502–510
41. Dodd ML, Klos KJ, Bower JH, Geda YE, Josephs KA, Ahlskog JE (2005) Pathological gambling caused by drugs used to treat Parkinson disease. Arch Neurol 62(9):1377–1381