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Title

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Abstract

Background: The Cognitive Estimation Test (CET) is widely used in clinical and research settings to assess the ability to produce reasonable estimates to items that individuals would not know that the exact answer (e.g., "How fast do race horses run?"). **Objective:** In this study, we examined the performance of non-demented Parkinson's Disease (PD) patients on the CET, since previous studies reported heterogeneous results about possible cognitive estimation impairments in this population. We also examined whether PD patients improve their performance if given the chance to reconsider their initial CET responses. **Methods:** Thirty non-demented idiopathic PD patients and thirty healthy controls matched in age, gender and years of education performed the two parallel forms of Italian CET. The estimation scores for initial and final responses as well as the number of times individuals changed their answers were examined. Additional neuropsychological tests, evaluating intellectual, frontal executive, speed of processing, naming and arithmetical abilities, were also administered. **Results:** The PD group were not significantly poorer than healthy controls at estimating the answers to items on either CET versions. Moreover, PD patients did not significantly differ in their initial and final responses or number of response changes. Performance on the CET was significantly related to performance on a global measure of executive function, processing speed and arithmetic. However, when CET performance was considered in terms of the different components identified in MacPherson et al. (2014), PD patients were impaired compared to controls on the component involving mainly, but not exclusively, length-related estimations. **Conclusions:** Non-demented PD patients have mild impairments in cognitive estimation ability, which may depend on the estimations they are required to provide.

Keywords: Parkinson's Disease; cognitive estimation; cognitive impairments; executive function; neuropsychological test.

INTRODUCTION

The Cognitive Estimation task (CET) assesses the ability to produce estimations in response to questions that individuals do not know the exact answer to (Shallice, & Evans, 1978). The CET is widely used as a test of executive dysfunction with the generation of bizarre estimates thought to be associated with damage to processes associated with the frontal lobes of the brain (Shallice, & Evans, 1978; Smith, & Milner, 1984, 1988; MacPherson, Wagner, Murphy, Bozzali, Cipolotti, & Shallice, 2014; D'Aniello, Scarpina, Albani, Castelnuovo, & Mauro, 2015a; D'Aniello, Castelnuovo, & Scarpina, 2015b).

Despite the cognitive profile of Parkinson's Disease (PD) being characterized as executive dysfunction (e.g., Gotham, Brown, & Marsden, 1988; Levy et al., 2002), few studies have examined the ability of individuals with Parkinson's Disease (PD) to perform the CET. Those studies that have do not reach a consensus whether PD results in poorer cognitive estimation abilities compared to healthy controls. Most PD studies have concentrated on time estimation abilities where non-demented medicated (Smith, Harper, Gittings, & Abernethy, 2007; Nombela, Rittman, Robbins, & Rowe, 2014) and non-medicated (Pastor, Artieda, Jahanshahi, & Obeso, 1992) PD individuals are significantly poorer than healthy controls at estimating time intervals. These time estimation impairments are thought to be due to frontal executive dysfunction rather than impaired temporal processes (Harrington, Castillo, Greenberg, Song, Lessig, Lee, & Rao, 2011). In terms of the CET, Bullard, Fein, Gleeson, Tischer, Mapou and Kaplan (2004) found that demented PD individuals produced significantly poorer estimates than controls for weight- and quantity-related estimations, but not time- or distance-related estimations. However, in non-demented PD individuals, Appollonio and colleagues (2003) did not find deficits in CET, with only 6% of the studied participants performing below the impaired cut-off. More recently, our own work has reported cognitive estimation deficits in non-demented medicated PD patients, but again in only a small number of individuals (approximately 16% of the studied participants were pathological – below

the 5th percentile; 27% of the studied participants were borderline – between the 5th and 10th percentile) when compared against normative data cut-offs (D'Aniello et al., 2015a). Overall, these findings suggest that cognitive estimation impairments in PD are mild, if reported at all.

In the present work, we focused on investigating estimation in PD further using the more recent version of the CET (MacPherson et al., 2014; Scarpina, D'Aniello, Mauro, Castelnuovo, & MacPherson, 2015). One important feature of this CET, which exists as English- (MacPherson et al., 2014) and Italian-speaking (Scarpina et al., 2015) versions, is the inclusion of an additional administration step. This step encourages individuals to consider, and change if necessary, their responses before committing to a final response. The aim was to reduce responses where individuals simply respond with the first answer that comes to mind, without monitoring the appropriateness of that response.

