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Research Report

Personality Related to Quality-of-Life Improvement After Deep Brain Stimulation in Parkinson's Disease (PSYCHO-STIM II)

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Abstract.

Background: Deep brain stimulation of the sub-thalamic nucleus (DBS-STN) reduces symptoms in Parkinson's disease (PD) patients with motor fluctuations. However, some patients may not feel ameliorated afterwards, despite an objective motor improvement. It is thus important to find new predictors of patients' quality of life (QoL) amelioration after DBS-STN. We hypothesized that personality dimensions might affect QoL after DBS-STN.

Objective: To evaluate associations between personality dimensions and QoL improvement one year after DBS-STN.

Methods: DBS-STN-PD patients ($n=303$) having answered the "Temperament and Character Inventory" (TCI) before surgery and the PDQ-39 before and one year after surgery were included, from the cohort study PREDI-STIM. Linear regression models were used to evaluate associations between TCI dimensions and change in PDQ-39 scores after DBS-STN.

Results: Novelty Seeking and Cooperativeness scores before surgery were positively associated with PDQ-39 scores improvement after DBS-STN (FDR-adjusted $p<0.01$). Moreover, paradoxically unimproved patients with deterioration of their PDQ-39 scores after DBS-STN despite improvement of their MDS-UPDRS-IV scores had lower Cooperativeness scores, while paradoxically improved patients with amelioration of their PDQ-39 scores despite deterioration of their MDS-UPDRS-IV scores had higher Reward Dependence scores.

Conclusion: Some presurgical personality dimensions were significantly associated with QoL amelioration and discrepancy between motor state and QoL changes after DBS-STN in PD. Educational programs before DBS-STN should take in account patient personality dimensions to better deal with their expectations.

Keywords: Cooperativeness, DBS-STN, novelty seeking, Parkinson's disease, quality of life

INTRODUCTION

Deep brain stimulation of the sub-thalamic nucleus (DBS-STN) is proposed to Parkinson's disease (PD) patients with motor fluctuations and generally leads to a great improvement of their quality of life (QoL) [1–4]. Nonetheless, some patients do not feel DBS benefits despite objective motor improvement [5, 6]. That is why it seems crucial to find some individual predictive factors of QoL improvement after DBS-STN in order to assure at best patients' amelioration after this invasive therapy.

QoL improvement is an important outcome when evaluating treatment efficiency. It depends on both

objective and subjective factors such as physical and psychological health, as well as personal feeling of well-being and happiness experienced [7, 8].

Because personality is a very individual characteristic and describes how people think, behave and manage their life [9], it seems a factor of interest to predict QoL. To assess personality, several questionnaires have been developed, based on different concepts. From them, the Temperament and Character Inventory (TCI) evaluates personality through seven dimensions [10]. It is derived from the neurobiological and psychological concept of personality made by Cloninger [9]. The TCI was already used in several studies assessing PD personality [11] and was

64 validated by its stability [9, 12–15]. Moreover, our
65 preceding study on PD patients with motor fluctua-
66 tions has shown the adequacy of the TCI personality
67 questionnaire on predicting QoL in this population
68 before DBS-STN [16].

69 Our first objective was thus to identify associa-
70 tions between presurgical personality dimensions and
71 QoL improvement one year after DBS-STN. Our
72 second objective was to seek for characteristics of
73 PD patients experiencing discrepancy between motor
74 complications and QoL changes after DBS.

75 MATERIALS AND METHODS

76 This study is an ancillary analysis using data col-
77 lected from the PREDISTIM cohort which principal
78 objective is to define the predictive factors of the ther-
79 apeutic response to DBS-STN on the long-term QoL
80 in PD. PREDISTIM is an ongoing prospective multi-
81 centric cohort (Protocol 2013-A00193-42) sponsored
82 by the University Hospital of Lille, conducted in 17
83 PD expert centers from the clinical research network
84 in France (NS-Park/F-Crin), approved from the CPP
85 Nord Ouest-IV Ethical Committee and registered in
86 the ClinicalTrials.gov website (NCT02360683).

87 Patients

88 Briefly, patients undergoing DBS-STN in one of
89 the participating centers were consecutive included
90 into the study between 11/2013 and 09/2019. Inclu-
91 sion criteria are a diagnosis of PD according to the
92 UKPDSBB, disease duration ≥ 5 years, age between
93 18 and 75 and indication of DBS-STN. Exclusion
94 criteria are atypical parkinsonism, severe cogni-
95 tive impairment (Montreal Cognitive Assessment
96 (MoCA) score < 23), severe psychiatric disorders
97 (following psychiatric evaluation by a psychiatrist),
98 levodopa motor response $< 30\%$ and contra-indica-
99 tions to surgery.

100 Patients gave written informed consent, the study
101 was conducted according to the good clinical prac-
102 tice, local regulations and data collection was
103 compliant with GDPR rules.

