TOPIC - Temi di Psicologia dell'Ordine degli Psicologi della Campania
V. 4 N. 1 (2025)
https://doi.org/10.53240/2025topic4n1.0.001

Alterazioni della Rappresentazione Mentale del corpo in pazienti con Malattia di Parkinson

Mental body Representation alterations in patients with Parkinson's Disease

Chiara Alves[1], Giovanni Luca Di Benedetto[1], Mariachiara Gaita[1], Simona Raimo[2], Liana Palermo[2], Gabriella Santangelo[1], Alfonsina D'Iorio[1]

[1] *Dipartimento di Psicologia, Università degli Studi della Campania "Luigi Vanvitelli", Caserta, Italia.*

[2] *Dipartimento di Scienze Mediche e Chirurgiche, Università "Magna Graecia" di Catanzaro, Catanzaro, Italia*

Abstract

La rappresentazione mentale del corpo (RMC) è un dominio cognitivo complesso che include caratteristiche corporee di tipo strutturale, spaziale, lessicale e semantico. Una tassonomia ampiamente accettata in letteratura distingue tra due tipi di RMC: una "orientata all'azione", relativa alla pianificazione, all'esecuzione e al monitoraggio dei movimenti, e una "non orientata all'azione", riguardante, ad esempio, il riconoscimento delle parti del corpo, la conoscenza delle loro relazioni spaziali e l'autoconsapevolezza. Attualmente, pochi studi hanno indagato le alterazioni della RMC nei pazienti con Malattia di Parkinson (MP), producendo peraltro risultati discordanti. Pertanto, il presente lavoro intende esplorare ulteriormente e chiarire le alterazioni della RMC nei pazienti con MP. A tale scopo, 25 pazienti con MP e 24 controlli sani sono stati sottoposti ad una batteria neuropsicologica per valutare il funzionamento cognitivo globale, la RMC, la comparsa di sintomi depressivi, ansiosi e apatici, nonché i disturbi del controllo degli impulsi. Complessivamente, i risultati hanno evidenziato una maggiore compromissione della RMC nei pazienti rispetto ai controlli sani, suggerendo una difficoltà caratteristica dei primi nella rappresentazione mentale delle caratteristiche corporee. Infine, sono emerse correlazioni significative tra le abilità di RMC e la stadiazione della malattia e tra le abilità di RMC ed il funzionamento cognitivo globale, suggerendo che la RMC peggiori con la progressione della MP e lo stato cognitivo globale dei pazienti.

Parole chiave

Malattia di Parkinson; Rappresentazione Mentale del corpo; Rappresentazione corporea orientata all'azione; Schema corporeo; Rappresentazione corporea non orientata all'azione; Immagine corporea.

Autore responsabile per la corrispondenza: Chiara Alves, Dipartimento di Psicologia, Università degli Studi della Campania "Luigi Vanvitelli", Caserta, Italia, e-mail: chiara.alves@studenti.unicampania.it.

https://doi.org/10.53240/2025topic4n1.0.001

Abstract

Mental body representation (MBR) is a complex cognitive domain that includes structural, spatial, lexical and semantic body features. A widely accepted taxonomy in the literature distinguishes between two types of MBR: "action-oriented" MBR, relating to the planning, execution and monitoring of movements, and "non-action-oriented" MBR, concerning, for example, the recognition of body parts, knowledge of their spatial relations and self-awareness. Currently, few studies have investigated MBR alterations in patients with Parkinson's Disease (PD), producing however discordant results. Therefore, the present work aims to explore and clarify further the alterations of MBR in patients with PD. To this end, 25 patients and 24 healthy controls underwent a neuropsychological battery to assess global cognitive functioning, MBR, the occurrence of depressive, anxious and apathetic symptoms, along with impulsive-compulsive disorders. Overall, results showed a greater impairment of MBR in patients with PD compared to healthy controls, suggesting a characteristic difficulty of the former to mentally represent body features. Finally, significant correlations emerged between MBR abilities and disease staging and between MBR abilities and global cognitive functioning, suggesting that MBR worsens according to PD progression and the global cognitive status of patients.

Keywords

Parkinson's Disease; Mental body representation; Action-oriented body representation; Body schema; Non-action-oriented body representation; Body image.

Introduction

Parkinson's disease (PD) is the most common movement disorder and the second most prevalent neurodegenerative disease after Alzheimer's disease (Aarsland et al., 2021), affecting over 6 million people worldwide; in fact, it is currently recognized as one of the leading causes of neurological disability (Tolosa et al., 2021).

The typical onset occurs between the ages of 60 and 65; however, earlier onset is also observed (Kolicheski et al., 2022), as well as a higher prevalence in males than females (Bloem et al., 2021).

PD is primarily characterized as a movement disorder due to the distinctive presence of motor symptoms, which are considered hallmark clinical signs as well as the foundation of current diagnostic criteria (Jankovic, 2008; Tolosa et al., 2021). These symptoms result directly from nigral degeneration and striatal dopamine depletion (Jankovic, 2008; Tolosa et al., 2021) and include both primary symptoms—such as resting tremor, rigidity, akinesia/bradykinesia, and postural instability—and secondary symptoms, including gait disturbances, micrographia, hypomimia, dysarthria, and dysphagia (Tolosa et al., 2021).

However, PD is also associated with a wide range of non-motor symptoms. Although these are not considered core diagnostic features, they are regarded as supportive criteria (Postuma et al., 2015; Váradi, 2020) and, unlike motor symptoms, they are linked to neurodegeneration in extranigral sites such as the brainstem, olfactory bulb and peripheral autonomic nervous system (Tolosa et al., 2021). These non-motor symptoms can be categorized as follows: a) autonomic dysfunctions, including cardiovascular, gastrointestinal, urinary, sexual, and thermoregulatory disturbances (Pfeiffer, 2020); b) somatosensory deficits, such as paresthesia, anosmia/hyposmia, and ageusia/dysgeusia (Váradi, 2020); c) sleep disorders, including circadian rhythm disruptions, insomnia, REM sleep behavior disorder, excessive daytime sleepiness, restless legs syndrome, and obstructive sleep apnea (Xu et al., 2022); d) neuropsychiatric symptoms, including depression, anxiety, apathy, impulse control disorders, and psychosis (Weintraub et al., 2022); e) cognitive impairments, ranging from both subjective and mild cognitive decline to dementia (Aarsland et al., 2021).

The clinical manifestation of PD is highly heterogeneous in terms of both manifested symptomatology and disease progression (Greenland et al., 2019); however, non-motor symptoms often precede motor symptoms, marking the prodromal phase of the disease, which may last over 20 years. This phase is typically characterized by non-specific symptoms such as REM sleep disturbances, constipation, and hyposmia (Bloem et al., 2021).

The etiological mechanisms of PD remain poorly understood (Yang et al., 2020). It is widely reported (Hauser & Hastings, 2013; Bloem et al., 2021; Gopar-Cuevas et al., 2021) that only 5–15% of cases are hereditary and classified as "monogenic" or "familial", while most cases are "idiopathic" or "sporadic", lacking a clear genetic link and instead arising from interactions between genetic, epigenetic, and environmental factors (Simon et al., 2020; Jankovic & Tan, 2020).

The pathogenetic mechanisms are also not yet fully elucidated (Yang et al., 2020). PD is defined by the loss of dopaminergic neurons in the substantia nigra pars compacta and the mesencephalic spread of Lewy bodies and Lewy neurites (Armstrong & Okun, 2020; Lo, 2021); however, several mechanisms have been proposed to explain PD pathogenesis, including α-synuclein aggregation, oxidative stress, neuroinflammation, impaired autophagy, mitochondrial dysfunction, and widespread disruptions of neurotransmitter systems—primarily dopaminergic, but also noradrenergic, serotonergic, GABAergic, and cholinergic (Miguelez et al., 2020).