We focused on individuals with non-amnestic, single-domain PD to reduce the heterogeneity in our PD sample, and because it is the most common subtype of non-demented PD; the executive impairments of which are thought to predict later development of dementia (Mahieux, Fenelon, Flahault, Manifacier, Michelet, & Boller, 1998; Levy et al., 2002; Janvin, Aarsland, & Larsen, 2005). We examined the estimation scores for participants' initial and final responses to examine whether PD patients improve their CET performance if given the chance to reconsider their responses. The number of times individuals changed their answers was also examined.

MATERIALS AND METHODS

Participants

Thirty non-demented PD patients (male = 9, female = 21) aged between 33 and 83 years (*M* = 66.67; *SD* = 11.69) and 30 healthy control participants (male = 9; female = 21) aged between 44 and 81 years (*M* = 62.93; *SD* = 8.84) took part in this study. The PD patients had a mean education of 10.97 years (*SD* = 4.49; range = 5-21) and the control group had a mean education of 9.40 years

(*SD* = 3.39; range = 5-17). All participants were right-handed and native Italian speakers. The PD patients were recruited through the Division of Neurology and Neurorehabilitation at San Giuseppe Hospital in Piancavallo (VCO), which specializes in the diagnosis, treatment and rehabilitation of neurodegenerative diseases including PD. As part of a routine yearly hospitalization for a period of 7-18 days, PD patients are given a medical health check, a drug efficacy assessment, a neuropsychological assessment, and physiotherapy.

The PD group had a mean disease duration of 8.13 years (*SD* = 4.81) and their unified Parkinson's disease rating scale (UPDRS) (Fahn, & Elton, UPDRS Program Members, 1987) scores ranged between 14 and 66 out of 260 (*M* = 37.07, *SD* = 14.99). Their mean Levodopa equivalent dose was 550mg/day (*SD* = 303.18). Inclusion criteria were: a diagnosis of idiopathic PD according to the UK Parkinson's Disease Society Brain Bank clinical diagnostic criteria (Hughes, Daniel, Kilford, & Lees, 1992); no deficit on any cognitive domain except the executive domain (non-amnestic, single-domain PD-MCI subtype; Litvan et al., 2012); no deficits severe enough to impair daily life (social, occupational, or personal care), over and above motor or autonomic symptoms (Emre et al., 2007); a score of 24 or more out of 30 on the Mini-Mental State Examination (MMSE) Folstein, Folstein, & McHugh, 1975) (*M* = 27.70, *SD* = 1.94); and written informed consent to use their clinical data. Exclusion criteria were evidence of other neurological (e.g., ictus, traumatic brain injury) or pathological conditions (e.g., psychiatric syndromes, potus). The clinical details are reported in Table 1.

[Table 1 around here]

The healthy participants were not patients of the hospital, and were recruited through personal contact with the researchers or word-of-mouth. No control participant had a previous history of head injury or stroke, major neurological or psychiatric illness, or alcohol abuse. The PD and healthy control groups did not significantly differ in terms of their age, $t(58) = 1.39$; $p = 0.16$,

or education, t(58) = 1.52; p = 0.13. The study was approved by the ethical committee of IRCSS Istituto Auxologico Italiano and was performed in compliance with the Declaration of Helsinki. All participants gave their written consent to take part in the study.

Neuropsychological assessment

Background neuropsychological measures. The background neuropsychological tests were administered to the PD patients as part of their inpatient stay but were also administered to the healthy control group who took part in the study. Clock Drawing was administered (Agrell & Dehlin, 1998; Esteban-Santillan, Praditsuwan, Veda, & Geldmacher, 1998; Storey, Rowland, Basic, & Conforti, 2001), as it is considered predictive of dementia in primary care (Kirby, Denihan, Bruce, Coakley, & Lawlor, 2001). Abstract reasoning was assessed using Raven's Coloured Progressive Matrices (Raven, Raven, & Court, 1998), verbal intelligence through the Brief Intelligence Test (Isella, Villa, Forapani, Piamarta, Russo, & Appollonio, 2005), and general knowledge through the WAIS information subtest (Wechsler, 1997). Processing speed was measured using Trail Making Test Part A (Reitan, & Wolfson, 1985; Giovagnoli, Del Pesce, Mascheroni, Simoncelli, Laiacona, & Capitani, 1996). Naming and arithmetical abilities were assessed using the Oral Denomination task from Batteria per l'Analisi dei Deficit Afasici (BADA) (Miceli, Laudanna, Burani, & Capasso, 1994) and the Graded Difficulty Arithmetic (McKenna, & Warrington, 1983) respectively.

