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Parkinson disease patients' performance in Theory of Mind (ToM) and decision-making tasks with and without Deep Brain Stimulation (DBS)

Desempeño de pacientes con Parkinson con y sin estimulación cerebral profunda (ECP) en Teoría de la Mente (ToM) y toma de decisiones

Laura Orduz-Bastidas
0000-0002-1931-5622
lauraorduzb@gmail.com
Pontificia Universidad Javeriana, School of Psychology, Bogotá, Colombia.

Adriana Martínez-Martínez
0000-0001-6342-0342
martinez.adriana@javeriana.edu.co
Pontificia Universidad Javeriana, School of Psychology, Bogotá, Colombia.

Camilo Hurtado-Parrado
0000-0001-5923-8054
hhurtadoparrado@troy.edu
Troy University,Dept of Psychology, USA. Fund. Univ. Konrad Lorenz, Colombia

Wilson López-López
0000-0002-2964-0402
lopezw@javeriana.edu.co
Pontificia Universidad Javeriana, School of Psychology, Bogotá, Colombia.

César Acevedo-Triana
0000-0002-1296-9957
cesar.acevedo02@uptc.edu.co
Universidad Pedagógica y Tecnológica de Colombia, School of Psychology, Tunja, Colombia. University of Alabama at Birmingham, Dept.of Neurobiology, USA

Abstract:

Background: Patients with Parkinson's Disease (PD) show non-motor symptoms, such as cognitive impairment, disrupting executive functions, and mood alterations. Two processes currently researched in these areas are Theory of Mind (ToM) and decision-making in PD patients. ToM is the ability to identify mental states (affective or cognitive) in others, and it is a necessary skill for successful communication in social situations. Decision-making is researched in PD patients due to alterations in dopaminergic pathways involved in cortico-striatal circuits. These pathways have been linked to cognitive functions. Both processes (ToM and decision making) could be altered in PD patients after deep brain stimulation (DBS) therapy. **Objective:** To compare the performance of PD patients (with and without DBS) and healthy controls (HC) in Theory of Mind and decision-making tasks. **Methods:** We implemented in three groups of patients (PD, n = 4; PD-DBS, n = 5 and HC, n = 5) the Yoni task to identify affective and cognitive features in ToM, and Iowa Gambling Task (IGT) to assess decision-making. **Results:** There were no differences across the PD groups in ToM, both in the affective and cognitive features. Regarding decision-making (IGT scores), we obtained results consistent with previous findings, with PD patients showing impairments in this process. **Conclusions:** Some results suggest that DBS therapy affected PD patients' decision-making performance when compared to healthy controls. Our results describe some non-motor changes related to DBS often seen in PD patients.

Keywords: Theory of Mind; Decision-making; Parkinson Disease; Deep Brain Stimulation (DBS)

Resumen:

Los pacientes con enfermedad de Parkinson (EP) muestran síntomas no motores, como deterioro cognitivo, alteración de las funciones ejecutivas y alteraciones del estado de ánimo. Dos procesos que se investigan actualmente en este tipo de pacientes son la Teoría de la Mente (ToM) y la toma de decisiones. La Teoría de la Mente es la capacidad de identificar los estados mentales (afectivos o cognitivos) en los demás, y es una habilidad necesaria para la comunicación exitosa en situaciones sociales. El proceso de toma de decisiones se investiga en los pacientes con EP debido a las alteraciones en las vías dopaminérgicas implicadas en los circuitos corticoestriatales, las cuales se han vinculado a las funciones cognitivas. Ambos procesos podrían estar alterados en los pacientes con EP después de la terapia de estimulación cerebral profunda (ECP). Con el objetivo de comparar el rendimiento de pacientes con EP (con y sin ECP) y controles sanos (HC) en teoría de la mente y tareas de toma de decisiones, aplicamos a tres grupos de pacientes (PD, n = 4; PD-DBS, n = 5 y HC, n = 5) la tarea de Yoni para identificar las características afectivas y cognitivas en TM y la Tarea de Juego de Iowa (IGT) en la toma de decisiones. No hubo diferencias entre los grupos de EP en TM tanto en las características afectivas como en las cognitivas. En cuanto a la toma de decisiones, obtuvimos resultados consistentes con los hallazgos anteriores, con pacientes con EP que mostraron impedimentos en este proceso. Algunos resultados sugieren que la terapia de ECP afectó el desempeño de los pacientes con EP en la toma de decisiones cuando se comparó con el grupo de control sano. Nuestros hallazgos describen algunos cambios no motores debidos a la ECP que se observan a menudo en los pacientes con EP.

Palabras clave: Teoría de la mente, Toma de decisiones, Enfermedad de Parkinson, Estimulación cerebral profunda (ECP)

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Introduction

Parkinson's Disease (PD) is a progressive neurodegenerative disorder that mainly affects the nigrostriatal dopamine system, specifically in reducing dopamine neurons in the cortical-thalamus-striated loop (Haelterman et al., 2014; Marín et al., 2018; Micheli, 2006). PD is characterized by motor symptoms, such as shaking, abnormal increase in muscle tone, postural instability, bradykinesia, impaired balance and walking, and mood alteration (Demakis, 2007; Goetz & Kompoliti, 2005; Martinez-Martinez et al., 2017). In the early stages of PD, the altered functioning produces low stimulation in the dorsolateral prefrontal cortex (dlPFC) (Goetz & Kompoliti, 2005; Haelterman et al., 2014; Lees et al., 2009). In later stages, dopamine depletion is between 60% and 80%, there is a widespread occurrence of Lewy bodies (toxic and abnormal aggregates of protein inside neurons), and motor manifestations become evident. This is called the symptomatic phase (Demakis, 2007; Micheli & Luquin-Piudo, 2012).