Currently, no disease-modifying therapies are available; treatment is symptomatic, targeting both motor and non-motor manifestations' attenuation (Balestrino & Schapira, 2020; Armstrong & Okun, 2020). Available therapeutic approaches include both pharmacological and non-pharmacological strategies, tailored to the specific symptoms. For motor symptoms, effective interventions include dopaminergic medications (Armstrong & Okun, 2020), deep brain stimulation (Balestrino & Schapira, 2020; Hariz & Blomstedt, 2022), focused ultrasound ablation (Armstrong & Okun, 2020; Stefani et al., 2022), physical exercise (Bloem et al., 2021), and physiotherapy (Bloem et al., 2021). For non-motor symptoms, interventions such as non-dopaminergic pharmacotherapy (Armstrong & Okun, 2020), cognitive training (Orgeta et al., 2020), physical therapy (Sun & Armstrong, 2021), cognitive-behavioral therapy (Seppi et al., 2019), non-invasive brain stimulation (Seppi et al., 2019), and occupational therapy (Tofani et al., 2020) have shown effectiveness.

Despite the vast literature on PD, one underexplored and controversial aspect remains the relationship between PD and body representation. Mental body representation (MBR) is a complex cognitive domain that includes structural (what the body looks like and what its parts are), spatial (extent of the body and location of body parts), lexical (names of body parts) and semantic (encyclopedic knowledge about the body and its various parts) features related to the body (Grossi & Trojano, 2011; Schwoebel & Coslett, 2005); this domain is

https://doi.org/10.53240/2025topic4n1.0.001

based on the processing and integration of stimuli from interoceptive and exteroceptive sources of information (Park & Blank, 2019; Raimo et al., 2021b), which are continuously updated to create the body construct (Vastano et al., 2022).

Given the complexity of this construct, the idea of the existence of multiple bodily representations is widely accepted (Berlucchi & Aglioti, 2010). A pioneering attempt in this direction was made over a century ago by Head and Holmes (1911), who proposed two distinct types of body representation: one dedicated to posture and passive movement and the other related to the localization of body parts. Subsequently, Gallagher (1986) developed a dyadic taxonomy based on the functional distinction between the "body schema", a sensorimotor representation of the body that guides actions and enables the unconscious regulation of posture and movement, and the "body image", which comprises perceptual, conceptual, or emotional representations of the body that are not employed for action. Later, Schwoebel and Coslett (2005) introduced a triadic taxonomy, which retained previous notions while proposing a finer distinction within the body image; specifically, the body image was further divided into the "structural body representation", a visuo-spatial map of the body that includes information about the boundaries of body parts and their spatial relationships, and the "semantic body representation", a conceptual and linguistic representation of the body that encompasses the names and functions of body parts as well as their associations with objects.

Although a universally agreed-upon taxonomy has yet to be established (De Vignemont, 2010; Di Vita et al., 2016), a functional differentiation between a "dynamic" or "action-oriented" MBR (body schema) and "static" or "non-action-oriented" MBR (body image) — with the former referring to body representations involved in movement planning, execution and monitoring, and the latter pertaining to body representations dedicated to the recognition of body parts, the knowledge of their spatial properties and self-awareness — is almost uncontroversial (Di Vita et al., 2016; Pitron & de Vignemont, 2017; Raimo et al., 2021b; Raimo et al., 2021c). Overall, the body schema and the body image can be differentiated according to the type of information conveyed about the body and their functions. Specifically, the body schema serves as a reference framework for planning, monitoring, and controlling body configurations and movements; to fulfill this function, it leverages past somatosensory experiences to generate mental representations of typical sensorimotor configurations, which are then used to assess the body's current states. Conversely, the body image refers to the pictorial aspects of the body and relies heavily on prior visual experiences, including the mental representation of one's body as seen from an external perspective (Martinez et al., 2022); in other words, it constitutes the subjective image that individuals have of their own body, regardless of its actual appearance and, as such, it encompasses thoughts, emotions, evaluations and behaviours related to one's body (Hosseini & Padhy, 2023). An open question in the literature concerns the relationship between these two constructs. The "fusion model" posits the existence of a single, multifunctional long-term body representation, which spatially frames bodily experiences and guides body movements. In contrast, the "independence model" assumes the presence of two functionally distinct long-term body representations that are constructed separately: one action-oriented and the other perception-oriented (Pitron & de Vignemont, 2017). A more

https://doi.org/10.53240/2025topic4n1.0.001

recent alternative to these models is the "co-construction model," which maintains a functional distinction between the body schema and the body image, while also proposing that their development is partially shaped by their interactions. From this perspective, MBR are co-constructed yet separate, rather than being entirely independent or fully integrated (Pitron & de Vignemont, 2017).

Distortions of MBR are a prominent feature of numerous clinical disorders (Longo, 2022; Palermo & Di Vita, 2023). Indeed, they are observed in various psychiatric conditions, such as eating disorders (McLean & Paxton, 2019; Longo, 2022), schizophrenia (Graham-Schmidt et al., 2016; Costantini et al., 2020), body dysmorphic disorder (Tomas-Aragones & Marron, 2016), and Body Integrity Dysphoria (Turbyne et al., 2021); they are also present in several neurological conditions, including stroke (Schwoebel & Coslett, 2005; Razmus, 2017; Raimo et al., 2022); frontotemporal dementia (Snowden et al., 2012; Downey et al., 2014), multiple sclerosis (Pfaffenberger et al., 2011; Nava et al., 2018; Di Cara et al., 2019; Raimo et al., 2024).

Otherwise, alterations of MBR in Parkinson's disease (PD) are not much explored and the few studies conducted so far on this theme have yielded conflicting results, with some suggesting an impairment of the ability to mentally represent one's own body, especially with respect to its more implicit component (Dominey et al., 1995; Helmich et al., 2007; Bek et al., 2022), and others indicating a limited impairment of MBR to its more explicit component (Scarpina et al., 2019) or a total preservation of this cognitive function (van Nuenen et al., 2012).

Therefore, the present work aimed at further exploring and clarifying alterations of MBR in patients with PD, firstly considering that body schema is an essential factor for proper daily life functioning, as its deficits could affect motor planning and execution processes, thus promoting motor deficits (Abraham et al., 2021). Hence, understanding how patients with PD access the representation of their body "is of uttermost importance to further develop treatments and to allow patients to have a better chance at managing physical changes associated with the condition" (Scarpina et al., 2019).

Method

Participants

The present study involved a total of 49 participants: 25 patients with PD (13 male participants and 12 female participants) and 24 healthy controls (8 male participants and 16 female participants).

Outpatients from IDC-Hermitage Capodimonte in Naples, Italy, were enrolled according to the following inclusion criteria: (1) a diagnosis of idiopathic PD according to the clinical diagnostic guidelines (Gelb et al., 1999); (2) presence of global cognitive efficiency, indicated by a score > 15.5 on the Italian version of the Montreal Cognitive Assessment (Santangelo et al., 2015); and (3) absence of other neurological and/or psychiatric diseases.

Healthy controls were enrolled according to the following inclusion criteria: (1) age between 40 and 80 years; (2) presence of global cognitive efficiency, indicated by a score > 15.5 on the Italian version of Montreal Cognitive Assessment (Santangelo et al., 2015); and (3) absence of previous or actual diagnoses of neurological and/or psychiatric diseases.

Demographic data (i.e., sex, age, years of education) and clinical characteristics such as disease duration and severity of motor symptoms assessed by both the UPDRS part III (Fahn et al., 1987) and Hoehn and Yahr staging (H&Y; Hoehn & Yahr, 1967) were recorded.

https://doi.org/10.53240/2025topic4n1.0.001

All participants provided written informed consent. The study was approved by the local ethics committee and conducted in accordance with the ethical standards set by the 1964 Declaration of Helsinki and subsequent amendments.