Frontal executive abilities were assessed using the Frontal Assessment Battery (FAB) (Dubois, Slachevsky, Litvan, & Pillon, 2000; Appollonio et al., 2005). The Stroop Test (Stroop, 1935; Caffarra, Vezzadini, Dieci, Zonato, & Venneri, 2002) was also administered to assess inhibition: in this version, three different conditions were presented: i) participants read color-words printed in black ink (W); ii) participants stated the color of colored circles (C); iii) participants stated the color of color-words printed in colored ink (CW). Two scores were derived: a *time interference* score based on execution time, and an *error interference* score based on number of

errors (Caffarra et al., 2002). Both scores were derived according to the following formula: I = CW-[(W + C)/2]. Set shifting was measured using the Trail Making Test Part B (Reitan, & Wolfson, 1985; Giovagnoli et al., 1996) and finally, Digit Span Backwards (Monaco, Costa, Caltagirone, & Carlesimo, 2013) was used to assess focused attention and manipulation within working memory (Baddeley, 1974, 2000).

All neuropsychological tests were scored according to the procedures described in their original articles or test manuals. PD patients were considered impaired if their performance was below the 5th percentile and borderline if their performance was between the 5th and 10th percentile on the cut-offs for the standardized Italian versions of the tests.

Cognitive Estimation Test. All participants performed both versions A and B of the Italian version (Scarpina et al., 2015) of the Cognitive Estimation Test (CET, MacPherson et al., 2014). The questions were asked out loud by the experimenter and participants gave their answers orally. Participants were instructed that there was no exact answer for most questions or it was unlikely they would know the answer so they should provide their best guess or estimate.

Following the standard CET instructions (MacPherson et al., 2014; Scarpina et al., 2015), participants could respond using any unit of measurement and were given the opportunity to change their response if they decided that their first response was not a reasonable estimate; moreover, they could take as much as time as they needed to produce their estimates. All responses produced by participants were recorded. Initial and final responses for each individual CET item were scored 0, 1, 2 or 3 points according to the normative data from 227 healthy Italian participants (Scarpina et al., 2015). A score of 0 was awarded for responses that were deemed normal and fell between the 20th and 80th percentile. One point was awarded for responses considered quite extreme and were equal to or more than the 10th but less than the 20th percentile or more than the 80th percentile but less than or equal to the 90th percentile. Two points were awarded to responses considered extreme that were more than or equal to the 5th percentile but less than the 10th percentile or more than the

90th percentile but less than or equal to the 95th percentile. Finally, 3 points were awarded to very extreme responses that were less than the 5th or more than the 95th percentile. Where a response corresponded to more than one percentile category, the response was awarded the fewer number of points. Therefore, participants could obtain a maximum error score of 27 for each parallel CET version (version A and version B) where a higher score indicates poorer cognitive estimation abilities.

Data analyses

Firstly, independent samples t-tests were conducted to examine differences between the PD group and the healthy control group performing the background neuropsychological tests. In cases where the assumption of normality was violated, non-parametric Mann-Whitney U tests were used instead. Independent samples t-tests or Mann-Whitney U tests were then conducted to examine differences between the PD group and the healthy control group on CET-A and B. PD performance on the two CET versions and healthy control performance on the two CET versions were also compared independently using Wilcoxon tests. The p-values for these group comparisons were corrected for simultaneous comparisons using False Discovery Rate (FDR) where the corrected p-values are calculated using the actual p-values produced rather than the number of comparisons made (Benjamini & Hochberg, 1995).

Spearman correlations were conducted to explore the relationship between performance on the two CET versions and age, education, disease duration, patients' unified Parkinson's disease rating scale score (UPDRS) (Fahn et al., 1987) and their Levodopa equivalent dose (LED). Spearman correlations were also conducted to explore the relationship between performance on CET-A and B and the neuropsychological tests in the PD patients and the control group; the p-values for these correlations were also corrected for simultaneous comparisons using FDR.

Finally, the Wilcoxon Signed Ranks Test was used in order to assess possible differences between the first total CET score (i.e., based on the first answer provided by participants) and the

final total CET score (i.e., based on the final answer provided by participants), for the two groups independently for both CET versions. The overall number of changes made by the PD group and the healthy control group for both CET-A and B versions were compared using Mann-Whitney U tests. Spearman correlations were conducted to explore the relationship between the first and final CET-A and B measures and the neuropsychological tests in the PD patients and the control group; again the p-value was FDR-corrected for multiple comparisons.

RESULTS

Background neuropsychological measures. Figures 1a and 1b demonstrate the percentage of PD participants who were classified as impaired (<5th percentile), borderline (5th-10th percentile) and unimpaired (>10th percentile) on the neuropsychological tests.

[Figures 1a and 1b around here]

In terms of our healthy control group, only 0.6% were classified as impaired and 0.3% as borderline on Digit Span Backwards. On the Frontal Assessment Battery, only 0.3% of healthy controls were categorized as impaired and 0.3% as borderline. No other neuropsychological tests demonstrated impaired or borderline performance in our healthy participants.