Pharmacological treatment for advanced PD has been supplemented with deep brain stimulation (DBS). DBS is a surgical intervention when motor symptoms are inadequately managed with medications (Pérez de la Torre et al., 2016; Weaver et al., 2009). It consists of the administration of high-frequency continuous electrical stimulation through an electrode surgically implanted to the basal ganglia (subthalamic nucleus, STN), the internal globus pallidus (GPi), or the pedunculopontine nucleus (PPN) (Deuschl et al., 2006; Dowsey-Limousin & Pollak, 2001; Liu et al., 2014; Shils et al., 2008). In the last 20 years, DBS clinical use has increased because it is adjustable and reversible, if necessary (Dowsey-Limousin & Pollak, 2001). Some studies have reported that secondary effects of DBS intervention includes changes in non-motor symptoms, including learning of verbal information, visuoconstructive skills, working memory, impulse control, decision-making and cognitive performance (Evens et al., 2015; Martinez-Martinez et al., 2017; Oyama et al., 2011; Parker et al., 2013; Waterfall & Crowe, 1995; Witt et al., 2008; Wu et al., 2014).

Theory of Mind (ToM)

ToM is the ability to attribute mental states to others and understand and to perceive the emotional (emotional ToM) and cognitive (cognitive ToM) states (Kemp et al., 2012; Poletti et al., 2012). Neurobiological studies have shown that performance during emotional ToM tasks increases the brain activity in the ventromedial prefrontal cortex (vmPFC) and the orbitofrontal cortex (OFC). During cognitive ToM tasks, increases in the bilateral dorsolateral prefrontal cortex (dlPFC) activity have been detected (Freedman & Stuss, 2011; Péron et al., 2009;

Shamay-Tsoory & Aharon-Peretz, 2007; Yu et al., 2012). Due to these abnormalities in the different dopamine circuits (medial, frontal and frontostriatal, and fronto-subcortical circuits) of PD patients, the performance in ToM tasks might be modified, when compared to healthy controls (Bora et al., 2015; Poletti et al., 2012; Poletti, Cavedini, & Bonuccelli, 2011). Although some studies have shown that different components of ToM are impaired in PD patients, which support this relationship (Bodden, Mollenhauer, et al., 2010; Bora et al., 2015; Kemp et al., 2012; Péron et al., 2009, 2010; Shamay-Tsoory & Aharon-Peretz, 2007; Yu et al., 2012), a study that compared social cognitive abilities in PD-DBS, PD no-DBS, and Healthy Control did not show detrimental effects on emotion recognition and emotional and cognitive ToM (Enrici et al., 2017).

The need for assessment of the affective and cognitive components of ToM in PD with DBS results from the fact that ToM is a critical ability in adapting to our complex social environment. Difficulties in recognition of emotional and cognitive states of other individuals, limits PD patients' social interactions, and ultimately reduces their quality of life (Bodden, Dodel, et al., 2010; Bodden, Mollenhauer, et al., 2010; Bora et al., 2015). Research that has assessed social emotions in PD patients, including envy or schadenfreude, have shown that alterations in these complex behaviors could coincide with ToM alterations (Poletti et al., 2012; Shamay-Tsoory et al., 2007; Shamay-Tsoory & Aharon-Peretz, 2007; Steinbeis & Singer, 2014).

Decision-making

Process Currently, mounting research is directed towards assess decision-making processes in patients with different neurochemical alterations, damage in frontal structures and PD patients (Bechara, 2004; Bechara et al., 1994; Evens et al., 2016; Gescheidt et al., 2013; Kobayakawa et al., 2010; Wallis, 2012). In PD patients, this interest is related to the non-motor and cognitive symptoms previously mentioned. Some studies have also identified pathological-gambling behavior associated with pharmacological treatment in PD patients (Kobayakawa et al., 2010; Miranda et al., 2010; Voon et al., 2007). These repetitive and impulsive behaviors entailed in pathological gambling are generally associated with dysfunctionality in reward and punishment systems that affect decision-making (Gescheidt et al., 2013).

One standard and widely used measure associated with decision-making is the Iowa Gambling Task (IGT) (Bechara, 2004; Bechara et al., 1994). The IGT is a decision-making task where participants make a card selection out of four decks in a game of winning and losing money. Each card deck has different reward and punishment profiles. The task consists of finding the optimal strategy by avoiding punishment, for that, healthy controls usually develop a "safe" strategy (e.g., avoid cards that produce high rewards and high punishment; Bechara, 2004; Bechara et al., 1994; Kobayakawa, Koyama, Mimura, & Kawamura, 2008; Manes et al., 2002). This task was developed to assess different pathologies associated with compromises in frontal, orbitofrontal, or vmPFC or striatum, in which patients make risky decisions (Poletti, Cavedini, & Bonuccelli, 2011). Another possible explanation for alteration in the decision-making process of PD patients exposed to the IGT relates to dopamine (DA) depletions. Progressive dopaminergic reduction in substance nigra diminishes DA inside the striatum and the frontostriatal loop, which results in executive and cognitive functioning impairments (Gescheidt et al., 2012, 2013; Poletti, Cavedini, & Bonuccelli, 2011).