104 Study design and clinical measures

105 For PREDISTIM, clinical data was collected at
106 baseline, and then at 1-, 3-, and 5-years post-surgery.
107 Clinical assessments at each visit included collec-
108 tion of demographic data, medical and treatment

109 history, MDS-UPDRS part I-IV [17], part-III being
110 performed in OFF and ON state during a standard-
111 ized acute levodopa challenge, neuropsychological
112 testing, patient and caregivers' questionnaires. Along
113 our ancillary study, only one personality question-
114 naire was added to evaluation at baseline: the TCI.
115 Here, only patients evaluated before (V0) and after
116 one year of DBS-STN (V1) were used in this study.

117 The MDS-UPDRS-III was evaluated for two condi-
118 tions at V0: OFF and ON medication; and for
119 four conditions at V1: ON stimulation ON medica-
120 tion (stimON-medON), ON stimulation OFF med-
121 ication (stimON-medOFF), OFF stimulation ON
122 medication (stimOFF-medON) and OFF stimulation
123 OFF medication (stimOFF-medOFF).

124 The total Levodopa Equivalent Dose (LED) was
125 calculated [18].

126 The Parkinson's Disease Questionnaire 39-items
127 (PDQ-39) is a self-questionnaire evaluating specifi-
128 cally QoL of PD patients [19] and was assessed at
129 V0 and V1. Its eight sub-scales can be divided into a
130 Physical Component Score ("Mobility", "Activities
131 of Daily Living" and "Bodily Discomfort" sub-
132 scores) and a Mental Component Score ("Emotional
133 Well-Being", "Stigma", "Social Support", "Cogni-
134 tion" and "Communication" sub-scores) of QoL.

135 The TCI was measured only at V0 in order to
136 serve as predictive factor of QoL improvement after
137 DBS-STN. It is a self-questionnaire of 226 binary
138 questions used to assess patients' personality through
139 seven dimensions [10]. It includes four temperaments
140 (which are supposed to be genetically determined
141 personality traits [9]): Novelty Seeking (NS), Harm
142 Avoidance (HA), Reward Dependence (RD), and
143 Persistence (P); and three characters (which are
144 developmental personality traits evolving through
145 time and life history [9]): Self-Directedness (SD),
146 Cooperativeness (C), and Self-Transcendence (ST).
147 Each of these seven personality dimensions are mea-
148 sured by an independent score: higher is the score,
149 higher the individual will present the personality
150 characteristic associated. NS corresponds to impul-
151 sive and curious temperament; HA to anxious and
152 pessimist traits; RD to socially attached and sensi-
153 tive individuals; P to hardworking and perseverant
154 personality; and the three characters are associated
155 to levels of maturity: SD to individual maturity, C to
156 social maturity, and ST to spiritual maturity. Except
157 the P, each of these seven dimensions is subdivided
158 into sub-dimensions: NS and HA are formed by 4
159 sub-dimensions, RD and ST by 3, and SD and C by 5.
160 Each of these twenty-four sub-dimensions represents

161 a specific aspect of the global dimension, also ranging
162 in a spectrum of scores.

163 *Statistical analyses*

164 Descriptive analyses were performed. Moreover,
165 Kruskal-Wallis tests or ANOVA (according to nor-
166 mality of our data) followed by *post-hoc* analysis
167 were done to control for homogeneity across centers
168 for several variables (age, disease duration, LED at
169 V0, percentage of PDQ-39 total score and sub-scores
170 changes at V1, and TCI dimensions).

171 *Impact of DBS-STN at V1*

172 After DBS-STN, changes between V0 and V1 in
173 LED, MDS-UPDRS, PDQ-39, Hamilton Depression
174 Rating Scale (HAMD), Hamilton Anxiety Rating
175 Scale (HAMA), Lille Apathy Rating Scale (LARS),
176 and MoCA were checked (Wilcoxon Signed Rank
177 Test for Paired Samples).

178 *Associations between TCI dimensions and* 179 *PDQ-39 scores at V0*

180 Linear regression models were performed to test
181 the association between the different PDQ-39 sub-
182 scores and total score at V0 and the seven TCI
183 dimensions. Models were univariate with only one
184 explanatory variable (each TCI dimensions) by mod-
185 els, resulting in seven models per response variable
186 (each PDQ-39 scores) which were adjusted by age,
187 sex, disease duration and LED at V0. A False Dis-
188 covery Rate (FDR) correction was applied for 31
189 comparisons with calculation of q values (corre-
190 sponding to FDR adjusted *p* values). We have chosen
191 univariate models to study if some TCI personal-
192 ity dimensions were separately associated with QoL.
193 Moreover, because studying TCI sub-dimensions as
194 well as main dimensions seemed of interest, multi-
195 variate analysis seemed inappropriate since too many
196 explanatory variables would be used (that is 31 vari-
197 ables – 7 dimensions plus 24 sub-dimensions) which
198 can be too much in view of the parsimony rule.