The means and standard deviations for performance on the neuropsychological tests are reported in Table 2. The results demonstrated that although the PD participants tended to perform more poorly than the healthy control group on the majority of the neuropsychological tests, the two groups did not significantly differ on any of these measures when the p-values were FDR adjusted for multiple comparisons.

[Table 2 around here]

Cognitive Estimation Test. The gender adjusted scores of the PD patients and healthy controls on both versions of the CET are demonstrated in Table 3. The PD patients did not achieve significantly higher error scores (i.e., poorer performance) than the healthy controls on either CET version. Performance on the two versions of the CET did not significantly differ in the PD group, $Z(30) = 200.0$; $p = 0.70$, or in the healthy control group, $Z(30) = 117.5$; $p = 0.03$. See Figure 1a for the percentage of PD participants who were classified as impaired, borderline and unimpaired on the two versions of the CET. In the healthy control group, only 0.6% were impaired and 0.3% were borderline on CET-A and 0.3% were impaired on CET-B. The remaining participants were unimpaired on the two CET versions.

[Table 3 around here]

We also considered the PD patients' and healthy controls' scores based on the CET principal component (PC) factor structure identified in MacPherson et al. (2014). Considering the three components in version A, the PD group had significantly higher error scores on PC2 compared to healthy controls, $t(49.43) = 2.98$; $p = 0.004$. No significant group differences were found for PC1, $t(58) = 1.36$; $p = 0.17$, or PC3, $t(58) = 1.07$; $p = 0.28$ (see Table 3). Considering the four components in version B, the PD group had significantly higher error scores compared to the healthy control group for PC2, $t(52.85) = 2.33$; $p = 0.02$. However, significant differences did not emerge for PC1, $t(58) = 1.22$; $p = 0.23$, PC3, $t(49.47) = 1.99$; $p = 0.05$, or PC4, $t(58) = 1.36$; $p = 0.17$. Both PC2 components of CET-A and CET-B largely included length-related estimations.

CET correlations with demographic and clinical variables. In the PD group, neither version of the CET significantly correlated with age, education, disease duration, UPDRS score, or LED

dosage. In the healthy controls, the CET versions did not significantly correlate with age or education. The correlational analyses are reported in Table 4.

[Table 4 around here]

CET correlations with background neuropsychological scores. The correlations between CET performance and performance on the neuropsychological background tests are demonstrated in Table 5. In the PD group, performance on CET-A was significantly related to poorer performance on the Frontal Assessment Battery, Trail Making Test Part A, and Graded Difficulty Arithmetic, whereas CET-B only significantly correlated with performance on the Graded Difficulty Arithmetic. In the healthy control group, no significant correlations were found between performance on the CET and the background measures.

[Table 5 around here]

Initial versus final CET scores. In the PD group, Wilcoxon Signed Ranks Test showed no significant difference between the initial (M = 8.56; SD = 5.11) and final (M = 8.23; SD = 4.88) CET-A error scores for the PD group, $Z(30) = -1.38$; $p = 0.16$; a similar result emerged in relation to the healthy controls (initial error score: M = 6.80; SD = 3.71; final error score: M = 6.80; SD = 3.94), $Z(30) = -0.10$; $p = 0.91$. The two groups also changed their estimation responses a similar number of times (PD group: M = 0.46; SD = 1.00; healthy control group: M = 0.63; SD = 0.80), $U(60) = 372.5$; $p = 0.18$.

In the PD group performing CET-B, Wilcoxon Signed Ranks Tests showed that no significant difference emerged between the initial (M = 7.83; SD = 4.89) and final (M = 7.86; SD = 4.86) error scores, $Z(30) = -0.27$; $p = 0.78$; however, a significant difference emerged for the healthy controls (initial error score: M = 5.56; SD = 3.56; final error score: M = 5.23; SD = 3.61),

Z(30) = -2.27; p = 0.02, suggesting an improvement in their estimation accuracy. No significant difference in the number of times the two groups changed their estimates was found (PD group: M = 0.46; SD = 1.00; healthy control group: M = 0.63; SD = 0.76), U(60) =360.5; p = 0.12.

DISCUSSION

The aim of the current study was to examine further estimation abilities in non-demented PD. Despite some PD individuals being impaired on the CET according to the cut-offs for the standardized versions, significant differences between the PD and healthy control groups were not found on either version of the CET (Scarpina et al., 2015). This supports previous results about which only small numbers of non-demented PD patients perform below the cut-off on other CET versions (Appollonio et al., 2003; D'Aniello et al., 2015a). In addition, our results showed that the PD and healthy control groups did not significantly differ in their initial and final responses provided or the number of response changes, which suggests that PD patients do not improve their CET performance if given the opportunity to revise their initial responses. When encouraged to consider their responses before finally committing, it was the healthy control group who corrected their responses on CET-B to achieve a better estimation score. From the current data, it is not clear why this is the case, but possible explanations might be that the CET-B items elicit faster initial, incorrect responses, the items are more difficult to estimate or participants are less confident about their responses to these items.