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After the DBS procedure, PD patients showed a recovery from preoperative addictive behaviors (Eusebio et al., 2013). According to this, when PD-DBS were evaluated before and after surgical procedure, the IGT scores showed a change in the strategy and reward and punishment system associated with DA depletion (Castrioto et al., 2015). In addition, studies with ON and OFF medication stages show ambiguous results regarding decision-making (Evens et al., 2016; Pagonabarraga et al., 2007). Other reports suggest that PD-DBS do not show an apparent effect on decision-making processes (Herz et al., 2018; Oyama et al., 2011). Accordingly, these contradictory results suggest an unclear implication of decision-making in PD patients across different stages, resulting not only from alterations in the frontrostriatal loop, but in different dopaminergic pathways. This variability might correspond to individual differences across patients, which suggests differential affectation depending of age, prognosis, stage of the disease, or treatment. In the present study, we aimed to compare the performance in two non-motor cognitive functions (ToM and decision-making), and associations between them, across PD-DBS, PD without DBS, and Healthy Controls.

Thus, a crucial question concerning emotion processing in PD-DBS and ToM is whether the decision-making process under ambiguity can be specifically explained by emotional or cognitive components. Although recent studies have investigated the dimensions of emotional ToM and decision-making in PD (Enrici et al., 2015, 2017; Xi et al., 2015), there is a lack of a study that has compared these same components (decision-making and ToM) in PD-DBS patients. We hypothesized that PD-DBS patients show less deficit in IGT, as compared to PD without DBS; however, we expected that both groups should be less impulsive than control patients. Also, we explored whether affective ToM is correlated with decision-making during the IGT.

Materials and Methods

Patients

Nine patients diagnosed with PD (8 male, 1 female; 9 right-handed) (Parkinson Disease with Deep Brain Stimulation [PD-DBS] n = 5; Parkinson Disease without DBS [PD] n = 4) and 5 Healthy Control (HC; 5 male, 5 right-handed) participated (see Table 1). Participants were Colombian adult, with basic competences to read and write. They had no comorbidities such as systemic, neurologic, or psychiatric illness, did no report recent history of alcohol or drugs consumption, and provided written consent to participate. Diagnostic of PD was made by neurologists, and PD patients were recruited from the Department of Neurosurgery and Neurology at the Hospital Universitario San Ignacio (HUSI), Bogotá, Colombia. All patients received dopaminergic precursor medication during their PD treatment. The Ethics Committee of the School of Medicine and at HUSI approved the study, and all participants gave written informed consent before the study.

Tabla 1: *Demographic information for PD, PD-DBS and HC group (mean ± SD).*

	PD (n = 4)	PD-DBS (n = 5)	HC (n = 5)
Gender (M, F)	4, 0	4, 1	5, 0
Age in years (SD)	55.7 (14.5)	62.2 (4.8)	60.8 (10.4)
Education (years)	10.25 (5.7)	16 (3.3)	18.40 (2.3)
Duration of disease in years (SD)	6.5 (2.38)	13.75 (7.68)	-
DBS surgery	-	1 month to 7 years	-

SD = standard deviation; PD = Parkinson's disease;
PD-DBS = Parkinson's disease with Deep Brain Stimulation; HC = healthy controls.

Procedure

The current study was framed in a cross-sectional descriptive-correlational design, comparing the punctuations across tasks and groups. The PD and PD-DBS groups were invited to participate in neurology and neurosurgery departments at HUSI. The HC volunteers were primary care patients at the HUSI, which were matched with PD patients for age and schooling years. None of the subjects received payment for participation in the study. Tests duration ranged between one and three hours. A neuropsychological evaluation was implemented in PD patients following testing, but the results of this evaluation are not reported in this paper. Groups performed the following tasks: Theory of Mind - Yoni Task (Shamay-Tsoory & Aharon-Peretz, 2007)

The computerized version of the Yoni Task comprises 98 trials divided into three blocks. This task involves the ability to infer mental states based on verbal and visual cues. A cartoon outline of a face (named "Yoni") is presented briefly in the center of the screen, accompanied by four options in order to respond to a verbal instruction located at the top of the screen (Figure 1 and 2). The correct answer is based on the instruction and following cues, such as eyes or facial expression, or a combination of both. The organization of the blocks was: "affective" condition (24 trials divided into two levels, 12 first order and 12 second order) with sentences such as "Yoni loves to _____" (first order) and "Yoni loves the toy that ______ loves" (second order); "cognitive" condition (24 trials divided into two levels, 12 first order and 12 second order) with sentences such as "Yoni is thinking of _____" (first-order) and "Yoni is thinking of the toy that ______ wants" (second-order). A combination of affective and cognitive conditions (12 trials) with sentences such as "Yoni is thinking of the toy that ______ loves" or "Yoni loves the toy that…is thinking"; control or physical recognition to assess following of instructions (14 trials); single emotion-recognition condition (12 trials with images of real faces and similar to Ekman emotion task) with sentences such as "Yoni is identified with ______" or "Yoni feels like _______"; social emotions recognition condition (12 trials divided in two emotions, 6 for envy and 6 for schadenfreude) with sentences such as "Yoni envy the success of ____" or "Yoni rejoices in the misfortune of ___."