Measures

Participants underwent a neuropsychological battery to assess global cognitive functioning, MBR, the occurrence of depressive, anxious and apathetic symptoms, along with impulsive-compulsive disorders.

The global cognitive functioning was assessed using both the Italian version of Montreal Cognitive Assessment (Santangelo et al., 2015), that has been proven to be most suitable test for detecting mild and major cognitive decline in PD (Lucza et al., 2015), and the Parkinson's Disease Cognitive Rating Scale – Alternative Form (D'Iorio et al., 2022), that has been proven to be the optimal PD-specific scale for detecting early cognitive deficits in PD and tracking the transition to PD dementia (Chou et al., 2010). Specifically, Montreal Cognitive Assessment is a screening test consisting of 30 items exploring eight cognitive domains: short- and long-term verbal memory, visuo-spatial skills, executive functions, attention, concentration, working memory, language, spatial and temporal orientation. Parkinson's Disease Cognitive Rating Scale – Alternative Form is a PD specific screening test consisting of 9 items, evaluating both fronto-cortical (naming and clock copy) and fronto-subcortical (immediate verbal memory, sustained attention, working memory, clock drawing, delayed free recall, alternating verbal fluency and action fluency) functions. The combined use of both Montreal Cognitive Assessment and Parkinson's Disease Cognitive Rating Scale – Alternative Form enabled us to achieve a more comprehensive and accurate cognitive assessment of the patients with PD, as well as to be sure that they had the necessary cognitive resources to undertake MBR tasks; by confirming adequate cognitive functioning through these tools, we can be confident in the validity of the experimental findings related to body representation tasks.

The MBR was evaluated using a computer-based battery developed by Raimo et al. (2021a) that has been proven useful in identifying MBR deficits in different clinical conditions (for stroke, see Raimo et al., 2022; for multiple sclerosis, see Raimo et al., 2024). The battery includes the Frontal Body Evocation task (a modified version of the test by Daurat-Hmeljak et al., 1978), assessing non-action-oriented MBR, and the Hand Laterality Task (modified and simplified from the version by Parsons, 1987; see also Fontes et al., 2014), evaluating action-oriented MBR (for details see Raimo et al., 2021a, Raimo et al., 2022). In the Frontal Body Evocation task, participants are asked to correctly position nine specific body parts (left and right leg, left and right hand, left and right arm, left and right-side chest and neck), having as a reference point only a head. Otherwise, in the Hand Laterality Task, participants are required to decide on the laterality of twenty rotated hands (for details, see Raimo et al., 2021a). The battery also includes two computer-based control tasks, that allow to evaluate the MBR independently of task-specific aspects (i.e., visual processing, mental imagery, visuo-spatial attention, decision making, etc.): the Christmas Tree Task and the Object Laterality Task. The Christmas Tree Task involves the visuospatial processing of non-body stimuli, as participants are asked to correctly position nine specific parts of a Christmas tree (upper left and right branch, middle left and right branch, lower left and right branch, left and right part of the pot and the top

https://doi.org/10.53240/2025topic4n1.0.001

tip), having as a reference point the star at the tip of the tree. Differently, the Object Laterality Task involves the mental rotation of non-body stimuli, as participants are required to decide on the laterality of twenty rotated flowers (for details, see Raimo et al., 2021a). The combined use of both Hand Laterality Task and Frontal Body Evocation task enabled us to comprehensively investigate MBR and to delineate a more detailed cognitive-representational profile of patients with PD; moreover, the implementation of both Object Laterality Task and Christmas Tree Task allowed us to isolate and account for specific cognitive domains—namely attentional, linguistic, and perceptual functions—that are common across all mental representation tasks, both related and non-related to the body.

Depression was assessed using the Beck Depression Inventory-II (Beck et al., 1996), which has been found to be reliable and valid for the measurement of depression in patients with PD (Maggi et al., 2023). It is a self-report questionnaire consisting of 21 items measuring the intensity of depressive symptoms considering the last two weeks.

Apathy was evaluated using the Italian Dimensional Apathy Scale (Santangelo et al., 2017a), a self-report questionnaire consisting of three subscales: executive subscale, assessing apathy associated with planning, attention or organisation, emotional subscale, assessing apathy associated with altered emotion integration, and behavioural/cognitive initiation subscale, assessing apathy associated with loss of self-generation of behaviours or cognition.

Anxiety was assessed using the Observer Rated - Parkinson Anxiety Scale (Santangelo et al., 2016), a PD specific questionnaire exploring the presence and the severity of anxiety through three subscales: persistent anxiety, episodic anxiety and avoidance behaviour.

Finally, impulsive-compulsive disorders were evaluated using the Italian version of the Questionnaire for Impulsive-Compulsive Disorders in Parkinson's Disease - Rating Scale (Maggi et al., 2024), a rating scale designed to measure the severity of symptoms of impulse control disorders and related disorders in PD, considering different behavioural categories: gambling, sex, buying, eating, hobbism-punding and PD medication use.

Overall, behavioral assessment tools (Beck Depression Inventory-II, Italian-Dimensional Apathy Scale, Observer Rated - Parkinson Anxiety Scale, Questionnaire for Impulsive-Compulsive Disorders in Parkinson's Disease - Rating Scale) were included to explore potential correlations with MBR abilities, as well as to investigate their possible influence on MBR. Indeed, it is well-established in the literature that symptoms such as depression (Santangelo et al., 2009), apathy (Santangelo et al., 2018), anxiety (Ehgoetz Martens et al., 2018), and impulse control disorders (Santangelo et al., 2017b) are associated with cognitive functioning, sometimes exerting an influence on it, in patients with PD. This investigation is crucial for identifying additional pathological markers of a such multifaceted disease.

Statistical analyses

Mann-Whitney test was conducted to compare patients with PD and healthy controls' performances with respect to cognitive tasks and behavioural measures (Montreal Cognitive Assessment, Parkinson's Disease Cognitive Rating Scale – Alternative Form, Frontal Body Evocation, Hand Laterality Task, Christmas Tree Task, Object Laterality Task, Beck Depression Inventory-II, Italian-Dimensional Apathy Scale, Observer Rated - Parkinson Anxiety Scale and Questionnaire for Impulsive-

Compulsive Disorders in Parkinson's Disease - Rating Scale).

In addition, three different non-parametric bivariate correlation analyses with Spearman's rho index were conducted for the patient group. Specifically, the first analysis explored the possible association between MBR tasks (Frontal Body Evocation and Hand Laterality Task) and clinical characteristics of patients with PD (duration of the disease, severity of motor symptoms on the UPDRS-III and staging of disease on the H&Y scale). The second analysis investigated the possible correlation between MBR tasks (Frontal Body Evocation and Hand Laterality Task) and cognitive variables (Montreal Cognitive Assessment and Parkinson's Disease Cognitive Rating Scale – Alternative Form). The third analysis explored the relationship between MBR tasks (Frontal Body Evocation and Hand Laterality Task) and behavioral measures (Beck Depression Inventory-II, Italian-Dimensional Apathy Scale, Observer Rated - Parkinson Anxiety Scale and Questionnaire for Impulsive-Compulsive Disorders in Parkinson's Disease - Rating Scale).

Moreover, stepwise regression analyses were conducted for the patient group to identify clinical and cognitive predictors for each of the two MBR tasks (Frontal Body Evocation and Hand Laterality Task). Specifically, H&Y scores were included as a predictor of Frontal Body Evocation scores, Montreal Cognitive Assessment scores were included as predictors of Hand Laterality Task scores, and Parkinson's Disease Cognitive Rating Scale – Alternative Form scores were included as predictors of both Frontal Body Evocation and Hand Laterality Task scores.