We found that CET performance in our PD patients was significantly related to their global executive abilities as measured by their FAB total score (CET-A only), speed of processing (CET-A only) and arithmetical abilities (CET-A and CET-B). These findings are in line with previous research that suggests that the CET is a complex task that relies on several cognitive abilities in order to perform the task successfully (Shoqeirat, Mayes, MacDonald, Meudell, & Pickering, 1990; Liss, Fein, Bullard, & Robins, 2000; Brand, Kalbe, Fujiwara, Huber, & Markowitsch, 2003a;

Brand, Fujiwara, Kalbe, Steingass, Kessler, & Markowitsch, 2003b; Gansler, Varvaris, Swenson, & Schretlen; 2014; MacPherson et al., 2014; D'Aniello et al., 2015b). Our findings also suggest that versions A and B of the CET involve different cognitive processes in order to perform the tasks successfully.

Our work suggests that CET impairments in non-demented PD are mild. When considered as a group, no differences were found between PD patients and healthy controls. However, there were a small number of PD patients who were categorized as impaired in terms of CET performance based on normative data cut-offs. Moreover, when CET performance was examined based on the factor structure identified in MacPherson et al. (2014), our PD group performed more significantly poorly than healthy controls on the second principal component of the CET, which mainly involves items estimating length. In previous studies, time estimation has been reported to consistently show deficits in non-demented PD, with individuals performing significantly more poorly than healthy controls when estimating time intervals (Pastor et al., 1992; Smith et al., 2007; Nombela et al., 2014). Together, these findings suggest that specific categories of estimation may indicate deficits in PD patients.

PD is a heterogeneous disease with various subtypes, which is possibly due to differences in the mechanisms that underlie PD and complications of dopamine therapy (van Rooden et al., 2011). As our PD sample participants were largely similar in terms of their age and mean disease duration, it is difficult to determine from our current data whether different PD subtypes impact impulsivity differently. However, future work might explore this further in a larger PD sample. We also acknowledge that the MMSE is considered a less sensitive measure of cognitive status in PD compared to the Montreal Cognitive Assessment Battery (MOCA; Nasreddine et al., 2005), as the MOCA also assesses executive, visuospatial and memory abilities (Aarsland, 2016; Biundo et al., 2016). A limitation of our study may be the inclusion of some PD individuals in the earliest stages of dementia, who were not detected using the MMSE.

In summary, the findings of our study suggest that CET impairments in non-demented PD patients are mild. When considered as a group, no differences in overall CET performance were found between PD patients and healthy controls. Moreover, non-demented PD patients do not improve their CET performance if given the opportunity to reassess their initial cognitive estimates. However, there were a small number of PD patients who were categorized as impaired based on existing cut-off scores from normative data and a subset of CET items demonstrated poorer estimation in non-demented PD patients compared to controls. These findings provide evidence for the multidimensional nature of the CET, with only certain estimations resulting in impaired PD performance.

CONFLICT OF INTEREST

The authors have no conflict of interest to report.

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TABLE 1

Demographic and clinical details for the non-demented Parkinson's disease participants.

	Age	Education	Sex	Disease duration	H&Y stage	UPDRS score	LED	Medication
	76	15	F	17	4	46	400	rotigotine; amantadine;apomorphine
	65	13	F	8	3	38	150	pramipexole
	68	13	M	15	3	40	350	quetiapine
	60	13	M	8	3	23	550	pramipexole; selegiline
	79	7	F	19	3	42	850	pramipexole
	68	8	F	19	3	46	575	pramipexole, rotigotine
	75	13	F	8	2	18	300	-
	75	13	M	8	4	56	700	amantadine;apomorphine
	71	3	F	3	3	44	450	-
	62	13	F	8	3	36	650	pramipexole
	74	3	F	14	4	64	1200	amantadine; quetiapine
	75	5	F	5	3	38	700	ropinirole
	47	8	M	4	1	14	400	pramipexole; rotigotine; rasagiline
	37	21	M	5	1	16	200	-
	82	13	F	11	4	66	900	quetiapine
	62	13	F	5	3	35	275	pramipexole; rasagiline
	69	13	F	1	1	16	100	rotigotine
	83	18	M	8	2	28	400	-
	67	13	M	4	2	26	200	rasagiline; ropinirole
	64	8	F	1	2	20	300	-
	69	8	F	7	4	32	700	rotigotine; rasagiline
	58	5	M	13	2	26	550	pramipexole; rasagiline
	33	18	F	8	3	42	600	rotigotine; rasagiline; amantidine
	78	10	F	5	3	34	400	-
	71	8	M	15	3	54	900	-
	72	15	F	9	3	50	1100	pramipexole
	55	13	F	6	4	65	300	-
	65	8	F	2	2	22	550	pramipexole
	73	5	M	10	-	-	-	-
	67	13	F	11	3	38	1200	amatindine; ropinirole
Mean	66.67	10.97		8.13		37.07	550.00	
SD	11.69	4.49		4.81		14.99	303.18	
Median	68.50	13.00		7.00		38.00	550.00	