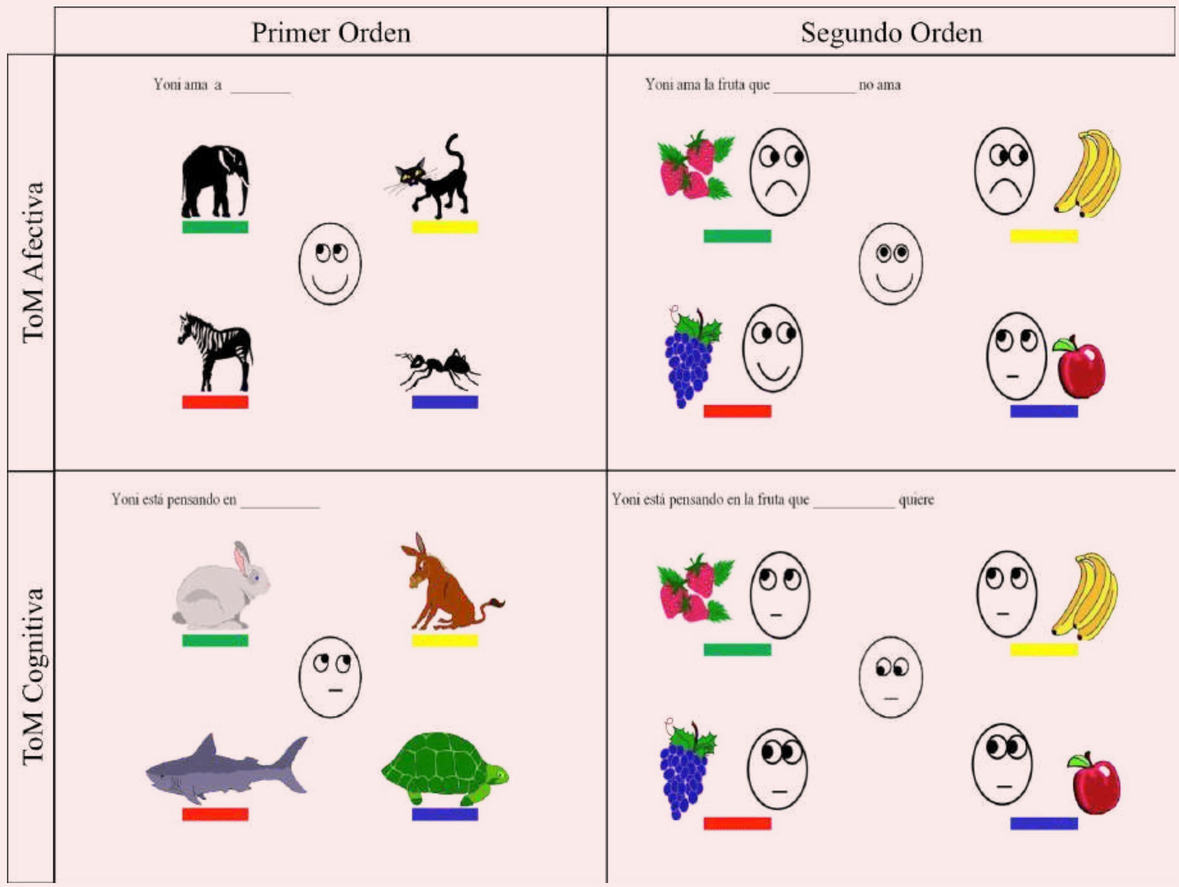

Figure 1. Sample of items: cognitive and affective conditions first and second level