199 *Associations between MDS-UPDRS and* 200 *PDQ-39 scores at V1*

201 These associations were tested using linear regres-
202 sion models adjusted by age, sex, disease duration,
203 and LED at V1. The PDQ-39 scores at V1 served
204 as response variables (the total and eight PDQ-39
205 sub-scores) and the MDS-UPDRS (part-I, part-II
206 stimON-medON, part-III stimON-medON and part-
207 IV) scores at V1 as explanatory variables. Models

were univariate with only one explanatory variable
by models, resulting in four models per response
variable. An FDR correction was applied for 4 com-
parisons.

Associations between TCI dimensions at V0 and *PDQ-39 changes at V1*

Percentages of changes from V0 to V1 were
calculated from the PDQ-39 total and sub-scores.
Linear regression models were performed. The
response variables corresponded to each calculated
percentages of PDQ-39 change. The explanatory
variables corresponded to each TCI dimensions and
sub-dimensions. As explained above, models were
univariate with only one explanatory variable by
models, resulting in thirty-one models per response
variable, adjusted by age, sex, disease duration and
LED at V0, to account for any potential center effect.
The same FDR correction was applied with q values
calculation for 31 comparisons.

PD population was also divided into two groups
according to the Minimal Clinically Important Dif-
ference (MCID) of PDQ-39 total score change [20]:
an “improvement” (difference of PDQ-39 total score
between V1 and V0 < -4.72) and a “no improvement”
group (difference of PDQ-39 total score between
V1 and V0 ≥ -4.72). TCI dimensions and sub-
dimensions scores were compared in these groups
(two-sample Mann-Whitney tests with FDR correc-
tion for 31 comparisons).

Differences between groups of responding *patients*

As supplementary exploratory analysis, we have
chosen to study discrepancy between motor compli-
cations (MDS-UPDRS-IV) and QoL (PDQ-39 total)
evolution. From the two PDQ-39 groups above and
two similar MDS-UPDRS-IV groups (an “improve-
ment” group based on MCID [21] (difference of
MDS-UPDRS-IV score between V1 and V0 < -0.9)
and a “no improvement” group (difference of MDS-
UPDRS-IV score between V1 and V0 ≥ -0.9)), PD
patients were divided into three final groups of
responding patients: a “paradoxically unimproved”
group (MDS-UPDRS “improvement” group and
PDQ-39 “no improvement” group), a “realistic”
group (MDS-UPDRS and PDQ-39 “improvement”
groups or MDS-UPDRS and PDQ-39 “no improve-
ment” groups) and a “paradoxically improved”
group (MDS-UPDRS “no improvement” group and
PDQ-39 “improvement” group). Each group were
compared two by two in terms of TCI dimensions and

Table 1
Description of TCI dimensions and clinical characteristics at V0 and V1

	V0 (mean ± SD)	V1 (mean ± SD)	<i>p</i>	CI of the difference
Age	60.0 ± 7.4	/	/	/
Disease duration	10.1 ± 3.9	/	/	/
Novelty Seeking	16.7 ± 5.0	/	/	/
Harm Avoidance	17.4 ± 6.5	/	/	/
Reward Dependence	15.4 ± 3.5	/	/	/
Persistence	5.4 ± 1.7	/	/	/
Self-Directedness	34.4 ± 6.0	/	/	/
Cooperativeness	33.8 ± 4.7	/	/	/
Self-Transcendence	12.3 ± 5.8	/	/	/
LED	1348.6 ± 740.2	689.6 ± 480.3	$9 \times 10^{-33**}$	535.7; 674.0
HAMD	5.2 ± 4.1	4.6 ± 4.1	$4 \times 10^{-02*}$	0.0; 1.5
HAMA	5.9 ± 5.1	4.7 ± 4.2	$2 \times 10^{-03**}$	0.5; 2.0
LARS	-27.9 ± 5.7	-25.2 ± 8.3	$1 \times 10^{-06**}$	-3.0; -1.0
MoCA	27.1 ± 2.2	25.9 ± 2.8	$1 \times 10^{-11**}$	1.0; 1.5
MDS-UPDRS I	10.9 ± 5	9.3 ± 5.2	$5 \times 10^{-06**}$	1.0; 2.5
MDS-UPDRS II OFF [†]	18.7 ± 7.6	15.1 ± 8.5	$9 \times 10^{-12**}$	3.5; 5.5
MDS-UPDRS II ON [‡]	6.5 ± 5.9	8.1 ± 5.8	$8 \times 10^{-05**}$	-2.5; -1.0
MDS-UPDRS III OFF [†]	43 ± 16.2	21.8 ± 12.9	$3 \times 10^{-46**}$	19.0; 22.5
MDS-UPDRS III ON [‡]	12.5 ± 7.8	10.8 ± 7.9	$3 \times 10^{-02*}$	0.0; 2.5
MDS-UPDRS IV	8.8 ± 3.3	4.1 ± 3.7	$3 \times 10^{-33**}$	4.5; 5.5
PDQ-39 Total	31.3 ± 11.4	26.8 ± 13.5	$3 \times 10^{-11**}$	3.4; 6.0
PDQ-39 Mobility	36.7 ± 20.4	32.6 ± 22.7	$2 \times 10^{-03**}$	1.3; 6.3
PDQ-39 ADL	37.7 ± 18.1	29.2 ± 20	$5 \times 10^{-13**}$	8.3; 12.5
PDQ-39 Emotional Well-being	32 ± 17.7	31.1 ± 19.2	0.30	-0.00004; 4.2
PDQ-39 Stigma	33.2 ± 22.3	23.1 ± 20.3	$5 \times 10^{-15**}$	9.4; 15.6
PDQ-39 Social support	11.7 ± 15.9	14 ± 18	$1 \times 10^{-02*}$	-8.3; 0.0
PDQ-39 Cognition	28.3 ± 17.1	24 ± 17.2	$6 \times 10^{-05**}$	3.1; 6.3
PDQ-39 Communication	24.9 ± 17.9	28.1 ± 21	$3 \times 10^{-03**}$	-8.3; 0.0
PDQ-39 Bodily discomfort	46.3 ± 21.1	32.5 ± 21.4	$9 \times 10^{-19**}$	12.5; 20.8