H&Y stage = Hoehn & Yahr stage; UPDRS score = Unified Parkinson's disease rating scale; LED = Levodopa equivalent dose; M = male; F = female. *Education* and *Disease duration* expressed in years. *Dosage of L-dopa* expressed in mg/day.

TABLE 2

The means and standard deviations (in parentheses) for the scores of the PD patients and healthy control group performing the background neuropsychological tests.

Neuropsychological test	PD group	Healthy group	Statistic	p
Clock Drawing Test (max = 10)	7.55 (3.34)	9.35 (1.39)	316.5[a]	0.03
Raven's Coloured Progressive Matrices (max = 36)	26.92 (6.74)	29.97 (3.60)	2.00[b]	0.05
Brief Intelligence Test (max =108)	6.53 (7.67)	6.93 (7.50)	447.5[a]	0.97
WAIS - information subtest (max = 29)	18.11 (6.69)	18.17 (6.46)	0.03[b]	0.97
Frontal Assessment Battery (max = 18)	14.47 (2.47)	15.77 (2.06)	304.5[a]	0.03
· Similarities (max = 3)	1.87 (0.82)	2.33 (0.92)	300[a]	0.01
· Lexical fluency (max = 3)	2.57 (0.68)	2.87 (0.35)	354[a]	0.05
· Motor series (max = 3)	2.47 (0.94)	2.63 (0.77)	415.5[a]	0.51
· Conflicting instructions (max = 3)	2.63 (0.81)	2.77 (0.50)	431.5[a]	0.70
· Go-no go (max = 3)	1.93 (0.91)	2.27 (0.91)	357[a]	0.14
· Prehension behaviour (max = 3)	3.00 (0.00)	2.97 (0.18)	435[a]	0.31
Stroop Test – speed index	28.79 (15.32)	18.52 (13.22)	626[a]	0.01
Stroop Test – error index (max = 30)	5.58 (8.71)	1.00 (1.33)	608.5[a]	0.02
Digit Span Backward (max = 8)	3.60 (1.10)	4.30 (1.62)	323[a]	0.05
Trail Making Test – A	64.74 (39.77)	50.00 (23.25)	491.5[a]	0.16
Trail Making Test – B	111.14 (63.06)	101.17 (55.53)	369.5[a]	0.46
Oral Denomination – Bada (max = 30)	25.43 (4.51)	27.33 (1.37)	348.5[a]	0.12
Graded Difficulty Arithmetic (max = 24)	11.78 (6.07)	15.53 (6.08)	2.33[b]	0.02

max = maximum score; [a] = U; [b] = t; p-values adjusted using FDR

TABLE 3

The scores and standard deviations for the PD and healthy control groups performing both versions of the CET and for the CET factors derived in MacPherson et al. (2014).

		PD group M (SD)	**Healthy group M (SD)**	**U**	**p**
CET A	First Error Score	8.56 (5.11)	6.80 (3.71)	538.5	0.18
	Final Error Score	8.23 (4.88)	6.80 (3.96)	505.0	0.41
	Number of changes	0.46 (1.00)	0.63 (0.80)	372.5	0.18
				t	p
	PC1	4.26 (2.85)	3.26 (2.82)	1.36	0.17
	PC2	4.30 (2.94)	2.40 (1.89)	2.98	0.004*
	PC3	1.70 (1.60)	2.16 (1.76)	1.07	0.28
CET B	First Error Score	7.83 (4.89)	5.56 (3.56)	568.0	0.82
	Final Error Score	7.86 (4.86)	5.23 (3.61)	592.5	0.03*
	Number of changes	0.46 (1.00)	0.63 (0.76)	360.5	0.12
				t	p
	PC1	3.33 (2.74)	2.56 (2.12)	1.20	0.23
	PC2	2.76 (2.28)	1.56 (1.65)	2.33	0.02*
	PC3	2.73 (2.46)	1.66 (1.58)	1.99	0.05
	PC4	2.86 (2.5)	2.1 (1.78)	1.36	0.17

* $p < 0.05$

TABLE 4

Spearman correlational analyses between the parallel forms of the CET, and the demographic and clinical variables in the PD and healthy control groups.