The critical alpha level for all analyses was set at 0.05, but Bonferroni correction for multiple comparisons was applied to cognitive and behavioural scores on the Mann-Whitney test (0.05/15=0.003). All statistical procedures were conducted using IBM SPSS-23.

Results

Descriptive statistics were performed for clinical, demographic, cognitive and behavioural variables.

Regarding the demographic variables, no statistically significant differences were found between the two groups in terms of age and sex, whereas the two groups significantly differed in terms of years of education, with patients' group having more years of education with respect to controls' group. Concerning the cognitive variables, statistically significant differences were seen between the two groups in the Hand Laterality Task, where patients with PD performed worse compared to healthy controls. As regards behavioural variables, statistically significant differences emerged between the two groups in the emotional component of the Italian-Dimensional Apathy Scale, with patients showing greater severity of apathy symptoms (*Table 1*).

Regarding the correlational analysis between MBR tasks and clinical characteristics of patients with PD, a positive significant correlation was found between the Frontal Body Evocation task and H&Y staging, indicating that higher scores on the Frontal Body Evocation task, which reflect lower accuracy, are associated with more advanced disease staging. Concerning the correlational analysis between MBR tasks and cognitive variables of patients with PD, a negative significant correlation emerged between Frontal Body Evocation and Parkinson's Disease Cognitive Rating Scale – Alternative Form, suggesting that lower accuracy on the Frontal Body Evocation task is associated with lower scores on the Parkinson's Disease Cognitive Rating Scale – Alternative Form which reflect a lower global cognitive functioning;

https://doi.org/10.53240/2025topic4n1.0.001

Table 1. Descriptive statistics and Mann-Whitney U test for demographic, clinical, cognitive, and behavioral variables in the two groups.

	Patients (n=25)	Healthy controls (n=24)	U/χ^2	p	ES
Demographic variables					
Age	60.28±9.83	59.50±8.87	273.500	0.596	-
Education	13.36±4.27	11.00±3.40	195.000	**0.031**	-
Sex (F/M)	12/13	16/8	1.742	0.187	-
Clinical variables					
Disease duration	9.18±4.23				-
UPDRS	15.26±9.43				-
H&Y	2.14±0.49				-
Cognitive variables					
MoCA	22.68±3.25	23.25±3.04	265.500	0.487	-0.099
PD-CRS/AF total score	85.48±16.69	91.96±11.50	242.000	0.246	-0.016
PD-CRS/AF cortical score	26.52±2.20	26.04±2.51	263.000	0.456	-0.106
PD-CRS/AF subcortical score	58.96±15.58	65.92±10.20	225.500	0.136	-0.213
FBE	90.43±42.73	68.85±25.06	206.000	0.060	-0.268
HLT	17.52±3.41	19.58±0.83	166.000	**0.003#**	-0.421
CTT	167.17±75.79	135.36±38.02	238.000	0.215	-0.177
OLT	17.76±4.30	20.54±4.23	201.000	0.017	-0.340

continued on the next page

https://doi.org/10.53240/2025topic4n1.0.001

Behavioural variables					
BDI-II	9.04±6.93	7.63±7.30	249.500	0.311	-0.144
I-DAS total score	24.96±8.45	19.08±7.42	185.000	0.021	-0,239
I-DAS executive score	6.04±4.20	6.58±4.33	275.000	0.616	-0,071
I-DAS emotional score	10.20±3.00	6.04±2.91	96.500	**<0.001#**	-0,584
I-DAS behavioural/cognitive score	8.72±4.84	6.46±3.59	214.500	0.086	-0.245
OR-PAS	13.00±6.14	12.25±7.39	273.000	0.588	-0.077
QUIP-RS	24.84±18.00	13.75±13.87	198.000	0.040	-0.293

 # significant after Bonferroni correction for multiple comparisons (0.05/15=0.003)
Notes. F: Female participants; M: Male participants; UPDRS: Unified Parkinson's Disease Rating Scale; H&Y: Hoehn and Yahr scale; MoCA: Montreal Cognitive Assessment; PD-CRS/AF: Parkinson's Disease - Cognitive Rating Scale/Alternative Form; FBE: Frontal Body Evocation task; HLT: Hand Laterality Task; CTT: Christmas Tree Task; OLT: Object Laterality Task; BDI-II: Beck Depression Inventory - II; I-DAS: Italian - Dimensional Apathy Scale; OR-PAS: Observed Rated - Parkinson Anxiety Scale; QUIP-RS: Questionnaire for Impulsive-Compulsive Disorders in Parkinson's Disease – Rating Scale.

moreover, positive correlations were found between Hand Laterality Task and both Montreal Cognitive Assessment and Parkinson's Disease Cognitive Rating Scale – Alternative Form, signaling that higher score on the Hand Laterality Task, reflecting a high level of accuracy, is associated with a better global cognitive functioning. No statistically significant correlations emerged between MBR tasks and behavioural variables (*Table 2*).

Regression analyses showed that global cognitive functioning, on both Montreal Cognitive Assessment and Parkinson's Disease Cognitive Rating Scale – Alternative Form, significantly predicted MBR scores. Specifically, Montreal Cognitive Assessment score emerged as a significant predictor of Hand Laterality Task score (beta=0.426; p=0.034), and Parkinson's Disease Cognitive Rating Scale – Alternative Form score was found as a significant predictor of both Hand Laterality Task (beta=0.525; p=0.007) and Frontal Body Evocation (beta=-0.565; p=0.003) scores. Finally, Parkinson's Disease Cognitive Rating Scale – Alternative Form cortical score did not significantly predict Hand Laterality Task score, whereas both Hand Laterality Task and Frontal Body Evocation scores were significantly predicted by Parkinson's Disease Cognitive Rating Scale – Alternative Form subcortical score (beta=0.531; p=0.006 and beta=-0.569; p=0.003, respectively).

Discussion

The present study was conducted with the aim of exploring alterations of MBR in patients with PD. We hypothesized that patients with PD may exhibit an altered ability in MBR, in line with recent literature suggesting dysfunctions, in PD, of cerebral regions—such as the primary motor cortex and the primary somatosensory cortex—which are shown to be critical for processing both action-oriented and non-action-oriented MBR (Di Vita et al., 2016).

https://doi.org/10.53240/2025topic4n1.0.001

Table 2. Correlational analyses, with Spearman's rho coefficient, between performance on MBR tasks and clinical, cognitive and behavioural variables in the patient group.

	FBE	HLT
Disease duration	rho=0.242 p=0.278	rho=-0.006 p=0.977
UPDRS	rho=0.030 p=0.891	rho=-0.181 p=0.409
H&Y	rho=0.494* p=**0.019**	rho=-0.169 p=0.453
MoCA	rho=-0.206 p=0.322	rho=0.438* p=**0.028**
PD-CRS/AF	rho=-0.492* p=**0.012**	rho=0.643** p=**0.001**
BDI-II	rho=0.323 p=0.115	rho=-0.171 p=0.414
I-DAS	rho=0.186 p=0.372	rho=0.101 p=0.631
OR-PAS	rho=-0.066 p=0.755	rho=0.049 p=0.816
QUIP-RS	rho=-0.345 p=0.091	rho=0.098 p=0.641

*. Correlation is significant at the 0.05 level (2-tailed); **. Correlation is significant at the 0.01 level (2-tailed).
Notes. FBE: Frontal Body Evocation task; HLT: Hand Laterality Task; UPDRS: Unified Parkinson's Disease Rating Scale; H&Y: Hoehn and Yahr scale; MoCA: Montreal Cognitive Assessment; PD-CRS/AF: Parkinson's Disease - Cognitive Rating Scale/Alternative Form; BDI-II: Beck Depression Inventory - II; I-DAS: Italian - Dimensionale Apathy Scale; OR-PAS: Observed Rated - Parkinson Anxiety Scale; QUIP-RS: Questionnaire for Impulsive-Compulsive Disorders in Parkinson's Disease – Rating Scale.