Mann-Whitney tests: * $p < 0.05$; ** $p \leq 0.01$; CI, confidence interval of the difference in means at 95% confidence level; V0, baseline; V1, one year after DBS-STN; [†]MDS-UPDRS medOFF (V0) vs. stimON-medOFF (V1); [‡]MDS-UPDRS medON (V0) vs. stimON-medON (V1); ADL, Activities of Daily Living.

cognitive and behavioral (HAMD, HAMA, LARS, and MoCA) changes after DBS-STN (two-sample Mann-Whitney tests). FDR adjusted p values (q values) were calculated for 7 comparisons for the TCI dimensions analysis and for 4 comparisons for the cognitive and behavioral changes analysis.

All analyses were conducted on R Studio Software Version 1.1.456 and a threshold of bilateral statistical significance of 0.05 was used. As explained above, FDR corrections were applied and interpretations were made carefully according to strength of the results.

RESULTS

Three hundred and three PD patients were enrolled in this study (204 men (67.3%) and 99 women (32.7%)) (Table 1). Statistical testing did not show relevant significant differences across centers: only age and disease duration shown significant

differences between centers in the Kruskal-Wallis testing ($p = 0.003$ and $p = 0.03$, respectively) which no more reached significance during the *post-hoc* analysis; LED at V0, percentage of PDQ-39 changes at V1 and TCI dimensions were not different between centers ($p > 0.05$). In any case, age, disease duration, sex and LED were used as adjustment variables in the linear regression models to control for any potential center effect.

Impact of DBS-STN at V1 (Table 1)

One year after DBS-STN, PD patients had a significant decrease in their dopaminergic treatments (LED). HAMD, HAMA, and MoCA scores significantly decreased after DBS, while LARS scores slightly increased.

All parts of the MDS-UPDRS scores improved significantly after DBS-STN except the part-II-ON which worsened.

Table 2
Significant associations between TCI dimensions at V0 and percentages of PDQ-39 change at V1 (n = 303)

Percentage of PDQ-39 evolution	TCI dimensions	coefficients	P	q	R2	CI
% PDQ-39 Total	NS	-1.02	0.04*	0.46	0.07	-2.01; -0.03
	HA4	-2.41	0.03*	0.46	0.07	-4.62; -0.21
	C3	-4.48	0.03*	0.46	0.07	-8.47; -0.49
% PDQ-39 Mobility	NS1	-9.42	0.0006**	0.02 *	0.05	-14.75; -4.08
	NS4	-7.34	0.047*	0.29	0.02	-14.55; -0.13
	C	-3.11	0.01**	0.12	0.03	-5.60; -0.62
	C1	-13.17	0.004**	0.04 *	0.04	-22.15; -4.19
	C4	-9.30	0.004**	0.04 *	0.04	-15.65; -2.96
% PDQ-39 ADL	C3	-10.24	0.047*	0.978	0.02	-20.30; -0.18
% PDQ-39 Emotional Well-Being	HA	-2.30	0.02*	0.37	0.04	-4.29; -0.32
	HA4	-7.54	0.01**	0.35	0.05	-13.34; -1.74
	P	8.18	0.04*	0.40	0.04	0.46; 14.89
% PDQ-39 Stigma	RD	-2.39	0.03*	0.40	0.01	-4.53; -0.24
	RD3	-5.84	0.04*	0.40	0.01	-11.41; -0.28
	ST3	4.20	0.03*	0.40	0.01	0.40; 8.01
% PDQ-39 Social Support	ST	1.80	0.02*	0.31	0.02	0.29; 3.31
	ST3	5.30	0.02*	0.31	0.02	0.92; 9.68
% PDQ-39 Cognition	NS	-2.56	0.009**	0.262	0.03	-4.45; -0.66
	SD	1.63	0.04*	0.26	0.02	0.07; 3.19
	SD1	6.84	0.02*	0.26	0.02	0.98; 12.70
	C1	7.72	0.04*	0.26	0.02	0.30; 15.13
	C2	6.56	0.04*	0.26	0.02	0.27; 12.85
% PDQ-39 Communication	HA4	-5.55	0.04*	0.70	0.00	-10.95; -0.15
% PDQ-39 Bodily Discomfort	NS	-1.90	0.01**	0.34	0.02	-3.37; -0.43
	NS1	-3.78	0.03*	0.34	0.02	-7.20; -0.35
	C3	-6.50	0.03*	0.34	0.02	-12.45; -0.56