		Age	Education	Disease Duration	UPDRS	LED
PD Patients	CET A	0.42	-0.14	0.20	0.09	0.03
	CET B	0.03	-0.13	0.14	0.07	0.12
Healthy Controls	CET A	0.12	0.13	-	-	-
	CET B	0.41	-0.07	-	-	-

UPDRS = Unified Parkinson's disease rating scale; LED = Levodopa equivalent dose

TABLE 5

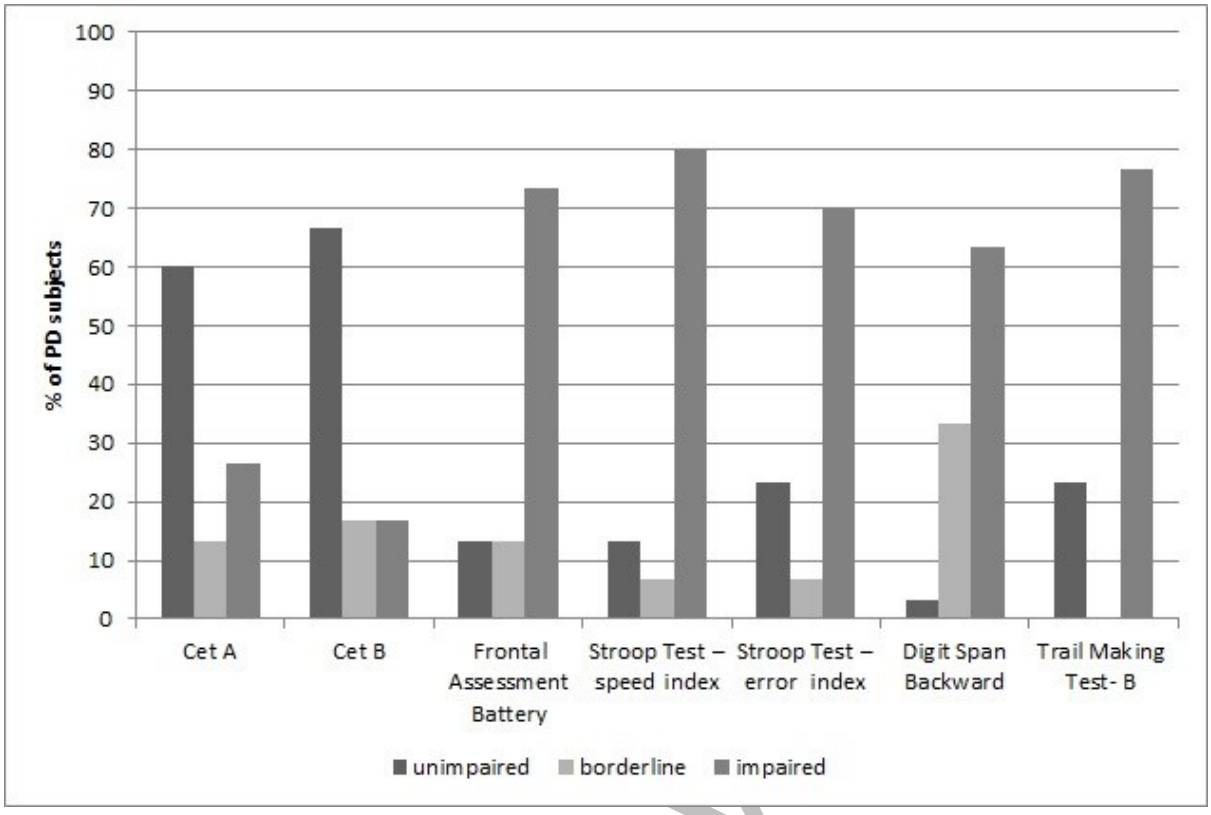
Spearman correlational analyses between the parallel forms of the CET and the background neuropsychological scores for the PD and healthy control groups.