Results revealed significant differences between patients with PD and healthy controls in the Hand Laterality Task, with the former performing worse than the latter. These differences cannot be attributed to other task-specific aspects (linguistic, perceptual, attentional, etc.), given the absence of significant differences between the two groups in the MBR control tasks (i.e., Christmas Tree Task and Object Laterality Task); moreover, as no significant differences emerged between the two groups regarding demographic variables related to age and sex as well as regarding cognitive variables related to Montreal Cognitive Assessment and Parkinson's Disease Cognitive Rating Scale – Alternative Form scores, it is possible to exclude that differences in Hand Laterality Task between the who groups are attributable to the abovementioned demographic or cognitive variables. Therefore, they may suggest a specific difficulty of patients with PD to create MBR involved in movement planning, execution and monitoring (i.e. body schema). On the other hand, the two groups did not significantly differ in Frontal Body Evocation task. One possible explanation of a such discrepancy between the two component of MBR may lie in their distinct neural correlates: action-oriented MBR involves the primary motor cortex, which, according to current evidence, is already altered in the early stages of the disease, due to dopaminergic depletion in the midbrain, from which it receives both direct and indirect inputs; in contrast, non-action-oriented MBR involves the primary somatosensory cortex, which appears to be affected at later stages (Underwood & Parr-Brownlie, 2021). As the sample involved in this study had an average disease duration of approximately nine years, corresponding to an early-to-intermediate stage of PD, it is possible to hypothesize that this is the reason why deficits were observed in the dynamic component but not in the static component of MBR. However, present results are fully consistent with Dominey et al. (1995), Helmich et al. (2007) and Bek et al. (2022), who reported significant differences between patients with PD and healthy controls in the Hand Laterality Task, in terms of greater slowness and/or lower accuracy in the former. Differently, present results are not in line with Scarpina et al. (2019), who found a limited impairment of MBR to its more explicit component in patients with PD, that is to say when they were asked to perform or to imagine performing movements with their limbs; our results also disagree with van Nuenen et al. (2012), who reported a total preservation of MBR in patients with PD. These discrepancies could be due to different aspects, such as methodological procedure and sample size; for example, Scarpina et al. (2019) divided their PD sample into two groups of ten, according to symptom lateralisation; on the other hand, van Nuenen et al. (2012) recruited a slightly small sample size (11 patients with PD versus 12 healthy controls). However, the comparison between the above-mentioned studies is complex and, in some ways, inappropriate, as they significantly differ from each other in terms of sample characteristics, methodological procedures and type of MBR tasks. First and foremost, most of the cited studies recruited a very small number of patients with PD (7 in Dominey et al., 1995; 12 in Helmich et al., 2007; 11 in van Nuenen et al., 2012), with some of them being relatively much younger than others (e.g., Mean= 52 in Helmich et al., 2007 versus Mean= 65 in Bek et al., 2022). Moreover, some of such studies divided PD sample into different groups according to symptom lateralisation (Scarpina et al., 2019) or just involved right-lateralized patients (Helmich et al., 2007). Furthermore, they all used different versions of the Hand Laterality Task, with some using no control task (Helmich et al., 2007). Finally, they all explored MBR in the context of motor imagery (MI), using Hand Laterality Task as an implicit measure of MI; indeed, to date, no study has explored MBR from a representative perspective, with a comprehensive assessment of action- and non-action-oriented BR within the same sample of participants and using both MBR and control tasks.

However, taken together, the results discussed above regarding the relationship between PD and MBR should be interpreted in light of the difference in educational level between the two groups. Indeed, one important limitation of the present study is that the level of education significantly differed between the two groups. Given the well-established association between educational attainment and cognitive performance, it is possible that education acted as a confounding variable influencing the observed group differences in MBR tasks. Although we did not statistically control for this variable in the present analysis, we acknowledge that education should be considered as a potential covariate in future studies; including education as a covariate would allow for a more precise understanding of whether the observed differences in the two groups are specifically attributable to PD-related factors rather than educational background.

The correlation analysis exploring the potential association between MBR tasks and clinical characteristics of patients with PD revealed a significant positive correlation between Frontal Body Evocation scores and disease staging on the H&Y scale, suggesting that MBR, particularly the static one, worsens as the disease progresses. However, we cannot state that disease staging predicts performance on Frontal Body Evocation as regression analysis has not found H&Y score to be a significant predictor of Frontal Body Evocation score. Nevertheless, as the sample here recruited consisted of patients in the early/intermediate stages of the disease (Mean = 9.18 years; SD = 4.23 years), it is plausible that MBR deficits do not occur so late during the course of PD; this hypothesis is in line with current literature, suggesting a reduced functional connectivity between the precuneus and motor regions, which plays a crucial role in processing non-action-oriented MBR (Corradi-Dell'Acqua et al., 2009; Di Vita et al., 2016), in the early stages of PD (Thibes et al., 2017).

The correlation analysis exploring the potential association between MBR tasks and cognitive characteristics of patients with PD revealed a negative significant correlation between Frontal Body Evocation and Parkinson's Disease Cognitive Rating Scale – Alternative Form, suggesting that a higher score on the Frontal Body Evocation task, indicating a low level of accuracy, is associated with lower scores on the Parkinson's Disease Cognitive Rating Scale – Alternative Form, reflecting a low global cognitive functioning; on the other side, positive correlations were found between Hand Laterality Task and both Montreal Cognitive Assessment and Parkinson's Disease Cognitive Rating Scale – Alternative Form, signaling that higher score on the Hand Laterality Task, reflecting a high level of accuracy, is associated with a better global cognitive functioning. Moreover, it seems that global cognitive functioning predicts both Frontal Body Evocation and Hand Laterality Task scores, as regression analyses found Parkinson's Disease Cognitive Rating Scale – Alternative Form and Montreal Cognitive Assessment to be significant predictors of Hand Laterality Task score as well as they indicated Parkinson's Disease Cognitive Rating Scale – Alternative Form to be a significant predictor of Frontal Body Evocation score. Altogether, these results suggest that typical cognitive functions explored by Montreal Cognitive Assessment and Parkinson's Disease Cognitive Rating Scale – Alternative Form are propaedeutical to a proper and functional mental representation of the body. This view is in line with recent literature, highlighting that performance on mental rotation tasks, such as the Hand Laterality Task, and on body structural representation tasks, such as Frontal Body Evocation, is supported by good cognitive functioning (Heiz et al., 2018; Raimo et al., 2021a).

Conclusion

Alterations of MBR in PD have not been explored much, and the few studies conducted so far on this theme have yielded conflicting results. Overall differences across studies can be related to the differences in sample characteristics, methodological procedures and type of MBR tasks used. However, our results extend previous studies, suggesting the possibility of an early impairment of MBR abilities, during the course of PD and also highlighting the importance of a good global cognitive functioning for a good MBR ability. In light of these findings and given the importance of this construct in everyday functioning, the present study suggests (i) to evaluate in detail the body processing in patients with PD (i.e., evaluating the performance in all body representations, static and dynamic ones, also exploring it out of the motor imagery field), (ii) to take into account the possible influence of other cognitive function on MBR (i.e., evaluating it also using control tasks with no body stimuli), iii) to explore the possible influence of PD staging on MBR (i.e., evaluating it through transversal or longitudinal studies). Regarding this latter aspect, it is important to consider that recent literature has highlighted a general decline of both types of MBR after 60 years of age in healthy people (Raimo et al., 2021a; Raimo et al., 2021b; Raimo et al., 2021c); so, a better understanding of MBR in patients with PD is necessary to improve our knowledge of MBR deviations from typical decline and to provide tailored rehabilitation training programs for specific MBR deficits.