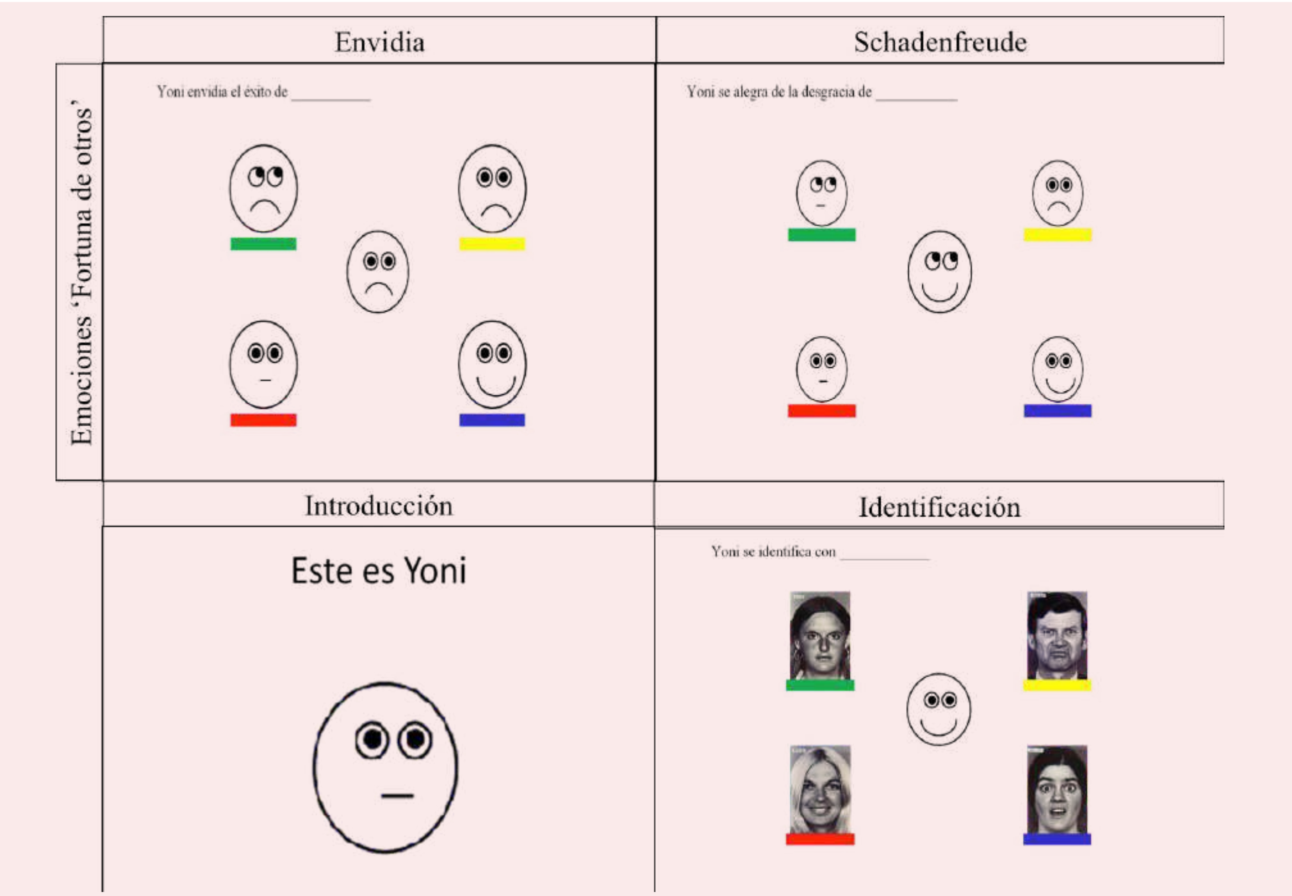

Figure 2. Sample of items: envy, schadenfreude and control conditions

Iowa Gambling Task (IGT) (Bechara et al., 1994)

The IGT was administered to assess decision-making under conditions of ambiguity. A computer version of the Iowa Gambling Task (IGT) was employed (Bechara et al., 1994). Briefly, the task consisted of 100 trials, and in each of these, the PD patients could choose one card out of four possible decks (decks A, B, C, or D). Each election, the patient could win or lose money from an initial amount ($2000; Gansler, Jerram, Vannorsdall, & Schretlen, 2011). The program of winning or losing for decks was distributed in advantageous decks (C and D decks) associated with smaller wins ($50 per trial) but smaller losses. On the other hand, decks A and B are associated with disadvantageous decks characterized by large wins ($100 per trial) and large losses (Gescheidt et al., 2012). It is possible to assess the number of choices from the deck. The total score of IGT entails subtracting the disadvantageous decks from the advantageous decks (CD - AB). However, in addition, some studies suggest to analyze in five blocks of 20 trials each (trial 1-20 [Block A]; 21-40 [Block B]; 41-60 [Block C]; 61- 80 [Block D] and 81 - 100 [Block E]). (Gansler et al., 2011).

Data analysis We calculated Mean or Median, Standard Deviation and Standard Error of the Mean (SEM) for each component of ToM and IGT tasks. Because of the non-normal distribution and limited sample size, non-parametric tests were used. In the ToM task, Kruskal-Wallis variance analysis was used to determine differences between groups. Then, the group of subjects was split based in the median value - ToM below and above Median - so the tendency of the two groups could be compared. A non-parametric Phi and Cramer's V test was used to determinate differences.

To explore relations between components of ToM (affective, cognitive, first and second order), Spearman Rho coefficient correlations were used for each group (PD, DBS-PD, HC).

Regarding the IGT task, U-Mann Whitney non-parametric tests were used to determinate differences between groups. Repeated measures ANOVA was used to compare performance across block of trials. The level of significance was established at .05.

Results

Theory of Mind

Mean performance on the ToM task across groups is shown in Table 2. There were no statistically significant differences comparing the three groups (see all statistical test in Table 2). However, visual inspection of Figure 3 shows that the HC group has higher scores in the majority ToM components, i.e., affective (first and second level), cognitive (first and second level), combined affective and cognitive, social emotions recognition (envy and schadenfreude), and control trials.

Tabla 2 : *Descriptive data of three groups in each category in ToM*

Category	PD *Mean (SD)*	*SEM.*	PD-DBS *Mean (SD)*	*SEM*	HC *Mean (SD)*	*SEM.*	K-W Sig.
AFFTOTAL	43.12 (13.87)	5.32	50.55 (8.95)	4.48	56.02 (6.63)	2.96	.173
Aff1	41.97 (12.42)	6.21	52.41 (8.96)	4.48	54.50 (5.34)	2.39	.170
Aff2	42.93 (10.46)	5.23	48.98 (8.27)	4.13	56.48 (7.95)	3.56	.174
COGTOTAL	43.12 (13.87)	6.90	50.82 (8.76)	4.38	54.85 (4.55)	2.04	.295
Cog1	41.81 (16.05)	8.02	52.71 (3.35)	1.68	54.38 (0.00)	0.00	.193
Cog2	47.92 (9.73)	4.86	47.92 (13.25)	6.63	53.32 (8.66)	3.87	.538
CogAff2	45.00 (8.82)	4.41	47.50 (12.28)	6.14	56.00 (7.22)	3.23	.256
FISTOTAL	43.78 (12.28)	6.14	51.68 (9.94)	4.97	53.65 (7.39)	3.30	.266
Fis1	46.84 (17.51)	8.75	51.41 (4.98)	2.49	51.41 (6.10)	2.73	.969
Fis2	44.64 (4.85)	2.42	50.98 (12.06)	6.03	53.51 (11.32)	5.06	.230