	Clock Drawing Test	Raven's Coloured Progressive Matrices	Brief Intelligence Test	WAIS - information subtest	Frontal Assessment Battery	Stroop Test – speed index	Stroop Test – error index	Digit Span Backward	Trail Making Test-A	Trail Making Test-B	Oral Denomination - Bada	Graded Difficulty Arithmetic
PD												
CET A	-0.38	-0.30	0.05	-0.27	-0.47*	0.00	0.41	-0.29	0.51*	0.38	-0.37	-0.48*
CET B	-0.27	-0.36	0.16	-0.41	-0.27	-0.15	0.06	-0.35	0.31	0.07	-0.15	-0.58*
Controls												
CET A	0.02	-0.26	0.16	-0.28	-0.06	0.02	0.44	-0.24	0.00	0.02	-0.01	-0.37
CET B	-0.15	-0.26	-0.01	-0.16	-0.11	0.18	0.27	-0.34	0.28	0.24	-0.24	-0.46

* $p \leq 0.01$

FIGURE CAPTION

Figures 1a and 1b. Percentage of PD participants[2] who were impaired, borderline and unimpaired on the neuropsychological background tests and CET-A and B according to Italian normative data.


100
90
80
70
60
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40
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20
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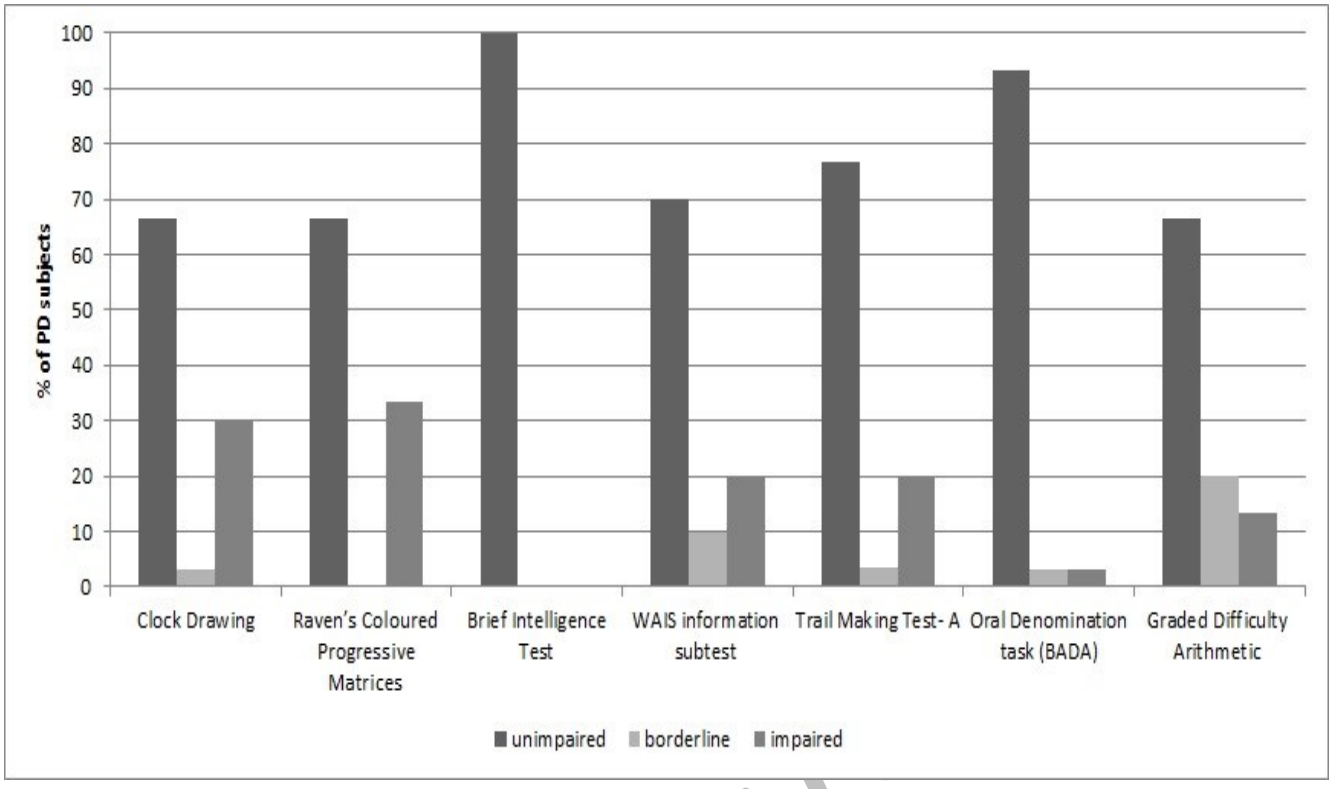
% of PD subjects
Cet A
Cet B
Frontal Assessment Battery
Stroop Test – speed index
Stroop Test – error index
Digit Span Backward
Trail Making Test- B
unimpaired
borderline
impaired


100
90
80
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60
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20
10
0
% of PD subjects
Clock Drawing
Raven's Coloured Progressive Matrices
Brief Intelligence Test
WAIS information subtest
Trail Making Test- A
Oral Denomination task (BADA)
Graded Difficulty Arithmetic
unimpaired
borderline
impaired