Finally, considering the limitations of the present study regarding the covariation of educational level, future research should aim to isolate the effects of PD on MBR, controlling for differences in education, either through matched samples or by including education as a covariate in the statistical analyses. This would help clarify the extent to which impairments in MBR are directly linked to PD pathology as opposed to educational attainment.

References

Aarsland, D., Batzu, L., Halliday, G. M., Geurtsen, G. J., Ballard, C., Ray Chaudhuri, K., & Weintraub, D. (2021). Parkinson disease-associated cognitive impairment. *Nature reviews. Disease primers*, *7*(1), 47.

Abraham, A., Duncan, R. P., & Earhart, G. M. (2021). The Role of Mental Imagery in Parkinson's Disease Rehabilitation. *Brain sciences*, *11*(2), 185.

Armstrong, M. J., & Okun, M. S. (2020). Diagnosis and Treatment of Parkinson Disease: A Review. *JAMA*, *323*(6), 548–560.

Balestrino, R., & Schapira, A. H. V. (2020). Parkinson disease. *European journal of neurology*, *27*(1), 27–42.

Beck, A. T., Steer, R. A., & Brown, G. K. (1996). *Manual for the Beck depression inventory-II*. San Antonio, TX: Psychological Corporation.

Bek, J., Humphries, S., Poliakoff, E., & Brady, N. (2022). Mental rotation of hands and objects in ageing and Parkinson's disease: differentiating motor imagery and visuospatial ability. *Experimental brain research*, *240*(7-8), 1991–2004.

Berlucchi, G., & Aglioti, S. M. (2010). The body in the brain revisited. *Experimental brain research, 200*(1), 25-35.

Bloem, B. R., Okun, M. S., & Klein, C. (2021). Parkinson's disease. *Lancet (London, England)*, *397*(10291), 2284–2303.

Committeri, G., Pitzalis, S., Galati, G., Patria, F., Pelle, G., Sabatini, U., Castriota-Scanderbeg, A., Piccardi, L., Guariglia, C., & Pizzamiglio, L. (2007). Neural bases of personal and extrapersonal neglect in humans. *Brain: a journal of neurology, 130*(Pt 2), 431–441.

Chou, K. L., Amick, M. M., Brandt, J., Camicioli, R., Frei, K., Gitelman, D., Goldman, J., Growdon, J., Hurtig, H. I., Levin, B., Litvan, I., Marsh, L., Simuni, T., Tröster, A. I., Uc, E. Y., & Parkinson Study Group Cognitive/Psychiatric Working Group (2010). A recommended scale for cognitive screening in clinical trials of Parkinson's disease. *Movement disorders: official journal of the Movement Disorder Society*, *25*(15), 2501–2507.

Corradi-Dell'Acqua, C., Tomasino, B., & Fink, G. R. (2009). What is the position of an arm relative to the body? Neural correlates of body schema and body structural description. *The Journal of neuroscience: the official journal of the Society for Neuroscience, 29*(13), 4162–4171.

Costantini, M., Salone, A., Martinotti, G., Fiori, F., Fotia, F., Di Giannantonio, M., & Ferri, F. (2020). Body representations and basic symptoms in schizophrenia. *Schizophrenia research, 222,* 267–273.

Daurat-Hmeljiak, C., Stambak, M., & Berges, J. (1978). Il test dello schema corporeo. Una prova di conoscenza e costruzione dell'immagine del corpo [The body schema test. A test of knowledge and construction of body image]. Firenze. Organizzazioni Speciali.

https://doi.org/10.53240/2025topic4n1.0.001

de Vignemont, F. (2010). Body schema and body image--pros and cons. *Neuropsychologia, 48*(3), 669–680.

Di Cara, M., Lo Buono, V., Corallo, F., Cannistraci, C., Rifici, C., Sessa, E., D'Aleo, G., Bramanti, P., & Marino, S. (2019). Body image in multiple sclerosis patients: a descriptive review. *Neurological sciences: official journal of the Italian Neurological Society and of the Italian Society of Clinical Neurophysiology, 40*(5), 923–928.

Di Vita, A., Boccia, M., Palermo, L., & Guariglia, C. (2016). To move or not to move, that is the question! Body schema and non-action oriented body representations: An fMRI meta-analytic study. *Neuroscience and biobehavioral reviews*, *68*, 37–46.

D'Iorio, A., Maggi, G., Baiano, C., & Santangelo, G. (2022). The Italian version of the alternative form of Parkinson's Disease-Cognitive Rating Scale (PD-CRS/AF): normative values from 260 Italian healthy subjects. *Neurological sciences: official journal of the Italian Neurological Society and of the Italian Society of Clinical Neurophysiology, 43*(6), 3613–3620.

Dominey, P., Decety, J., Broussolle, E., Chazot, G., & Jeannerod, M. (1995). Motor imagery of a lateralized sequential task is asymmetrically slowed in hemi-Parkinson's patients. *Neuropsychologia*, *33*(6), 727–741.

Downey, L. E., Fletcher, P. D., Golden, H. L., Mahoney, C. J., Agustus, J. L., Schott, J. M., Rohrer, J. D., Beck, J., Mead, S., Rossor, M. N., Crutch, S. J., & Warren, J. D. (2014). Altered body schema processing in frontotemporal dementia with C9ORF72 mutations. *Journal of neurology, neurosurgery, and psychiatry, 85*(9), 1016–1023.

Ehgoetz Martens, K. A., Silveira, C. R. A., Intzandt, B. N., & Almeida, Q. J. (2018). State anxiety predicts cognitive performance in patients with Parkinson's disease. *Neuropsychology*, *32*(8), 950–957.

Fahn, S. R. L. E. (1987). Unified Parkinson's disease rating scale. *Recent developments in Parkinson's disease*, 153-163.

Fontes, P. L., Moura, R., & Haase, V. G. (2014). Evaluation of body representation in children with hemiplegic cerebral palsy: toward the development of a neuropsychological test battery. *Psychology & Neuroscience, 7,* 139-149.

Gallagher, S. (1986). Body image and body schema: A conceptual clarification. *The Journal of mind and behavior, 7,* 541-554.

Gelb, D. J., Oliver, E., & Gilman, S. (1999). Diagnostic criteria for Parkinson disease. *Archives of neurology*, *56*(1), 33–39.

Gopar-Cuevas, Y., Duarte-Jurado, A. P., Diaz-Perez, R. N., Saucedo-Cardenas, O., Loera-Arias, M. J., Montes-de-Oca-Luna, R., Rodriguez-Rocha, H., & Garcia-Garcia, A. (2021). Pursuing Multiple Biomarkers for Early Idiopathic Parkinson's Disease Diagnosis. *Molecular neurobiology*, *58*(11), 5517–5532.

Graham-Schmidt, K. T., Martin-Iverson, M. T., Holmes, N. P., & Waters, F. (2016). Body representations in schizophrenia: an alteration of body structural description is common to wh with schizophrenia while alterations of body image worsen with passivity symptoms. *Cognitive neuropsychiatry, 21*(4), 354-368.

Greenland, J. C., Williams-Gray, C. H., & Barker, R. A. (2019). The clinical heterogeneity of Parkinson's disease and its therapeutic implications. *The European journal of neuroscience*, *49*(3), 328–338.

Grossi, D. & Trojano, L. (2011). Lineamenti di neuropsicologia clinica [Outlines of clinical neuropsychology]. Neuropsicologia dei lobi frontali (nuova edizione). Carocci editore.

Hariz, M., & Blomstedt, P. (2022). Deep brain stimulation for Parkinson's disease. Journal of internal medicine, 292(5), 764–778.