SD = standard deviation; PD = Parkinson's disease; PD-DBS = Parkinson's disease with Deep Brain Stimulation; HC = healthy controls. Aff 1 and 2 (affective first and second level respectively), Cog1 and 2 (cognitive first and second level), Fis1 and 2 (control items)

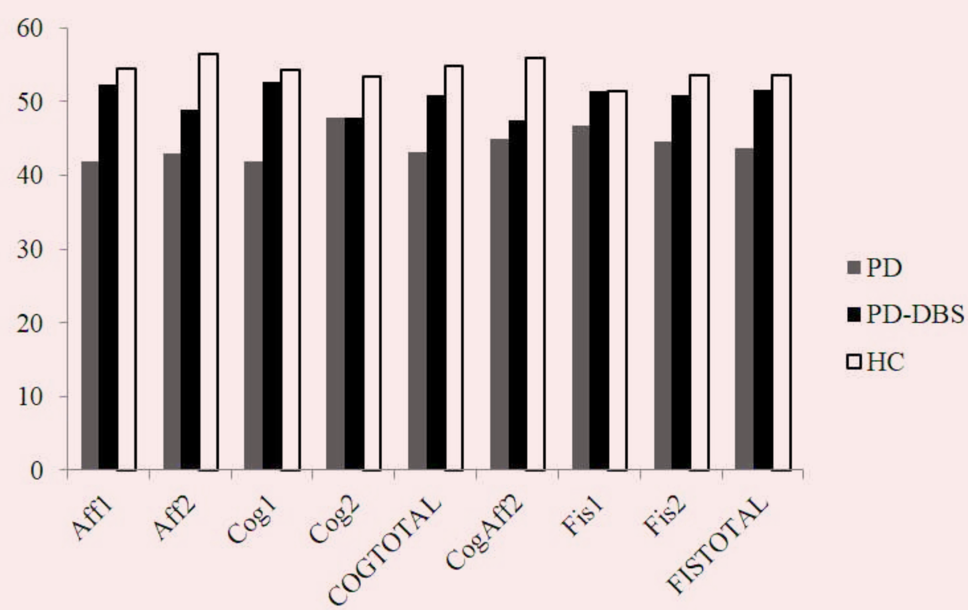

Figure 3. The mean scores on the Theory of Mind Task

To test if the tendency for differences in the Yoni Task was consistent, we split the group of subjects using the Median score – “below the median” and “above the median” – and compared performance in the Identification variable. Phi and Cramer’s V test showed that the PD group was significantly lower than PD-DBS and HC (Phi = .86; p = .008) (Figure 4).

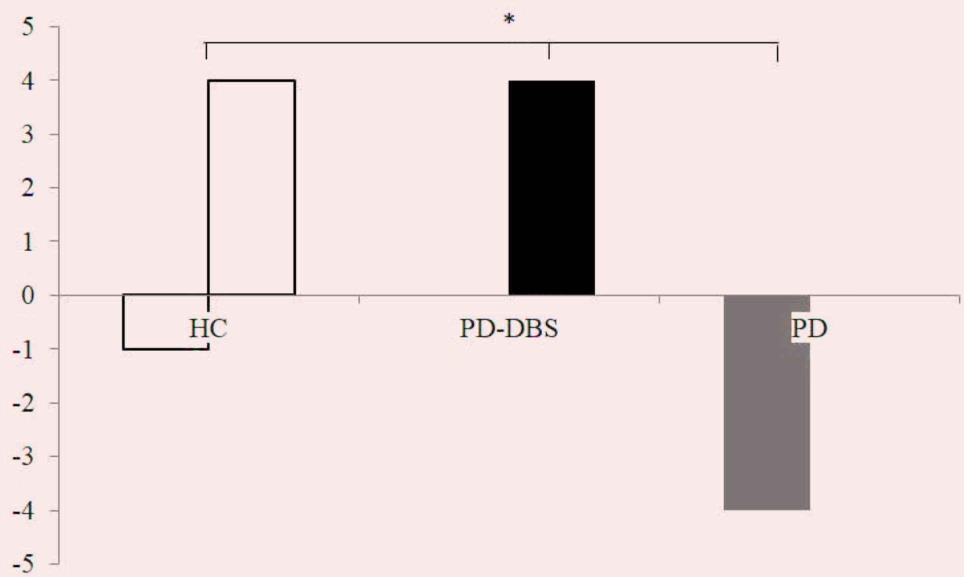

Figure 4. Data group splitting the groups according to the median score in identification variable (= Φ,008*). HC = Healty Control, four subjects above and one below of median; PD-DBS = Parkinson Disease – Deep Brain Stimulation group, four patients above median; PD = Parkinson Disease, four patients below median.

Spearman Rho coefficient correlations for each group (PD, DBS-PD, HC) were used to explore relations between components of ToM (affective, cognitive, first and second order). The score of the affective component in second level (Aff2) of the Yoni task significantly correlated with schadenfreude in PD (rho = .949, p < .001) and PD-DBS groups (rho = .949, p < .001).