Adjusted linear regression models: * $p < 0.05$; ** $p \leq 0.01$; q, FDR adjusted q value; significant p value in bold; CI, confidence interval at 95% confidence level; NS, Novelty Seeking; HA4, Fatigability; C3, Helpfulness; NS1, Exploratory excitability; NS4, Disorderliness; C, Cooperativeness; C1, Social acceptance; C4, Compassion; HA, Harm Avoidance; P, Persistence; RD, Reward Dependence; RD3, Dependence; ST3, Spiritual acceptance; ST, Self-Transcendence; SD, Self-Directedness; SD1, Responsibility; C2, Empathy.

Total PDQ-39 scores significantly improved after one year of DBS-STN as well as the “Mobility”, “Activities of Daily Living”, “Stigma”, “Cognition”, and “Bodily Discomfort” sub-scores, whereas the “Emotional Well-Being” sub-score did not significantly change. The “Social Support” and “Communication” sub-scores significantly worsened after surgery.

Associations between TCI dimensions and PDQ-39 scores at V0

TCI dimensions were mainly associated with the Mental Component Score of the PDQ-39 at V0. Indeed, the linear regression models between TCI dimensions and PDQ-39 sub-scores at V0 showed that HA and ST scores were significantly and positively associated with PDQ-39 total score ($q = 1 \times 10^{-8}$, $R^2 = 0.16$; and $q = 9 \times 10^{-3}$, $R^2 = 0.07$, respectively) whereas SD scores were significantly and negatively associated with PDQ-39 total score ($q = 2 \times 10^{-7}$, $R^2 = 0.14$).

Associations between MDS-UPDRS and PDQ-39 scores at V1

At V1, the MDS-UPDRS part-I and part-II stimON-medON were positively associated with PDQ-39 total and 8 sub-scores ($q < 0.01$). The MDS-UPDRS part-III stimON-medON and part-IV were positively associated with PDQ-39 total score ($q < 10^{-4}$), most of the Physical Component Score (“Mobility” and “Activities of Daily Living”) ($p < 10^{-3}$) and part of the Mental Component Score (“Emotional Well-Being”, “Stigma”, and “Communication”) ($q < 0.05$). The “Bodily Discomfort” was associated only with the MDS-UPDRS part-IV ($q < 10^{-3}$).

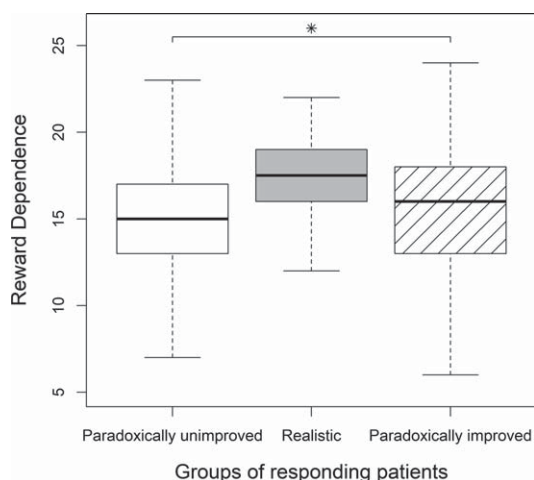
Associations between TCI dimensions at V0 and PDQ-39 changes at V1 (n = 303)

There were significant associations between TCI dimensions and PDQ-39 sub-scores change at V1 (Table 2). We mainly considered TCI dimensions

Table 3
Differences of TCI dimensions scores between PDQ-39 total improvement groups at V1 ($n = 303$)

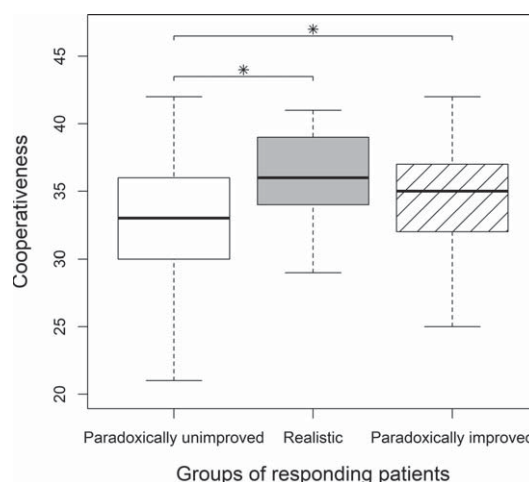
TCI dimensions	p	q	CI	Mean \pm SD	
				PDQ-39 total "improvement" group ($n = 150$)	PDQ-39 total "no improvement" group ($n = 153$)
HA4	0.03*	0.29	0; 1.0	5.4 \pm 2.0	4.7 \pm 2.4
C	0.01*	0.47	0; 2.0	34.4 \pm 4.5	33.2 \pm 4.7
C3	0.006**	0.78	0, 0.9	6.6 \pm 1.2	6.2 \pm 1.3