Hauser, D. N., & Hastings, T. G. (2013). Mitochondrial dysfunction and oxidative stress in Parkinson's disease and monogenic parkinsonism. *Neurobiology of disease*, *51*, 35–42.

Head, H., & Holmes, G. (1911). Sensory disturbances from cerebral lesions. *Brain*, *34*, 102–254.

Heiz, J., Majerus, S., & Barisnikov, K. (2018). How flexible is the use of egocentric versus allocentric frame of reference in the Williams syn drome population? *Archives of Clinical Neuropsychology, 33*(5), 619–630.

Helmich, R. C., de Lange, F. P., Bloem, B. R., & Toni, I. (2007). Cerebral compensation during motor imagery in Parkinson's disease. *Neuropsychologia*, *45*(10), 2201–2215.

Hoehn, M. M., & Yahr, M. D. (1967). Parkinsonism: onset, progression and mortality. *Neurology, 17*(5), 427–442.

Hosseini, S. A., & Padhy, R. K. (2023). Body Image Distortion (Archived). In *StatPearls*. StatPearls Publishing.

Jankovic J. (2008). Parkinson's disease: clinical features and diagnosis. *Journal of neurology, neurosurgery, and psychiatry*, *79*(4), 368–376.

Jankovic, J., & Tan, E. K. (2020). Parkinson's disease: etiopathogenesis and treatment. *Journal of neurology, neurosurgery, and psychiatry*, *91*(8), 795–808.

Kolicheski, A., Turcano, P., Tamvaka, N., McLean, P. J., Springer, W., Savica, R., & Ross, O. A. (2022). Early-Onset Parkinson's Disease: Creating the Right Environment for a Genetic Disorder. *Journal of Parkinson's disease*, *12*(8), 2353–2367.

Lo R. Y. (2021). Epidemiology of atypical parkinsonian syndromes. *Tzu chi medical journal*, *34*(2), 169–181.

Longo M. R. (2022). Distortion of mental body representations. *Trends in cognitive sciences*, *26*(3), 241–254.

Lucza, T., Karádi, K., Kállai, J., Weintraut, R., Janszky, J., Makkos, A., Komoly, S., & Kovács, N. (2015).

Screening Mild and Major Neurocognitive Disorders in Parkinson's Disease. *Behavioural neurology*, *2015*, 983606.

Maggi, G., Vitale, C., Giacobbe, C., Barone, A., Mastromarino, C., Iannotta, F., Amboni, M., Weintraub, D., & Santangelo, G. (2024). Validation of the Italian version of the Questionnaire for Impulsive-Compulsive Disorders in Parkinson's Disease-Rating Scale (QUIP-RS) in an Italian Parkinson's disease cohort. *Neurological sciences: official journal of the Italian Neurological Society and of the Italian Society of Clinical Neurophysiology*, *45*(7), 3153–3161.

Maggi, G., D'Iorio, A., Aiello, E. N., Poletti, B., Ticozzi, N., Silani, V., Amboni, M., Vitale, C., & Santangelo, G. (2023). Psychometrics and diagnostics of the Italian version of the Beck Depression Inventory-II (BDI-II) in Parkinson's disease. *Neurological sciences: official journal of the Italian Neurological Society and of the Italian Society of Clinical Neurophysiology*, *44*(5), 1607–1612.

Martinez, V. R., Giovanola, Y., & Ionta, S. (2022). Social Touch Somatotopically Affects Mental Body Representations. *Neuroscience*, *494*, 178–186.

McLean, S. A., & Paxton, S. J. (2019). Body Image in the Context of Eating Disorders. *The Psychiatric clinics of North America*, *42*(1), 145–156.

Miguelez, C., De Deurwaerdère, P., & Sgambato, V. (2020). Editorial: Non-Dopaminergic Systems in Parkinson's Disease. *Frontiers in pharmacology*, *11*, 593822.

Nava, E., Mattioli, F., Gamberini, C., Stampatori, C., Bellomi, F., Turati, C., Capra, R., & Bolognini, N. (2018). Altered bodily self-consciousness in multiple sclerosis. *Journal of neuropsychology*, *12*(3), 463–470.

Orgeta, V., McDonald, K. R., Poliakoff, E., Hindle, J. V., Clare, L., & Leroi, I. (2020). Cognitive training interventions for dementia and mild cognitive impairment in Parkinson's disease. *The Cochrane database of systematic reviews*, *2*(2), CD011961.

Palermo, L., & Di Vita, A. (2023). Body representation disorders. In G.G. Brown, T. Z. King, K.
Y. Haaland, & B. Crosson (Eds.), *APA handbook of neuropsychology: Neurobehavioral disorders and conditions: Accepted science and open questions* (pp. 103–122). American Psychological Association. https://doi.org/10.1037/0000307-006

Park, H. D., & Blanke, O. (2019). Coupling inner and outer body for self-consciousness. *Trends in Cognitive Sciences, 23*(5), 377-388.

Parsons L. M. (1987). Imagined spatial transformations of one's hands and feet. *Cognitive psychology, 19*(2), 178–241.

Pfaffenberger, N., Gutweniger, S., Kopp, M., Seeber, B., Stürz, K., Berger, T., & Günther, V. (2011). Impaired body image in patients with multiple sclerosis. *Acta Neurologica Scandinavica, 124*(3), 165-170.

Pfeiffer R. F. (2020). Autonomic Dysfunction in Parkinson's Disease. *Neurotherapeutics: the journal of the American Society for Experimental NeuroTherapeutics*, *17*(4), 1464–1479.

Piccardi, L. et al. (2011). Rotazioni Mentali. In: Come impariamo a muoverci nell'ambiente? [Mental rotations. In: How do we learn to move in the environment?]. Springer, Milano.

Pitron, V., & de Vignemont, F. (2017). Beyond differences between the body schema and the body image: insights from body hallucinations. *Consciousness and cognition*, *53*, 115–121.

Postuma, R. B., Berg, D., Stern, M., Poewe, W., Olanow, C. W., Oertel, W., Obeso, J., Marek, K., Litvan, I., Lang, A. E., Halliday, G., Goetz, C. G., Gasser, T., Dubois, B., Chan, P., Bloem, B. R., Adler, C. H., & Deuschl, G. (2015). MDS clinical diagnostic criteria for Parkinson's disease. *Movement disorders: official journal of the Movement Disorder Society*, *30*(12), 1591–1601.

Raimo, S., Ferrazzano, G., Di Vita, A., Gaita, M., Satriano, F., Veneziano, M., Torchia, V., Zerella, M. P., Malimpensa, L., Signoriello, E., Lus, G., Palermo, L., & Conte, A. (2024). The multidimensional assessment of body representation and interoception in multiple sclerosis. *Multiple sclerosis and related disorders*, *87*, 105692.

Raimo, S., Boccia, M., Di Vita, A., Iona, T., Cropano, M., Ammendolia, A., Colao, R., Angelillo, V., Maiorino, A., Guariglia, C., Grossi, D., & Palermo, L. (2022). Body Representation Alterations in Patients with Unilateral Brain Damage. *Journal of the International Neuropsychological Society: JINS*, *28*(2), 130–142.

Raimo, S., Iona, T., Di Vita, A., Boccia, M., Buratin, S., Ruggeri, F., Iosa, M., Guariglia, C., Grossi, D., & Palermo, L. (2021a). The development of body representations in school-aged children. *Applied neuropsychology. Child, 10*(4), 327–339.

Raimo, S., Di Vita, A., Boccia, M., Iona, T., Cropano, M., Gaita, M., Guariglia, C., Grossi, D., & Palermo, L. (2021b). The Body across the Lifespan: On the Relation between Interoceptive Sensibility and High-Order Body Representations. *Brain sciences, 11*(4), 493.