IGT total scores

Validation of IGT task by the software resulted in that three of the five data of the HC group were excluded from analysis. Accordingly, we only analyzed PD and DBS-PD groups data.

Mann-Whitney U test was used to determinate whether PD and PD-DBS groups differed in IGT total scores. A significant difference was found in total net scores (U= 2.0; p = 0.048), with PD-DBS group showing a higher score (M = 10.8; SEM = 4.128) than PD group (M= -8; SEM = 10.132) (figure 5). This difference based on all 100 trials suggests PD and DBS-PD patients chose dissimilar strategies.

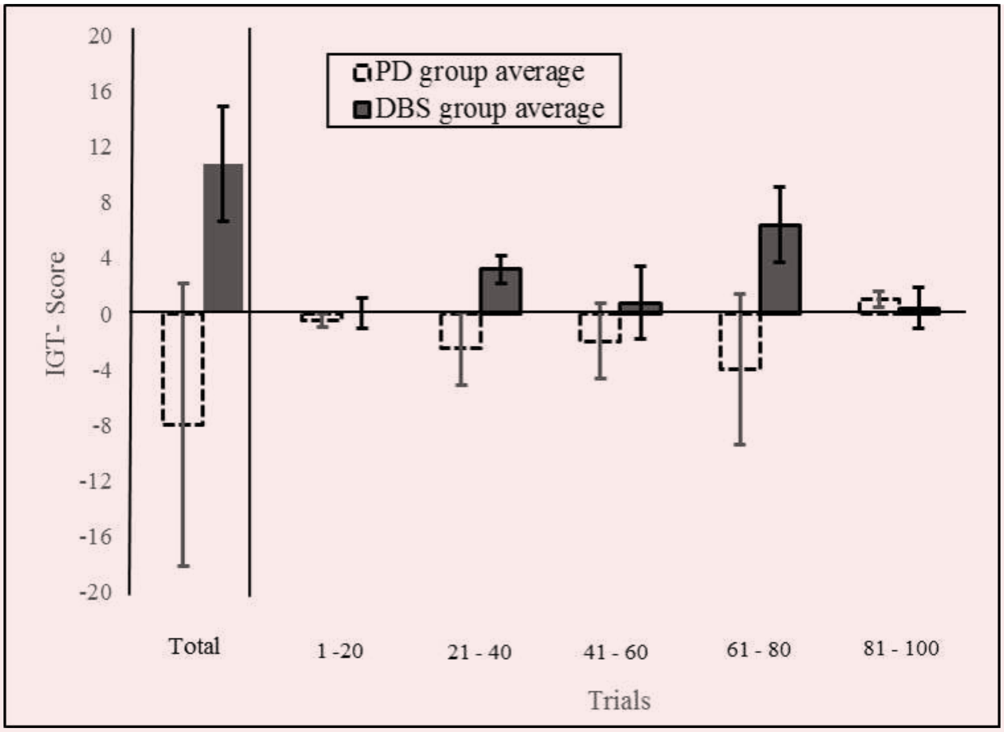

Figure 5. IGT scores during the Iowa Gambling Task performance

In addition, total net scores indicate that both groups (PD and PD-DBS) lost money, which indicates a bad choice strategy. However, a significant difference between two groups was found (M-W *U test:* $U = 1.0$; $p = .027$), which showed fewer losses in PD-DBS ($M = -44.64$; $SEM = 283.85$) than in PD ($M = -1532.5$; $SEM = 411.95$). With respect to T net score, there was no significant difference between the two groups (M-W *U test:* $U = 5.5$; $p = .266$).

IGT series

IGT scores close to zero resulting from subtraction of CD - AB decks suggest a random strategy. We found that choices tended to be random (block A) ($p > .05$) at the beginning of the task (see Figure 5). This pattern has been also observed in healthy subjects (Gescheidt et al., 2012).

Repeated measures ANOVA with blocks (1-5) as within-subject factors and groups (DBS-PD, PD) as between-subject factors was carried out on the frequency of choice of advantage (CD) and disadvantage decks (AB). The difference between decks was non-significant ($F_{(1, 7)} = .078$; $p = .789$), neither the decks*group interaction ($F_{(1, 7)} = 3.496$; $p = .104$). Again, although this difference between decks was not significant, the net total score of the PD-DBS group was above zero, which entails that chose more cards from the advantage deck ($M = 25.2$; $SEM =$

1.31) than PD group (*M* = 21.25; *SEM* = 1.25).

Discussion

This study aimed to compare decision-making and Theory of Mind (cognitive and affective components) across patients with PD and PD-DBS, and HC. Although the therapy's device was located in the STN, we hypothesized that the DBS group could show differences, due to the fact that the electric stimulation in STN could be related to differences in the functioning of prefrontal and limbic areas (Valls-Solé et al., 2008).

We did not find significant differences of ToM in affective and cognitive scores across the three groups (PD, PD-DBS, and HC). Probably this is due to the fact that the PD and PD-DBS patients were in the moderate phase of the disease (M = 6.5 years). According to Péron et al. (2009), advanced PD (more than 10 years) could present impairment in affective and cognitive ToM due dopaminergic deficit rather than damage in neural circuits. Despite not obtaining significant differences, the PD group showed the lower scores in all categories of ToM tasks in comparison to PD-DBS and HC. The PD-DBS group had similar scores to HC. Reaction times (RT) were similar across the groups, though HC had better performance than PD, which suggests anticipation and preparation of actions more altered in PD patients (Valls-Solé et al., 2008).