Mann-Whitney tests: * $p < 0.05$; ** $p \leq 0.01$; q , FDR adjusted p value; CI, confidence interval of the difference at 95% confidence level; HA4, Fatigability; C, Cooperativeness; C3, Helpfulness.



Mann-Whitney tests: * $q < 0.05$ between the "paradoxically unimproved" and "paradoxically improved" groups

Fig. 1. Differences in Reward Dependence scores between groups of responding patients.



Mann-Whitney tests: * $q < 0.05$ between the "paradoxically unimproved" and "paradoxically improved" or "realistic" groups

Fig. 2. Differences in Cooperativeness scores between groups of responding patients.

332 having the strongest association with PDQ-39 sub-
333 scores (presenting only significant FDR adjusted p
334 value that is $q \leq 0.05$) to avoid making assumption
335 about lower associations.

336 The NS1 sub-dimension and some C sub-dimens-
337 ions (C1 and C4) were significantly and negatively
338 associated with the PDQ-39 "Mobility" sub-score
339 change.

340 PD patients were separated into the PDQ-39 total
341 "improvement" ($n = 150$) and the "no improvement"
342 ($n = 153$) groups according to the MCID [20]. Among
343 the "no improvement" group, 63% of patients had
344 a no clinically relevant amelioration (that is a delta
345 PDQ-39 total score between the MCID of -4.72 and
346 0) and 37% were not ameliorated (that is a delta
347 PDQ-39 total score superior to 0). Uncorrected sig-
348 nificant differences of HA4, C and C3 scores were
349 found between the "improvement" group and the "no
350 improvement" group which did not maintain signifi-
cance with FDR correction (Table 3).

Differences between groups of responding patients ($n = 264$)

351 For this second exploratory objective, because of
352 missing data in the MDS-UPDRS-IV, only 264/303
353 PD patients were used to form the three groups of
354 responding patients according to their PDQ-39 and
355 MDS-UPDRS-IV changes: 97 patients were in the
356 "paradoxically unimproved" group, 149 in the "real-
357 istic" group, and 18 in the "paradoxically improved"
358 group.

359 Reward Dependence scores were significantly
360 higher in the "paradoxically improved" group com-
361 pared to the "paradoxically unimproved" group
362 ($q = 0.04$ and $CI = [1.0; 4.0]$) (Fig. 1). Cooperative-
363 ness scores were significantly lower in the "paradoxi-
364 cally unimproved" group compared to the "realistic"
365 and "paradoxically improved" groups ($q = 0.03$ and
366 $CI = [1.0; 3.0]$; $q = 0.04$ and $CI = [1.0; 5.0]$, respec-
367 tively) (Fig. 2).
368

369 Concerning the HAMA, HAMD, LARS, and
370 MoCA changes, there were no significant differences
371 between groups.

372 DISCUSSION

373 In this study, presurgical TCI personality dimen-
374 sions such as higher Cooperativeness and Novelty
375 Seeking sub-dimensions were associated with QoL
376 improvement after one year of DBS-STN in PD
377 population. This favorable outcome affected mainly
378 the physical component of QoL (“Mobility” evolu-
379 tion). Secondly, patients with lower Cooperativeness
380 scores were more paradoxically unimproved after
381 DBS-STN: their objective motor complications
382 improvement was not translated into QoL improve-
383 ment; while patients with higher Reward Dependence
384 scores were more paradoxically improved after DBS-
385 STN: they had QoL improvement despite the absence
386 of motor complications reduction.

387 According to the literature [1–3, 22, 23], this
388 study reported an improvement in MDS-UPDRS and
389 PDQ-39 scores after one year of DBS-STN and a
390 significant reduction of dopaminergic treatments. A
391 slight amelioration of depression and anxiety was also
392 shown after DBS, whereas apathy and global cog-
393 nition slightly deteriorated while remaining below
394 the threshold of apathy (LARS scale) and cogni-
395 tive deficit (MoCA). Thus, DBS did not affect much
396 behavior of our PD patients which globally did not
397 develop either anxio-depressive state or apathy or
398 cognitive decline.

399 First, we confirm the results of our previous study
400 showing that personality dimensions are associated
401 with different QoL sub-scores before DBS-STN in
402 PD [16].