Raimo, S., Boccia, M., Di Vita, A., Cropano, M., Guariglia, C., Grossi, D., & Palermo, L. (2021c). The Body Across Adulthood: On the Relation Between Interoception and Body Representations. *Frontiers in neuroscience, 15*, 586684.

Razmus, M. (2017). Body representation in patients after vascular brain injuries. *Cognitive processing, 18*(4), 359–373.

Santangelo, G., D'Iorio, A., Maggi, G., Cuoco, S., Pellecchia, M. T., Amboni, M., Barone, P., & Vitale, C. (2018). Cognitive correlates of "pure

https://doi.org/10.53240/2025topic4n1.0.001

apathy" in Parkinson's disease. *Parkinsonism & related disorders*, *53*, 101–104.

Santangelo, G., Raimo, S., Siciliano, M., D'Iorio, A., Piscopo, F., Cuoco, S., Bottone, M., Trojsi, F., Grossi, D., & Trojano, L. (2017a). Assessment of apathy independent of physical disability: validation of the Dimensional Apathy Scale in Italian healthy sample. *Neurological sciences: official journal of the Italian Neurological Society and of the Italian Society of Clinical Neurophysiology, 38*(2), 303–309.

Santangelo, G., Raimo, S., & Barone, P. (2017b). The relationship between Impulse Control Disorders and cognitive dysfunctions in Parkinson's Disease: A meta-analysis. *Neuroscience and biobehavioral reviews*, *77*, 129–147.

Santangelo, G., Falco, F., D'Iorio, A., Cuoco, S., Raimo, S., Amboni, M., Pellecchia, M. T., Longo, K., Vitale, C., & Barone, P. (2016). Anxiety in early Parkinson's disease: Validation of the Italian observer-rated version of the Parkinson Anxiety Scale (OR-PAS). *Journal of the neurological sciences, 367,* 158–161.

Santangelo, G., Siciliano, M., Pedone, R., Vitale, C., Falco, F., Bisogno, R., Siano, P., Barone, P., Grossi, D., Santangelo, F., & Trojano, L. (2015). Normative data for the Montreal Cognitive Assessment in an Italian population sample. *Neurological sciences: official journal of the Italian Neurological Society and of the Italian Society of Clinical Neurophysiology*, *36*(4), 585–591.

Santangelo, G., Vitale, C., Trojano, L., Longo, K., Cozzolino, A., Grossi, D., & Barone, P. (2009). Relationship between depression and cognitive dysfunctions in Parkinson's disease without dementia. *Journal of neurology*, *256*(4), 632–638.

Scarpina, F., Magnani, F. G., Tagini, S., Priano, L., Mauro, A., & Sedda, A. (2019). Mental representation of the body in action in Parkinson's disease. *Experimental brain research, 237*(10), 2505–2521.

Schwoebel, J., & Coslett, H. B. (2005). Evidence for multiple, distinct representations of the human body. *Journal of cognitive neuroscience*, *17*(4), 543–553.

Seppi, K., Ray Chaudhuri, K., Coelho, M., Fox, S. H., Katzenschlager, R., Perez Lloret, S., Weintraub, D., Sampaio, C., & the collaborators of the Parkinson's Disease Update on Non-Motor Symptoms Study Group on behalf of the Movement Disorders Society Evidence-Based Medicine Committee (2019). Update on treatments for nonmotor symptoms of Parkinson's disease-an evidence-based medicine review. *Movement disorders: official journal of the Movement Disorder Society*, *34*(2), 180–198.

Simon, D. K., Tanner, C. M., & Brundin, P. (2020). Parkinson Disease Epidemiology, Pathology, Genetics, and Pathophysiology. *Clinics in geriatric medicine*, *36*(1), 1–12.

Snowden, J. S., Rollinson, S., Thompson, J. C., Harris, J. M., Stopford, C. L., Richardson, A. M., & Pickering-Brown, S. M. (2012). Distinct clinical and pathological characteristics of frontotemporal dementia associated with C 9ORF72 mutations. *Brain, 135*(3), 693-708.

Stefani, A., Pierantozzi, M., Cardarelli, S., Stefani, L., Cerroni, R., Conti, M., Garasto, E., Mercuri, N. B., Marini, C., & Sucapane, P. (2022). Neurotrophins as Therapeutic Agents for Parkinson's Disease; New Chances From Focused Ultrasound?. *Frontiers in neuroscience*, *16*, 846681.

Sun, C., & Armstrong, M. J. (2021). Treatment of Parkinson's Disease with Cognitive Impairment: Current Approaches and Future Directions. *Behavioral sciences (Basel, Switzerland)*, *11*(4), 54.

Thibes, R. B., Novaes, N. P., Lucato, L. T., Campanholo, K. R., Melo, L. M., Leite, C. C., Amaro, E., Jr, Barbosa, E. R., Bor-Seng-Shu, E., Cardoso, E. F., & Sato, J. R. (2017). Altered Functional Connectivity Between Precuneus and Motor Systems in Parkinson's Disease Patients. *Brain connectivity, 7*(10), 643–647.

Tofani, M., Ranieri, A., Fabbrini, G., Berardi, A., Pelosin, E., Valente, D., Fabbrini, A., Costanzo, M., & Galeoto, G. (2020). Efficacy of Occupational Therapy Interventions on Quality of Life in Patients with Parkinson's Disease: A Systematic Review and Meta-Analysis. *Movement disorders clinical practice*, *7*(8), 891–901.

Tolosa, E., Garrido, A., Scholz, S. W., & Poewe, W. (2021). Challenges in the diagnosis of Parkinson's disease. *The Lancet. Neurology*, *20*(5), 385–397.

Tomas-Aragones, L., & Marron, S. E. (2016). Body Image and Body Dysmorphic Concerns. *Acta dermato-venereologica, 96*(217), 47–50.

Turbyne, C., Koning, P., Zantvoord, J., & Denys, D. (2021). Body integrity identity disorder using augmented reality: a symptom reduction study. *BMJ case reports, 14*(1), e238554.

Underwood, C. F., & Parr-Brownlie, L. C. (2021). Primary motor cortex in Parkinson's disease: Functional changes and opportunities for neurostimulation. *Neurobiology of disease*, *147*, 105159.

van Nuenen, B. F., Helmich, R. C., Buenen, N., van de Warrenburg, B. P., Bloem, B. R., & Toni, I. (2012). Compensatory activity in the extrastriate body area of Parkinson's disease patients. *The Journal of neuroscience: the official journal of the Society for Neuroscience*, *32*(28), 9546–9553.

Váradi C. (2020). Clinical Features of Parkinson's Disease: The Evolution of Critical Symptoms. *Biology*, *9*(5), 103.

Vastano, R., Costantini, M., & Widerstrom-Noga, E. (2022). Maladaptive reorganization following SCI: The role of body representation and multisensory integration. *Progress in neurobiology*, *208*, 102179.

V. 4 N. 1 (2025)
https://doi.org/10.53240/2025topic4n1.0.001

Weintraub, D., Aarsland, D., Chaudhuri, K. R., Dobkin, R. D., Leentjens, A. F., Rodriguez-Violante, M., & Schrag, A. (2022). The neuropsychiatry of Parkinson's disease: advances and challenges. *The Lancet. Neurology*, *21*(1), 89–102.

Xu, Z., Anderson, K. N., & Pavese, N. (2022). Longitudinal Studies of Sleep Disturbances in Parkinson's Disease. *Current neurology and neuroscience reports*, *22*(10), 635–655.

Yang, L., Mao, K., Yu, H., & Chen, J. (2020). Neuroinflammatory Responses and Parkinson' Disease: Pathogenic Mechanisms and Therapeutic Targets. *Journal of neuroimmune pharmacology: the official journal of the Society on NeuroImmune Pharmacology*, *15*(4), 830–837.