Although there is a meta-analysis that reports social cognition alterations in PD patients in the earliest stages (Palmeri et al., 2017), our small sample size and variability in stages of disorder of our patients limits our conclusions in this regard. In similar reports on social cognition alterations in PD patients, Perón et al. (2010) showed that DBS procedure had a negative impact on affective ToM. However, our results are consistent with studies that compared PD-DBS patients, PD patients with dopaminergic replacement therapy, and HC and found that DBS treatment does not affect social cognitive abilities (Enrici et al., 2017).

PD-DBS group presented a lower score in another ToM measure related to social emotions or fortune to others. Such lower score may imply that those processes depend on the connection with other structures, such as the temporal area, inferior parietal lobe, and anterior insula. All these areas could be involved in a network of complex mental states that may be altered by DBS procedure (Shamay-Tsoory & Aharon-Peretz, 2007). Social emotions have not been studied in depth in PD patients with DBS, which leaves open the possibility other mechanism could be altered with the procedure. Lastly, PD group had better scores in social emotions identification, which suggests a relationship between ToM and the limbic circuit (Raffo De Ferrari et al., 2015).

With respect to decision-making, we investigated whether or not these groups differed in their execution to wins or losses during the IGT task. Some studies have reported alterations in processes of decision-making in PD patients (Biundo et al., 2016; Castrioto et al., 2015; Mimura et al., 2006). Functionally, the alteration can be explained by injury in medial OFC and amygdala, with its main role the integration of emotional and cognitive information in decisions (Gansler et al., 2011; Ibarretxe-Bilbao et al., 2009; Manes et al., 2002; Thiel et al., 2003). It is worth noting that neither OFC nor the amygdala are involved directly in PD, but execution and neuroanatomical structures have been compared (Evens et al., 2016; Kobayakawa et al., 2010). The key structure seems to be the Subthalamic Nuclei (STN); not only it has motor functions, but also motivational and cognitive functions (Evens et al., 2015). Studying PD and PD-DBS in the present study allowed us to see similar performances comparing these groups, but with higher scores in patients with DBS.

Regarding dopaminergic impairment, it has been reported that alterations in decision-making occur concurrently with symptoms of enhancement of dopamine in PD patients (Castrioto et al., 2015; Evens et al., 2016). In our study, we found that patients without DBS show a lower performance in comparison to PD-DBS patients, which is align with findings of studies where PD patients without dementia are analyzed (Castrioto et al., 2015; Kobayakawa et al., 2008, 2010; Pagonabarraga et al., 2007; Poletti, Cavedini, & Bonuccelli, 2011). Castrioto et al. (2015) showed that when comparing the performance of patients before and three month after DBS surgery, there is a change in IGT strategy and scores, but changes similar are not found with dopaminergic agonist therapy (Castrioto et al., 2015; Evens et al., 2016; Oyama et al., 2011; Poletti, Cavedini, & Bonuccelli, 2011).

It is worth noting that measurement of performance solely using IGT total scores has some limitations, because the subject's decision could consist of randomly selecting decks (Gansler et al., 2011; Gescheidt et al., 2012; Poletti, Cavedini, Bonuccelli, et al., 2011). Accordingly, block analysis is a more detailed approach frequently reported (Gescheidt et al., 2012). In the first block of the IGT, the participants of the present study developed a strategy (Gescheidt et al., 2012; Pagonabarraga et al., 2007), and both PD and PD-DBS patients showed similar performances. In the second and fourth blocks, no significant differences were found between PD and PD-DBS patients. However, PD-DBS group overall performed better than PD patients, which replicates the finding o f other studies (Evens et al., 2015, 2016; Poletti, Cavedini, &

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Our results suggest differences in decision-making processes between a PD group without stimulator and a PD-DBS group. The stimulator seemed to have enhanced the decision-making strategy by changing the processing of reinforcement and punishment (Castrioto et al., 2015; Evens et al., 2015), which resulted in patients scoring higher. This change in performance could involve alterations in sensitivity to punishment (reduced) and reinforcement (increased) (Kobayakawa et al., 2010). This is in line with the findings of other studies with punishment, which showed changes in skin conductance and event-related potentials (Kobayakawa et al., 2008, 2010; Mapelli et al., 2014).

In Latin America, few studies have compared the non-motor symptoms of PD patients, against HC groups (Barbosa, 2013; Gómez et al., 2017; Leiva et al., 2019; Palacios Sánchez et al., 2019), even less have tried such comparisons after DBS intervention (Pérez de la Torre et al., 2016). However, the main limitation of the present study was the small sample size in each group. This difficulty resulted from the fact that participants were older adults that depended of a relative or caregiver. Accordingly, patients' availability was conditional on medical treatment, health condition and socio-economic status. In the DBS-PD group, the main limitation was finding patients with the implanted stimulator but no other comorbidities related to advanced aging (e.g., dementia). Finally, although HC group was matched by age and educational level to PD and PD-DBS groups, it was difficult to match other conditions (i.e., socio-economic, health conditions, etc.) found in PD patients.

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Conflict of Interest

The authors have no conflict of interest to report

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