403 Second, we found associations between personal-
404 ity dimensions and QoL improvement after one year
405 of DBS-STN. Some Cooperativeness and Novelty
406 Seeking sub-dimensions (C1 (Social Acceptance),
407 C4 (Compassion), and NS1 (Exploratory Excitabil-
408 ity)) were strongly related to the physical component
409 of QoL (“Mobility”): PD patients with high Coop-
410 erativeness and Novelty Seeking before DBS-STN
411 had the best QoL improvement (physical component)
412 after DBS-STN.

413 Cooperativeness is a character reflecting social
414 maturity and described as a tendency to consider
415 and accept others [24, 25]. PD patients with higher
416 Cooperativeness probably better listen to their rel-
417 atives and believe them, which can help them to

418 remember their past difficulties and to realize the
419 strong motor improvement they benefit from DBS-
420 STN. Indeed, it is usual that PD patients forget
421 their past difficulties after DBS and need a reminder
422 from their relatives or caregivers to become aware
423 of their improvements [26]. In literature, low Coop-
424 erativeness was associated with treatment-resistance
425 in depressive patients [27], and high Cooperativeness
426 was also linked with good QoL or life satisfaction in
427 different populations [28–30]. Also, this hypothesis
428 makes sense because Cooperativeness mostly impact
429 physical QoL improvement after DBS, only part of
430 QoL that can be assessed by patients’ relatives. There-
431 fore, relatives probably have a more objective feeling
432 on these improvements which may contrast with
433 patients’ subjective one. Moreover, it is interesting
434 to compare personality-QoL associations before and
435 after DBS. Before, Self-Directedness (representing
436 the individual maturity) was associated with better
437 QoL [16]; whereas, after, Cooperativeness (social
438 maturity) becomes associated with better QoL. This
439 may reflect that, before surgery, PD patients were
440 used to their disease and to their relatives’ comments
441 because of adaptive process through chronic dis-
442 ease; whereas, after DBS, PD patients are confronted
443 to abrupt changes [31] and motor improvement are
444 often obvious. Thus, their relatives can appreciate
445 these improvements and inform the patients, helping
446 them to become more aware of these changes. Hence,
447 before surgery, in case of a slowly evolving chronic
448 disease, PD patients may rely more on their personal
449 resources (individual maturity) to adapt and have a
450 better QoL [16]; whereas, after DBS, they focus more
451 on the external comments (social maturity) to adapt
452 to the abrupt changes. It would thus be interesting to
453 see the impact of Cooperativeness on QoL after long-
454 time of DBS, when PD patients would have become
455 used to these changes, with the PREDISTIM 5-year
456 QoL evaluation.

457 Novelty Seeking is a temperament representing a
458 tendency to respond positively and with excitation
459 to new stimuli [24, 25]. It reflects good adaptability
460 to new situations and motivation facing change. PD
461 patients with higher Novelty Seeking may thus better
462 adapt to the abrupt changes caused by DBS-STN and
463 so really feel the strong motor improvement they ben-
464 efit from the stimulation. In literature, higher Novelty
465 Seeking was also associated with better global QoL
466 and physical health in patients with schizophrenia
467 [32].

468 Interestingly, Novelty Seeking and/or Coopera-
469 tiveness are two personality dimensions potentially
470

470 implicated in placebo responses [33–35]. Therefore,
471 these two personality dimensions may enhance the
472 part of placebo effect induced by DBS-STN [36].
473 For example, the sub-dimension C3 (Helpfulness)
474 reflects solidarity and good level of team work which
475 may enhance placebo effect [37].

476 Moreover, our study has shown good associa-
477 tions between the more objective evaluation of PD
478 symptoms (MDS-UPDRS) and the subjective eval-
479 uation of PD QoL (PDQ-39). Mainly, the objective
480 motor examination, MDS-UPDRS-III, as well as the
481 motor complications assessed by the MDS-UPDRS-
482 IV, were mostly associated with physical components
483 of the PDQ-39 evaluation, assuring that both scales
484 are reliable and evaluate PD patients in the same
485 way [38]. Nonetheless, some PD patients (43.6%)
486 had a feeling of evolution after DBS-STN that differs
487 from the objective motor complications examina-
488 tion (MDS-UPDRS-IV). Indeed, eighteen patients
489 (6.8%) felt “paradoxically improved” after DBS: they
490 felt improvement of their QoL, whereas the MDS-
491 UPDRS-IV showed no improvement of their motor
492 complications. Also, ninety-seven patients (36.7%)
493 felt “paradoxically unimproved” after DBS: they did
494 not feel any improvement of their QoL, whereas the
495 MDS-UPDRS-IV showed an improvement of their
496 motor complications. This dissociation between real-
497 ity of PD symptoms improvement after DBS and PD
498 patients’ feelings has already been shown in several
499 studies [5, 6] and can be explained by differences
500 between patients’ expectations and reality, difficul-
501 ties of psychosocial adjustment, mood and behavioral
502 changes [26, 31, 39, 40], etc. Moreover, we have
503 decided to focus our analysis on discrepancy between
504 QoL evolution and MDS-UPDRS-IV change since
505 DBS preferentially improves motor complications.

506 Here, paradoxically unimproved PD patients had
507 lower Cooperativeness scores than realistic and para-
508 doxically improved ones. This result seems to be
509 congruent with our previous observation that lower
510 Cooperativeness scores before surgery lead to less
511 improvement of QoL after DBS-STN. Moreover,
512 paradoxically improved PD patients had higher
513 Reward Dependence scores than the paradoxically
514 unimproved ones. Reward Dependence temperament
515 is associated with sensitive, dependent and social
516 individuals [41]. It is a system facilitating condi-
517 tioning to reward stimuli [25] and therefore may
518 be associated with placebo effect. Indeed, some
519 studies have found associations between higher
520 Reward Dependence scores and better outcomes
521 after interpersonal therapy [42] or antidepressants

522 [43]. Moreover, treatment adherence was shown to
523 be related to higher Reward Dependence tempera-
524 ment in a weight-loss therapy, probably thanks to
525 better collaborative relationship with the clinicians
526 [44]. Nonetheless, these differences between realis-
527 tic, paradoxically improved or unimproved patients
528 could not be explained by differences in cognitive or
529 behavioral changes after DBS-STN.

530 This study has some limits. Being the first study on
531 this subject, only analyses of associations between
532 QoL outcomes and personality dimensions were
533 done. Thus, our results are not predictive but rather
534 suggestive. Hence, they should be used in order to
535 prevent disappointment of PD patients after DBS-
536 STN (not to select PD patients for DBS) acting in two
537 ways: 1) by supporting them upstream and explain-
538 ing them at best what they should expect of DBS, and
539 2) by preparing and encouraging their relatives to be
540 really present with the patients after the operation to
541 enhance their cooperation (which seems to facilitate
542 their positive outcomes). Additionally, our models
543 explaining less than ten percent of the variance (R^2)
544 of QoL improvement after DBS-STN, we are aware
545 that personality dimensions are not enough to guar-
546 anty PD patients’ QoL improvement after stimulation
547 and that other variable are needed to explain at best
548 QoL outcome after surgery. However, our focus being
549 concentrated on personality dimensions’ evaluation,
550 we did not look for other potential predictive variables
551 as it will be the aim of the main PREDI-STIM study.
552 Finally, only personality dimensions before DBS
553 were evaluated (there was no re-evaluation of person-
554 ality after stimulation), and it remains possible that
555 some personality dimensions evolve after DBS. Even
556 if temperaments are not supposed to change with
557 time [9], personality in PD patients seems to evolve
558 with the disease course particularly with the intro-
559 duction of dopaminergic treatments [45]. DBS could
560 also impact personality as shown by some studies
561 [46–50]. In any case, our aim was to find “predic-
562 tive” factors of QoL improvement after DBS. Thus,
563 even if personality changes after stimulation, it is not
564 supposed to affect our results. Lastly, our three groups
565 of responding PD patients (“paradoxically unim-
566 proved”, “realistic” and “paradoxically improved”) were
567 done according to their motor complications
568 improvement (reflected by MDS-UPDRS part-IV)
569 since it is the main purpose of DBS-STN action.
570 Nonetheless, improvements of non-motor symptoms
571 (pain, fatigue etc.) were not accounted in these anal-
572 yses, although non-motor symptoms can benefit of
573 DBS-STN [51] and are best predictors of QoL in PD

[52], because we were interested in more objective assessments than MDS-UPDRS parts I and II. Moreover, we are aware that using MCIDs to classify into groups of “improvement” or “no improvement” may not precisely reflect the evolution of patients after DBS, mainly since at this stage of motor fluctuations a change of 0.9 points in the MDS-UPDRS part-IV may not be sufficient to be clinically significant. Nonetheless, the choice of this MCID was done accordingly with literature. Ultimately, we are aware that there are other models of personality that could have been explored in this study to depict a more complete exploration of personality associated with QoL. Nonetheless, the TCI being a long questionnaire, we thought that using a multilayer approach (through different personality investigations) would have been too complex in clinical practice and too tiring for the PD patients.

In conclusion, PD patients with higher Cooperativeness and Novelty Seeking scores at baseline seem to have the best QoL outcome after one year of DBS-STN in the physical component of QoL. A tendency of being more trustful towards relatives and more motivated by changes could explain the ability of these PD patients to feel a better QoL improvement following the abrupt changes after surgery. Moreover, PD patients with low Cooperativeness were more paradoxically unimproved after DBS, whereas PD patients with high Reward Dependence were more paradoxically improved after DBS. Therefore, systematic TCI examination could be proposed as standard evaluation before DBS. Subsequently, according to PD patients’ scores at the Novelty Seeking and Cooperativeness dimensions, specific educational programs should be proposed to patients with higher risk of QoL unimprovement after DBS to prepare them at best for the stimulation. For this, we are now looking for cut-off scores for these dimensions.

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